Government of Papua New Guinea

Handbook for Upland Rice Farming in Papua New Guinea

Under the Project on the Promotion of Smallholder Rice Production [Phase 2]
between Department of Agriculture & Livestock (NDAL)
and Japan International Cooperation Agency (JICA)

February 2015

FOREWORD

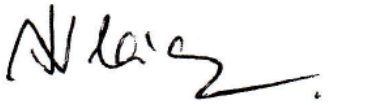
The Department of Agriculture & Livestock is pleased endorse this Handbook for Upland Rice Cultivation for its Smallholder Rice Farmers in Papua New Guinea. It is timely for such information to be made available when the Government of Papua New Guinea is encouraging the development of a rice industry in PNG under its 2015 – 2015 Rice Development Policy. The Government of PNG has two main strategies for developing the domestic rice industry and they are the large-scale investor driven, highly mechanized paddy rice production system and the smallholder rice production programme championed by the Rice Extension Unit of the Department of Agriculture & Livestock. The smallholder upland rice production program has benefited from funding by the JICA since Year 2003.

This Handbook, from outset, was designed as an extension and training tool for the rural development officers whose work has been to support smallholder rice farmers and growers in upland rice production development.

The PNG Rice Policy 2014-2030 was largely guided and influenced by the 2003 JICA sponsored study investigating smallholder rice projects in Central, Morobe, Madang, East Sepik and East New Britain provinces. This study was aimed at formulating a master plan for the promotion of smallholder rice production in PNG targeting subsistence farmers, public institutions interested in rice self-sufficiency and semi-commercial rice farmers. The report reaffirmed the strategic shift in policy emphasis taken by DAL from the highly subsidized smallholder rice development projects such the Bereina Rice Project and the Maprik Rice Development Program to smallholder rice production by farm households and institutions for the purpose of producing rice as a food crop for their own consumption. A key outcome of this program has been the training of a sizeable pool of local farmers with the basic competencies for upland rice farming. This handbook builds on this achievement and targets these pool of trained farmers and other interested farmers in upland rice production.

Indeed, this handbook can enrich and deepen the rice growers' basic knowledge and skills in rice farming. Officers and Model-farmers who support and conduct farmer-to-farmers-extension activity (FTFEA) will also find this handbook useful in demonstrating basic rice cultivation techniques to interested farmers and rice growers within his or her community. This Handbook contains notes and illustrations of basic skills in upland rice cultivation and is essential to promoting sustainable smallholder rice production. This Handbook is also useful to the rural development officers who are responsible for rice development program at the Ward, LLG, District and/or Province level; and givens insights to officers when providing a support to model farmers.

It is also the intent of the producers of this Handbook that it can be used for new rice growers training; new model farmer training, and new rice officers or rural development officers' training. It is the hope of the Department that smallholder rice growers, through their learned experiences, can become the foundation for the rice industry in PNG in the foreseeable future.



Dr. Vele Pat Ila'ava.
The Secretary
Department of Agriculture & Livestock
KONEDOBU

ACKNOWLEDGEMENT

This Handbook was developed from the experiences gained from and during the implementation of the Promotion of Smallholder Rice Production Projects Phase II between the Years 2011 and 2015.

Special mentioned is made for the stakeholders in the implementation of the Project, which was the bilateral technical cooperation between Department of Agriculture & Livestock (DAL) on behalf of the Government of PNG and Japan International Cooperation Agency (JICA) on behalf of the Government of Japan.

The following are acknowledged as member of collaborating provinces together with JICA Experts at the Rice Extension Unit of Department of Agriculture and Livestock. Their involvement were in the consultation and vetting of the draft documents in the month of February, 2015 in Madang, Wewak, Alotau and Lorengau, which resulted in the final output of the Handbook for Upland Rice Farming in Papua New Guinea..

NDAL
1. Heai Steven Hoko
2. John Jave
3. Miriam John
4. Anna Kimam
5. Boni Jules

East Sepik
1. Pius Numbatai
2. Kevin Hawan
3. John Worowan
4. Wilson Lambi

Manus
1. John Lale Helepet
2. Paul Bulei
3. Wamu Oma
4. Musato Sauto
5. Elisanty Eyabi
6. Simon Gunik
7. Adela Pomat
8. Michaline Tausim
9. Annie Pouru
10. Ambrose Silih

Madang
1. Mary Lilih
2. Dolores Kamang
3. Joseph Wanom
4. Godfred Agabara

Milne Bay
1. James Duks
2. Jonathan Kapoila
3. Ropsy Taudiri
4. Karajoy Domanai
5.
6.
7.
8.

JICA
1. Masakazu Kanamoto
2. Shigeo Watanabe
3. Masaya Matsumura
4. Mizuhiko Nishida
5. Tateo Ajika
1. Mari Ono

Table of Contents

Contents:

[Legend]

Check box for Confirmation:

✔	1Apr. 20xx			

Put either the completion mark (✔) or the completion date here after having learned/ having done at your field each technique item by respective user.

1 Rice Cultivation Cycle

What is a rice cultivation cycle? A cycle is a process or a motion in which one begins with one thing to go through a several stages, steps, or material before you arrive at what you started off with. In this case, a rice cultivation cycle begins with a handful of good viable seeds and you end up with a good harvest of rice grains, returning your rice seed tenfold.

Rice cycle practiced and promoted through the smallholder rice and model farmer approach of rice extension can be easily learned, understood and utilized for training farmers and interested persons because it is simple and easy to remember and follow. Figure 1 below illustrates the several stages of a basic rice cultivation cycle any one farmer or interested person can undertake;, and often it takes four to five months from land preparation to harvesting the grains, before one can store away the rice paddy or milling it for home consumption.

Figure 1: Illustrative Pictorial Stages of a Basic Rice Cultivation Cycle (4-5 months in duration)

A basic rice cultivation cycle includes land preparation, soil and seed-bed preparation, sowing of seeds, transplanting seedlings, general crop growth management practices such as weed control, application of composted organic matter for boosting soil productivity, water control, insect pest monitoring and control, harvesting, threshing, winnowing, drying, storing, selecting and collecting seeds for next cropping, and eventually milling the paddy for family consumption.

The key to sustainable rice cultivation is for every farmer or rice planter, at each harvest of rice crop, should actively select and harvest enough rice grains as seeds for the next cropping. When harvesting rice grains for seeds, the area of land for the next crop can be decided at this time and the adequate amount of grains as seeds can be safely set a side.

The Handbook on Upland Rice Farming basically follows basic rice cycle as illustrated in Figure 1 due to its simplicity; it can be easily integrated into the PNG's traditional root, tuber and banana crop farming system.
The following sub-sections further describe each stage of the rice cultivation cycle.

1.1 Land Selection And Preparation

1.1.1 Land selection

The first step is to select a land to cultivate rice. Upland rice cultivation is basically rain-fed farming practice. So it is also important to select an area with adequate rain-fall throughout the year. The land with soft-top black soil with more than 2 cm is preferable. It is preferable to select a site that has flat to middling rolling land ground surface rather than on steep, sloping and mountainous sites. Flat or mildly rolling land will have little or no problem with soil erosion and will hold the soil containing essential plant nutrients when there are high or intense rainfalls. If it is difficult to find a flat land, try to find an area that is not too steep. If you need to use a slopping site such as on mountain sides, you will need do some soil digging or excavation to build terraces where good gardening or organic surface top-soils can be filled onto the excavated material. Well-constructed terraces can hold the soil to hold essential plant nutrients, organic matters and even saturated soils or rain-water that can prevent plant nutrients and soils losses through soil erosion or land-slips.

When thinking of the size of farm, you need to consider the available resources such rice seeds and man power.

When you decide on the new garden and how big the garden should be, remember to take into consideration your available resources and inputs for rice cultivation. The first consideration is your rice seeds, then the family labour you have, and the tools and the means by which you will cultivate your land.

If you are going to cultivate rice for a first time, it is better to start with a area that is 25 m² (5m x 5m) or less, and this will require only 30 grams of rice seeds. It is preferable to select a site near or not so far from one's house or dwelling place (village) so that it is easier to manage and give a close attention to your garden. If you have somebody who can help you to manage your rice garden such as your relatives and sibling, you can start with the bigger area.

If you have 0.5 kg of rice seeds with a good germination rate (80%), the quantity of rice seeds and germination rate can enable you to plant garden as wide and as long as 20 m x 20 m giving you a total crop area of 400 square metres (400 m^2).

1.1.2 Land Preparation

After you have selected your rice garden site, you can now plan to clear your land at the time of year as indicated in your cropping calendar.

Clearing of thick wooded forested area may take longer time to clear so consideration should be given for their felling and clearing. Soft wooded forest may take shorter time to clear and for the grass and broad-leafed site, it may even take much shorter time to clear.

All forest tree twigs and leaves, brush, shrubs and grasses from the cleared sites can be utilized for composting and are excellent source of organic matter for composting and soil improvement when they are incorporated into the rice garden soils.

All cleared plant materials from the rice garden sites should not be thrown away. Burning of dried plant matters should be discouraged as well as. Burning of dried materials from the forest, brush, shrub and grass clearings will destroy all organic matter and in most cases will destroy the soil structure and its fertility.

Sites cleared for rice cultivation should be devoid of all solid materials that would obstruct planting of the rice crop. Where the soil is been tilled with hoeing or ploughing, the soil surface can be manually evened out with hand-tools or leveling equipment.

Figure 2: A farmer clearing the land by slashing grass and wood shrub.

Check box for Confirmation:

1.2 Soil and Compost Preparation

The next step after selecting the garden site and preparing the land is the soil preparation, which is one of the most important steps The condition of soil influences the fertility of land, presence of pests and diseases, and eventual yield. Therefore, the simplest and effective way of obtaining a good condition of the soil is to plough the available organic materials or green manures or composted organic matter into the soil. Weeds, kitchen wastes, home-yard shade tree leaves, including the previous crop stubbles, and rice husks, can be used and ploughed into the soil for adding plant nutrients into the soil.

1.2.1 Soil Preparation

Soil preparation should take place one month before transplanting in order to give enough time (1 month) for organic materials or plant or animal materials to de-compost completely and become fertilizers in the soil. Basic steps up to digging trench, which can be done in a day, are indicated below.

Figure 3: (1) Hoe the soil to a depth of Plough 20 to 30 cm depth to mix soil itself (plough 30-40 cm depth when using a machine)

Figure 4: (2) Till all grass or rice Plough straw, weeds, any soft plants like banana stem and leaves , and kitchen wastes (without seeds or flowers) into the soil

Figure 5: (3) Garden should look like this after tilling or ploughing with organic materials

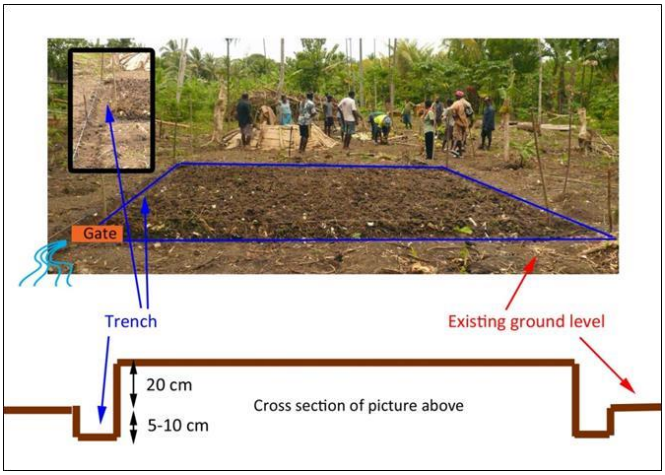


Figure 6: (4) Make a trench by digging the surrounding of the garden (10 cm depth) and putting soil back to the garden for covering green manure with soil. Make a gate to release water for water control.

Figure 7: (5) Soil after tillage and use of compost would be friable and easily crumbles in one's hand after a month

1.2.2 Compost Making

Compost should be used as an organic fertilizer and must be applied one month after sowing of the crop. The ideal time to make compost is during the garden site clearing and soil preparation. The reason for doing so is that compost making is similar to soil preparation. It is good to prepare compost right next to the rice garden to make it easy to create and apply compost to the garden. Basic steps for compost making are described below.

(1) Secure a site and designate an area for making a compost-heap.

(2) Dig the borders of the designated area for the compost-heap digging to about 10 cm depth or place logs to differentiate the compost area from the other areas.

(3) Collect rice straws and other organic materials (green manures) such as weeds, any soft plants parts like banana stem and leaves, kitchen wastes, etc. Weeds with seeds and flowers can be also put into compost because the temperature inside the compost will be high and hot enough to destroy most of the seeds and will not germinate.

(4) Lay the rice straws on the entire heap area as the first-layer as shown in Figure 9.

(5) Put a layer of plant materials or organic matter on top of the first-layer of straws.

(6) Sprinkle some soil over the plant materials, and build a thin-layer of soil. This soil layer should not be more than 1 cm in thickness (less than 1 cm in thickness).

(7) Even out the layer of the soil by hand and by using a straight-edge implement or stick. Slight down-down pressing can be done on the soil layer by foot.

(8) Repeat (5) to (7) to make three to five layers of green manures and thin layer of soil as illustrated in Figure 8.

(9) Sprinkle some water to make 50-60% wet-basis moisture content. An indication of 50%w.b. moisture content in the compost is achieved when you grab and squeeze it in the palm of your hand and be able to make a mass of earth or soil without it crumbling quickly. An indication of 60%w.b. moisture content is when there is visible small amount of water squeezed out of the soil. Further illustration of soils having 50-60% moisture content (w.b.) can be seen in Figure 25 and Figure 26.

(10) Cover the whole compost with banana leaves to promote de-composting to take place.

(11) Turn-over the compost heap after a month, and add some water if the heap is too dry and cover the heap again with fresh banana leaves again. The internal temperature of compost should be higher than 40°C at the peak stage of compost activity. It is preferable to turn-over the inner materials to that of the outside from time to time when checking the compost, to ensure even decomposition and break-down of organic matter.

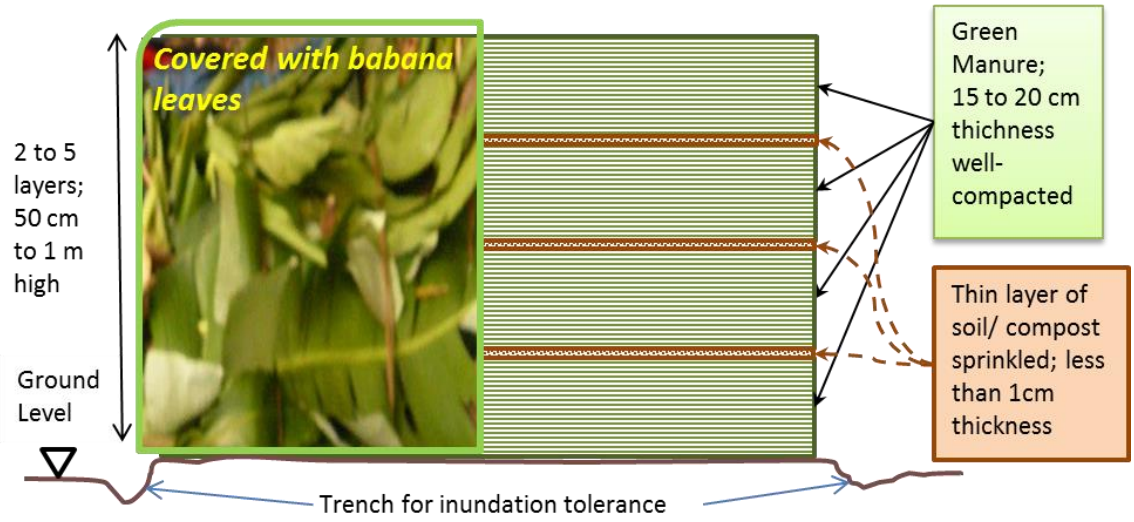


Figure 8: Schematic illustration of a compost-heap construction, showing each layer of material.

Figure 9: Compost-heap being pressed down-ward with foot as organic matter and soil are added on layer after layer (Step 1-5 in compost making).

Figure 10: Newly completed compost-heap with broad banana leaves covering the top.

Figure 11: A partially decomposed wood and tree twigs and leaf-matter in one-month old compost.

It is important not to put too much soil when making compost: just sprinkle over green manure and form a thin layer of soil. Covering the compost with banana leaves is also very important to ensure the heap does not dry-out and allow to green manure and organic matter to de-compost. A well-constructed compost heap will have its internal temperature rising above 40°C during de-composting. The height of compost should shrink down to one third of the original height after which the compost is ready to be used as an organic fertilizer.

Application of compost is explained in the 'Further Explanation' section below.

Check box for Confirmation:

Further Explanation:

About the soil

For the growth of rice, there are some basic necessary elements as depicted in the picture below.

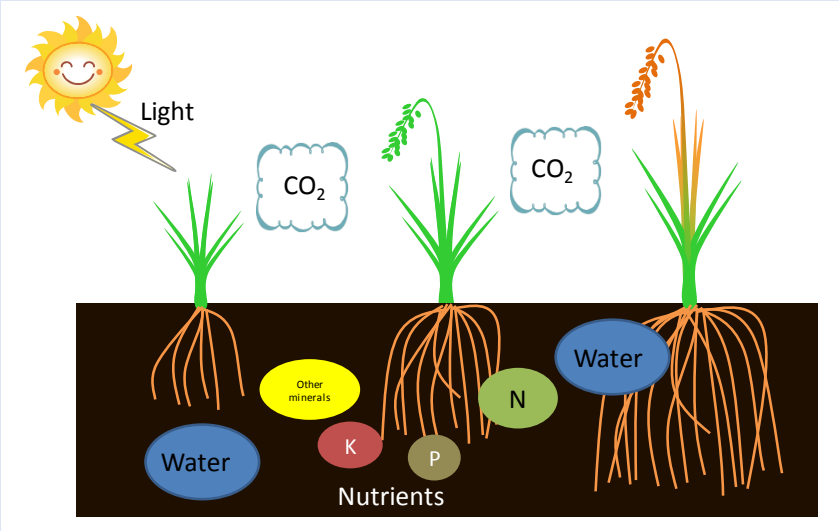


Figure 12: Schematic illustration of the relationship of soils, plants, and plant nutrients, including the air and water and light

The basic elements for rice to grow are sunlight, water, air (CO_2) and soil nutrients. If any one of the element is lacking, rice plants cannot grow or will stop growing. Similarly, it is true for human beings and all other living organisms that it requires sun light, water, air (O_2), and nutrients (food) for it to grow and live. All plants, including rice crop, extract and obtain its nutrients and water from the soils through its roots as illustrated in Figure 12 above. The major elemental nutrients that plants require and are essential for the growth of rice plants include Nitrogen (N), Phosphorus (P), and Potassium (K).

Nitrogen (N) promotes rapid growth and increase leaf size, spikelet number, and percentage of filled spikelet. Nitrogen (N) is the most influential element for the growth and yield. If there is not enough Nitrogen (N) in the soil, plant roots will not take enough of it and the rice plant growth will be is very slow and the normal green colour of leaves are will be light green to yellowish showing lack of nitrogen.

Phosphorus (P) promotes tillering, root development, early flowering and ripening. If there is not enough Phosphorus (P) in the soil, the number of panicles will be reduced and plant nutrients uptake from the soil will be reduced due to plant roots not developing well.

Potassium (K) increases the number of spikelet per panicle, percentage of filled grains and each grain weight. If there is not enough Potassium (K) in the soil, the leaf's time-span will be reduced and drop-off sooner and the incidences of crop lodging will be higher.

The adequate supply of plant nutrients in Nitrogen (N), Phosphorus (P) and Potassium (K) will greatly influence the eventual yield of the rice crop. See the sufficiency of essential elements' influence to yield in the picture below.

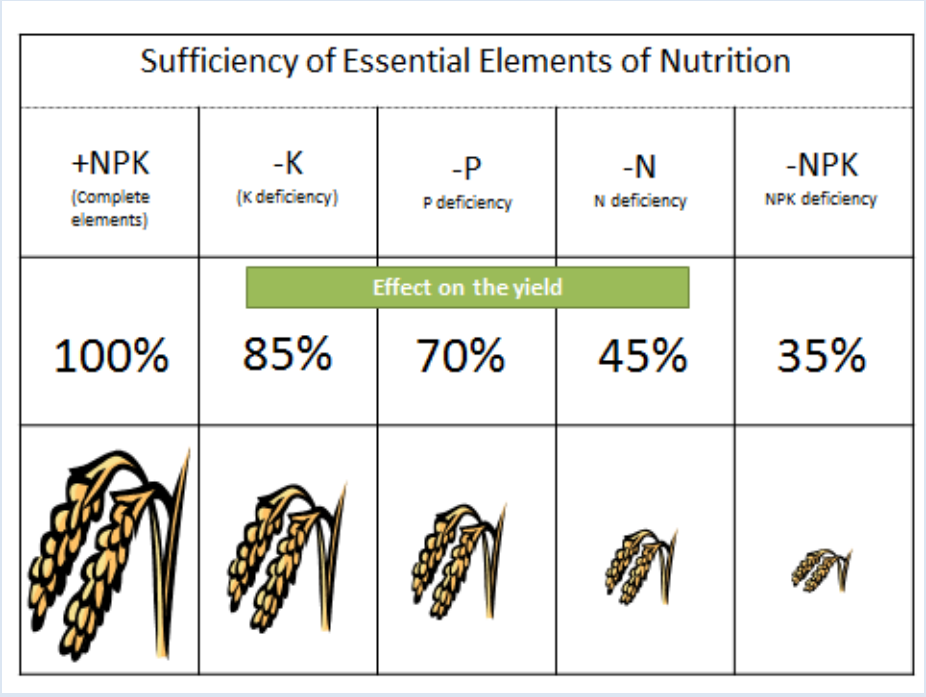


Figure 13: Level of plant nutrients influencing the rice crop yield.

The simplest way to enrich the soil with Nitrogen (N), Phosphorus (P) and Potassium (K) with soil is to apply available organic materials to the soil. Weeds, organic kitchen waste, leaves, husks, rice straw and root stumps are good sources of the organic materials one can used and returned to the soil to enrich essential elements of nutrition.

Adequate tillage or soil hoeing to return organic matter to the soil will improve the soil aeration, water control and resistance to soil borne diseases. Decomposed organic matters acts like glue that binds soil particle together and assists in the development of soil structure through the aggregates if forms. Soil aggregations creates both the small soil pores and larger soil pores as indicated in the picture below. Smaller soil-pores contribute to water-holding capacity of the soil while larger soil pores contribute to soil-water drainage and air movement. Organic materials also enrich the diversity of soil organisms and enhance the resistance to soil-borne diseases.

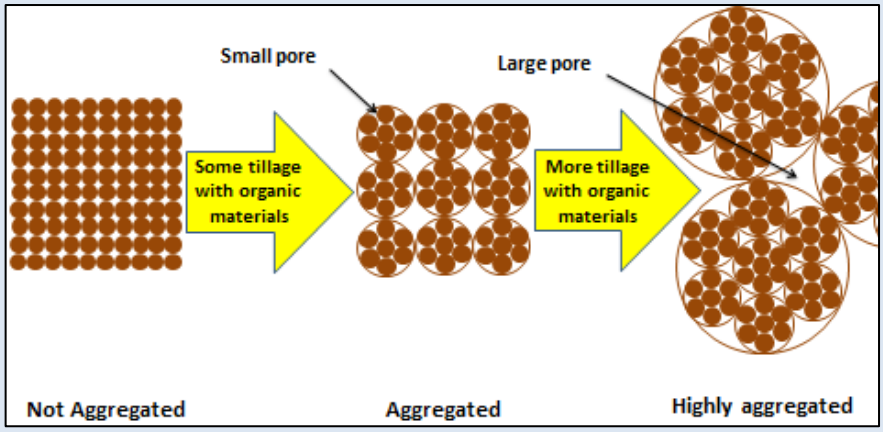


Figure 14: Schematic illustration of soil particle structures in the soils when treated with organic matter.

It is for this important reason that all organic materials should be returned to the soil, in another word applying "Back to the soil approach", for the improvement of soil fertility, capacity of the land to produce and sustaining rice production over long-term period.

Demonstration plot

The construction of the demonstration plot is the best way to see and show the importance and effectiveness of "Back to the soil approach". Farmers can apply this approach in the half area of the farm, and apply the usual approach (no application of organic materials or tillage) in the other half and compare the yield outcome as shown in the picture below. The outcome and yield of course will be influenced by other factors such as climate and pests. Past experiences have shown that the treated soil get 4-6 ton/ha while the untreated soil get 1-1.5 ton/ha. It is better to experience the difference by trying out both treatments of comparison.

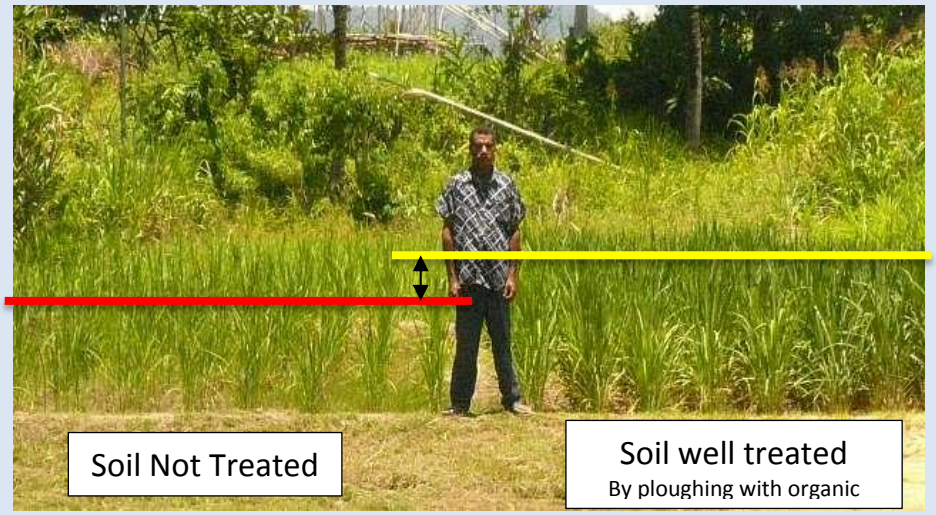


Figure 15: The Model Farmer Jack of Maprik besides his plot of rice treated with organic matter and simple hoeing of the soil.

1.3 Transplanting

There are two method of planting a rice crop. One is by directly sowing the seeds into the soils; whilst the other is to raise the rice plants as seedlings and transplanting it onto the prepared land or garden site.

When direct sowing, seeds are place into the soils at depth of 2 -3 cm; and when transplanting, rice seedlings are placed into the soil at depths ranging from 4-5 cm deep. In transplanted rice crop, there is uniformity in height, form, growth, and eventually tillering, flowing, and grain ripening. This will enable uniform harvesting of the rice crop. In directly seeded or sown crop, there may be high variability in crop establishment and the rice crop flowering, ripening and harvesting may not be uniform or within a narrow period to time.

This handbook promotes transplanting of rice crop over direct-sowing. Direct sowing may be easier and a quicker way of planting one's rice garden but it does not guarantee good rice crop establishment. It produces an uneven crop germination due to different soil conditions, resulting in variation in the crop stand, and the flowering and grain ripening is spread over time., Transplanting is less easier when its technique is understood well and properly practiced, it can produce a more uniform crop establishment, even crop ripening and hence allowing only one-time harvesting.

Transplanting of rice offers effective care and management on a small rice plant nursery bed then when directly sowing a large area of land where the crops' emergence may be problematic due to the sowing of seeds into the deep planting holes or some seeds sown are not viable or were bad seeds. It is better to obtain poor germination in the nursery bed rather poor emergence of rice crop in the field or garden because you can still make up for the short-fall in the nursery and in the field. A garden will fail plants growth or lines due to poor germination the crop is directly sown needs to be avoided at times.

Sowing seeds in the nursery bed allows one to obtain the level of germination and number of seedlings required for planting the prepared field or garden. Whether one obtains 100% germination or less than 50% germination in the nursery, you can select healthy seedlings to cover the entire area of your garden land or field then to get disappointed when your directly sown field has many missing plants. It is preferable to over-sow a rice nursery seed-bed and selecting healthy and vigorous seedlings to transplant the entire garden or field, giving 100 per cent crop establishment.

Transplanting of the garden or field will also allow quick and early establishment and a uniform crop growth and formation. This will then allow a more synchronized panicle initiation, flowering, and grain-filling. This will allow for a narrow period of crop performance, thus minimizing significant insect pests attack. Less or no pest damages means a good crop harvest is expected.

In terms of timing, sowing and transplanting should take place when the wet season starts while harvesting should take place in a dry season. It takes about 130 and 136 days from the time of sowing to harvesting for late-maturing varieties, 113 and 125 days for medium-maturing varieties, and 110 days for early-maturing varieties. Based on the information of varieties, you should decide the appropriate timing for sowing.

1.3.1 Preparing Seeds For Planting

You need to have good rice seeds for successful rice cultivation. After the 1st season, you should keep and use the best seeds from your own garden to continue to cultivate rice.

You should use the same variety of seeds for a garden to manage your farm well. If you don't have seeds, you can enquire about the available seeds which are resistant to pests and your environment at the local office of Division of Agriculture & Livestock (DAL) or National Agriculture Research Institute (NARI).

After obtaining seeds, you should check if your seeds are heavy, full and uniform in size. Make sure your seeds do not contain weeds or trash. If you find weeds or trash, you should winnow it (winnowing is explained in the Section 3.4 below).
In order to ensure the quality of seeds, you should conduct germination test in the following manner. You can consider the seeds are in good quality if the germination rate is higher than 80%.

(1) Select a number of small random samples from the seeds to be planted and select a subset (e.g., 100 seeds) of the combined sample. Soak the seeds in water for 24 hours;
(2) Arrange 100 soaked seeds in a grid pattern on a wet paper towel (10 seeds by 10 seeds) and place a cover for protection;
(3) Ensure paper remains moist;
(4) Count the germinated seeds 3 to 5 days later and record the germination percentage; and
(5) If more than 80 seeds have germinated, seeds have more than 80% of germination rate.

1.3.2 Making and Caring of Nursery Bed

You need to sow rice seeds in your nursery bed to grow seedlings. If you want to cultivate 0.5 kg of rice, you need the nursery bed of 2 m² size. Follow the steps below when making a nursery bed to raise rice seedling:

(1) Soak rice seeds in a dish or container of water for three days in an open sun before sowing, change water every day;
(2) Designate the area for the nursery bed and place logs to fence the nursery bed;
(3) Put the banana leaves with some holes beneath the nursery bed to make it easier to transplant seedlings later without damaging the roots;
(4) Put the soil over the banana leaves for less than 5 cm or a half finger height. It is good to use compost as the soil for nursery bed if it is ready;
(5) Sow rice evenly on the nursery bed (give at least 1 cm space between the seeds);
(6) Cover the seeds with light soil and sprinkle water over the nursery bed;
(7) Cover the nursery bed with banana leaves to make uniform germination and for protection;
(8) Sprinkle small amount of water every morning and afternoon;
(9) Seeds should germinate in 3-5 days. Remove banana leaves to give sunlight after germination; and
(10) Seedlings will be ready for transplant when they get three leaf-stage or two weeks after sowing;

Figure 16: Farmers sowing his rice seeds onto the specially prepared seed-bed using composted organic matter rich soils.

Figure 17: The resulting germinated rice seedlings from Figure 16.

1.3.3 Transplanting

Transplanting the seedlings from the nursery bed to the rice garden should take place when seedlings grow three leaf-stage. You have to be careful to transplant in the right time because if seedlings grow too big, the roots might be damaged when transplanting and will not grow further. It is better to transplant in the early morning or in the late afternoon when the sun light is not strong.

Spacing between the seedlings depends on the variety (size) of rice, but should be around 20-30 cm x 20-30 cm (depending on the variety) to give enough space for people to pass through such as for weed and pest control.

Figure 18: The laying out of a garden field for transplanting the rice seedlings can be done using sisal/agave strings.

The following are simple steps used in transplanting the rice seedlings:

(1) Monitor the growth of the seedlings and wait until it has reached the three leaf-stage or for two weeks after sowing;

(2) Make holes by a stick along a rope as a guide to plant seedlings in rows. Give about 20-30 cm x 20-30 cm spacing;

(3) Bring seedlings with full soil and place them in a reachable distance in the rice garden;

(4) Select only good seedlings and transplant one by one (or two by two) immediately, covering the root with soil gently. Press soil around the seedling softly;

(5) Go backward when planting not to damage the planted seedlings; and

(6) Give small amount of water in the afternoon after transplanting. The roots are exposed outside the soil and the seedling may look weak. The roots need to take some water to recover.

Figure 19: Rice seedling transplanting hole are may be using stick picket, along the straightened strings.

Figure 20: Rice seedlings been picked out of the seedling bed.

Figure 21: Individual seedling is selected for transplanting.

Figure 22: Seedling being placed into the planting hole and soil pressed firmly around it.

Check box for Confirmation:

Further Explanation:

About the number of seedlings per hill

Plant 1 to 2 seedlings per hill. If more than 3 seedlings grow per hill, they cannot take enough nutrients from the soil because of overcrowding. If seedlings are overcrowded, they attract more pests and diseases as well. It is important not to plant more than enough seedlings.

Thinning out [off]

It is also important to transplant only the good seedlings. Discard small and poor in colour seedlings, and transplant only good seedlings which are big, good colour, and have good root system to achieve the good yield. Transplanting seedlings which match in size is also important to harvest all at the same time for pest control measures.

As for the function of transplanting for synchronizing the harvesting period, this is the last opportunity to sort out poorly grown seedlings, thus it is necessary to thin them out without hesitation.

Homogenization upon the harvesting period/post-harvest treatment
Timings for unification:
1) To sort out seeds so as to plant only favorable ones
2) To prepare evenly fertile soil
3) Not to directly seed but to transplant
4) To shorten the tillering period
5) To control well-timed watering
6) Not to allow and not to use late growth
7) To complete harvesting in one or two days
8) To finish drying paddies evenly
9) To remove dust, including empty/immature grains

Figure 23: Ideal seedling

1.4 Care and Management of Rice Garden

You have to regularly visit your garden and check the condition of the garden and take necessary and timely care. It is during these visits, that the farmer will need to do weeding, some soil tillage to improve the surface soils, and undertake some water control and pest control activities.

1.5 Weed Control, Soil Mounding And Soil Improvement

3 weeks to 1 month after transplanting, you need to control weeds at your garden. Weeds take nutrients from the soil and compete with rice growing. Weeds also attract pests and diseases as well. If you control weeds, you are also controlling pests and diseases as well.

What you have to do is to remove weeds from roots using a hoe between rows and put them back to the soil as organic fertilizer as indicated in the picture below. Make sure you shave and stir more than 10 cm to remove roots completely and mix with soil well. At the same time, you should land up area where the soil flew out.

You should also apply compost during the time of weed control. Just bring compost between the rows and stir together with existing weeds.

In terms of frequency, one time weed control 3 weeks to 1 month after transplanting is enough. You should do weed control, soil mounding and soil improvement all at once to save your time and energy. After 1 month, weeds rather work to prevent water evaporation of the soil.

Figure 24: Farmer weeding the rice garden using a weeding hoe.

1.5.1 Water Control

The ideal moisture content of the soil is 50-60%w.b. A good indicator of 50%w.b. moisture content in the soil is when you work the soil with your hand and are able to make a mass as shown in Figure 25. A 60%w.b. moisture content or higher in the soil is indicated by you being about to able to squeeze small amount of water out of soil ball held in your hand as shown in Figure 26.

Figure 25: Soil ball made between the palm-of-the-hand with 50% moisture content.

Figure 26: Soil with higher moisture content of above 60% may look this when worked between of palm-of-the-hand.

Check the moisture content especially when the weather changes and give water if the moisture content of soil is less than 50%w.b. This should be practiced in the case where irrigation is practiced. If the moisture content is more than 60%w.b., you have to open the gate of the trench and release excess water.

When rice starts to bloom, it is better to create a dry environment soon after 4-5 days of flowering so then the rice crop will stop further tillering and panicle initiation and concentrates all its energy to filling in the grains. If you see some water in the trench or paddy field, improve the drainage to remove excess ground and surface water to influence the crop to start filling-in the grains rather than causing more tillering and more flowering, with extended period of flowering.

1.5.2 Pest Control

It is also important to protect your garden from pests. You have to go to the rice garden every day from the time of flowering stage till harvesting and control pests if you see any, before it gets too late to control.

Some of the major pests and control measures are indicated below.

(1) Stem Borer

Stem bores are one of the major pests in Papua New Guinea. The life cycle of stem borers is 41-60 days. Eggs of stem borers are laid on leaves or leaf sheath. Larvae bore into stem, eat through the node, and bore down to the base of stem. Full-grown larvae pupate in rice straws or stubbles. Infested rice plants get white heads or white colored panicles. Boring causes panicles with half or empty grains, destroy the crop and reduce the yield.

As a control measure, stems with white heads should be pulled off from stem based and opened up to reveal the larvae and pupae. Stem borers larvae and pupae must be pick-off by hand and destroyed immediately. Ants are one of the natural enemies of stem bores; once larvae are put down on the ground, ants will prey on them as shown in Figure 30.

Having a fallow or rice-free period for two months between cropping is the **best preventative measure** as this allows the removal of the habitats of stem borers. Harvesting all at once is important; if you leave some rice plants still standing after harvest, adult stem borers can continue to lay eggs on those plants, thus maintaining its life-cycle. Harvesting all at once needs to be applied to all the surrounding farms and destroying all standing crops after harvest. Just doing this to your farm is not enough as other farmers' field would provide the habitats to stem borers and other pests. Therefore, harvesting at the communities level at the same requires good cropping planning. This can be achieved by communities developing their own crop calendar to implement synchronous cropping, which is explained in section 4.1.

It is also important to remove stubble and stems completely and immediately after harvesting not to give the habitats to stem borers. Stubbles and stems should be removed completely and ploughed into the soil.

Figure 27: 'White-head' is the sun-bleached rice plant's panicle that is an indication of rice stem borer attack.

Figure 28: Adult moth of the rice stem borer.

Figure 29: A stem boring larvae or worm extracted from a rice stem.

Figure 30: Rice-stem borers being devoured by ants.

(2) Rice Bugs

Rice bug is one of the major pests in Papua New Guinea. The presence of the insects can be easily determined by an offensive smell it gives off when touched. Milky stage of the rice plant attracts rice bugs. They prefer to feed on the endosperm of the rice grain during the grains-filling (milky) stage and often cause empty or stained grains after the milky stage. The bugs feedings also causes the grains to loss form and becomes stained when milled. The bugs' feedings causes yield losses and lowers the quality of grains due to the presence of defective grains.

The life cycle of rice bugs is 88-101 days (Juvenile stage: 23-36 days, Adult: 65 days – See Figure 32). Rice bugs live off on wild hosts, mainly weeds of rice family (*Poaceae*) one or two generations before migrating into the rice field at the flowering stage.

As a control measure, rice bugs should be removed by hand, using a net or plastic bag by sweeping the top of the panicles as shown in Figure 34. Rice garden should be visited in the morning and afternoon during the milky stage to carry out pest scouting and administer control measures. **As the preventive measures**, weeds of grass and rice family should be weeded or slashed eliminate the habitats of rice bugs.

Figure 31: General appearance of the rice crop been attacked by rice bugs.

Figure 32: Adult rice bug, on the rice panicle with grains at the milky-stage.

Figure 33: A road side Grasses like this act as the alternative hosts for rice bugs.

Figure 34: Rice bugs being caught and collected in a sweeping-net.

(3) Brown Plant Hopper

Rice is the only host plant for brown plant hoppers (BPH). The life cycle of brown plant hoppers is 19-24 days. Brown plant hoppers lay 200-500 eggs on the rice leaf-sheath and the nymphs and adults feed at the lower stems of rice plant. They migrate from other rice fields and can reproduce or generate 2-3 generations within on crop of rice. Hopper-burns observed in crops area main symptoms of serious BPH infestation, causing complete death of the plants, resulting in yield loss. They also transmit plant virus and plant diseases related to virus to healthy rice crop.

As the control measure, BPH should be removed by net or plastic bug to reduce the number. However, once the brown plant hopper occurs in high density, no other option is available to control the BPH except for insecticide spray or early harvesting.

As the preventive measures, you can use the rice variety which is resistant to the brown plant hopper such as NR 1. But any variety can become susceptible to BPH so it is advisable to check the latest information with DAL or NARI.

Having a fallow or rice-free period for two months between cropping is the best control and preventative measure removing the habitats of BPH and stem borers. Harvesting the entire rice crop at once is important; if you leave some rice plants from the crop harvested still standing in the garden or field, all the BPH and stem-borers will move to those plants and can survive to cause further damage. Synchronous rice cropping is another control measure for avoiding the BPH population.

It is thus important to remove stubble and stems completely and immediately after harvesting so as not to give BPH a habitat or host plant to thrive on. Stubbles and stems should be removed completely and ploughed into the soil.

Figure 35: Female BPH 5-6mm in length.

Figure 36: Male BPH 5-6mm in length.

Figure 37: Cluster of BPH infestation & causing hopper damage on rice.

(4) Rice Root Aphids

Rice root aphids (*Tetraneura*) are pests found in Madang and East Sepik Provinces (see Figure 38). They are also known as the grass root aphids because they infest the roots of other plants such as yam. They suck the plant sap from the roots and cause change of colour and distort the growth of rice grains. When these plants are pulled out, a large number of aphids can be seen on the roots.

The control and preventive measures are now studied and yet to be made known.

Figure 38: Root aphids on rice plants roots.

Check box for Confirmation:

Further Explanation:

Insect pest control

It is important for all rice growers and training instructors to learn and understand the life cycles of all the insect pests. Practically identifying the insects in the field and taking note of the different life stages and behaviour will help identify cut-off points in the life cycle of each pest species. Knowing this, farmer can take actions to terminate the insects. For this purpose, it is essential to organize study meetings involving model farmers and instructors working from each region to study the life-cycles of each insect pest. Studies will include different life-forms from eggs to larvae, juveniles or nymphs to adults, their migrating habits, sites, feeding habits & life cycles (metamorphosis from egg to adult stage and the numbers of days of passing through each stage). Knowing the weakest point in the insect life-cycle, farmers can devise means or methods apply to knock or terminate the life of the insect, thus controlling insect pests.

It has been shown that rice brown plant-hoppers are rampant in East Asia region and that BPH infestations in all rice growing areas have reached epidemic proportion due to large-scale planting of broad area of rice fields with susceptible rice varieties. Many BPH have also built up tolerance or resistance to many insecticides due to over-use of only one or two pesticides. Break-out of BHP is also attributed to destruction of natural predators with the regular use of insecticides. This is one of important point that PNG's emerging rice production and farming system developers need to be aware of before it becomes a similar outcome for PNG, if it is not careful—use of chemical insecticides must not be encouraged carelessly as being the case and used in other tropical countries.

At present (Year 2015), PNG does not have entomologist specializing in rice insect pests and its ecology. Thus, there are very few opportunities for government workers in charge of agriculture, agricultural instructors, and model farmers to acquire present-knowledge on the biology and control of insect pests occurring on upland rice fields. Partly, the reason for this is, although some of these people have some knowledge of rice insect pests, pest names and their control measures in general, many do not have in-depth understanding and knowledge of life-cycle of rice insect pests and their ecology. Therefore, for all who are involved in the development of smallholder rice production in PNG to control and minimize the destructive effects of rice insect pests without resorting to the use of expensive, highly toxic, and environmentally unfriendly synthetic chemical insecticides, one must understand and have an in-depth knowledge on the life-cycle so that cultural and biological control methods can be used for pest control in rice crops.

Rice Stems-borers (Pickle-worms)

In PNG, the stem-borers larvae that infests and damage rice crops includes the Red Stem-Borer (*Sesamia inference*) and a type of White Stem Borer (*Scirpophaga sp*.). These are the two main species that infest and affect rice plants and crop. The other species is the Gold-Fringed Stem Borer (related) *Chilo auricilius* that was confirmed to occur in rice crops. A Rice Leaf-Roller (*Cnaphalocrosis medinalis*) has also been found in the rice crops in PNG.

The most cost effective and practical way to control and limit rice stem-borer infestation is not to allow any rice plant or plant stumps still standing in the garden or field after the crop is harvested. All the rice straws should be completely destroyed on the field or garden after the harvest is completed. This will reduce the chance of insects building up their population. Synchronizing the rice cropping season is another effective way to minimize the population build up, and all cropping should be organized within the entire rice farming community or region and not just for one or few rice growing gardens or areas. This includes when rice garden fallows are set in and when fallows are opened, at least for three months after the harvesting of rice. Croprotation is one site management technique used to confound the insect pest dynamics and hence disrupt its breeding cycle.

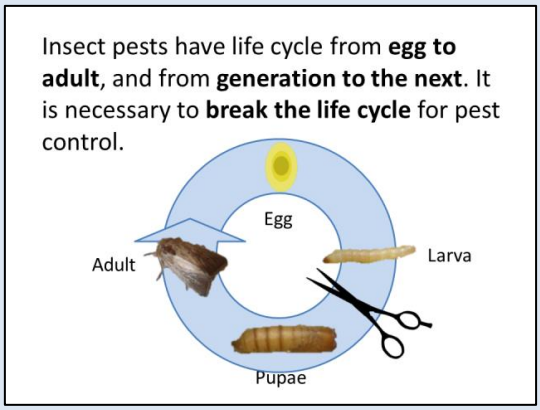


Figure 39: Life Cycle of Rice Stem Borer

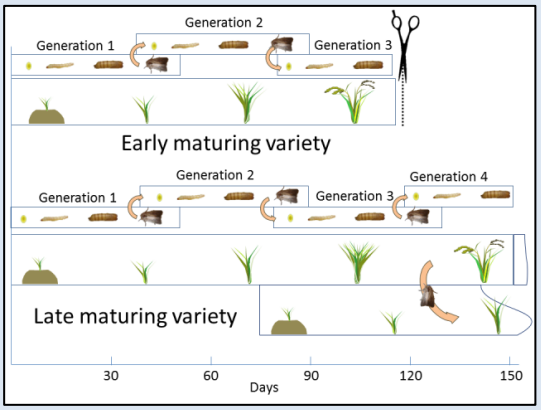


Figure 40: Selection of Crop

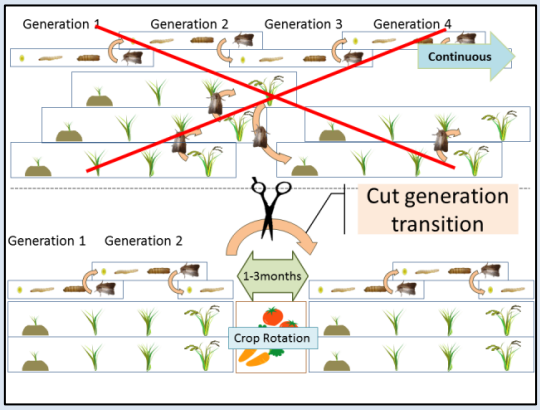


Figure 41: Synchronous Crop

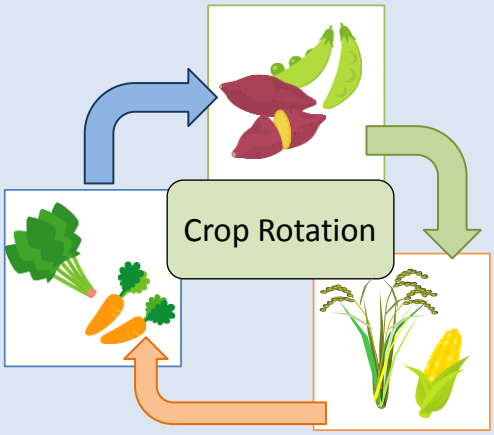


Figure 42: Crop rotation

Rice bugs [*Dimorphopterus pilosus* (Barber, 1958)]

Of all the rice bugs that infest and damage emerging rice grains, *Leptocorisa sp./ Dimorphopterus pilosus (Barber, 1958)* is the most dominant species in PNG.

Rice bugs thrive on other grass weeds, and often the adult bugs migrate to upland rice fields by flying and cause damage to the emerging rice grains in the early stage of grains formation (milky stage). In order to control and reduce the insect population density, one effective method of control is to manually catch the insect with the use of trap net. Trap net is used in a scooping manner but the action to use is often in sweeping manner across the top of the crop. Catch insects are killed by crushing them against hard surfaces or burning them in a fire furnace. Another approach of control and minimizing rice bug infestation is to remove and clean the garden site or field perimeter area of all grasses and grass-like weeds. Therefore, it is important not to neglect your rice garden and the areas surrounding your rice garden against the insect pests and follow the simple practical ways suggested above to control your pests.

Stem-borer and Rice bugs do have alternatives host food crop plants to survive and thrive on and this includes sugar-cane, corn, and sorghum. Scouting for insect pests and their movement within the cropping area is important for their control and management.

Practicing crop-rotation with vegetables and non-graminous food crops; and weeding out and clearing all grass related weed species is an effective method for limiting the population growth of stem-borer. As the larvae and pupae of stem borers tend to get into the lowest part of rice stubble, it has been shown that when harvesting rice, cutting off the straw as low as possible will leave little or not much plant part for the insect pest to thrive on. Rice plant stumps should be dug up and ploughed back into the soil; and where there are lots of stumps and straw, burning can also help to reduce insect population. In order for such cultural insect pest control method to be effective, it must be im-

plemented by all individual farmers at the community level or region level at large, thus the importance of the community-based adoption of these methods is very important and should be comply by all when implemented.

Rice planthoppers

The brown planthopper (*Nilaparvata lugens*) and the white-backed planthopper (*Sogatella furcifera*) were detected. As they often come in from a distance, selecting tolerant cultivars is the most effective method.

Rice root aphid

The rice root aphid (*Tetraneura nigriabdominalis*) is presently the dominant species. Although this type of insect pest occurs rampantly during the dry season, its density seems to be reduced during the rainy season; and, as shown below, the possibility of seasonal changes in host plants has been indicated. Also, the occurrence of the rice root aphid has been confirmed on rice after the ear emergence stage, and the aphid is known to change host plant by season. In addition, in temperate zones such as Japan, in the summer it occurs on dry rice and on gramineous weeds, while in winter it forms galls on tree leaves such as the ulmaceous Japanese elm and lives in the leaves. However, in tropical zones including Papua New Guinea, it is not yet known whether the rice root aphid changes host plants as it does in temperate zones or if it lives with dry rice and gramineous weeds all year round. Clarifying this point is the most important issue when considering measures against this type of insect pest in PNG; thus, the survey on occurrence status studied host plants other than dry rice. As a result, numerous galls were found to have been formed by this aphid on one type of tree (name of tree not currently identified).

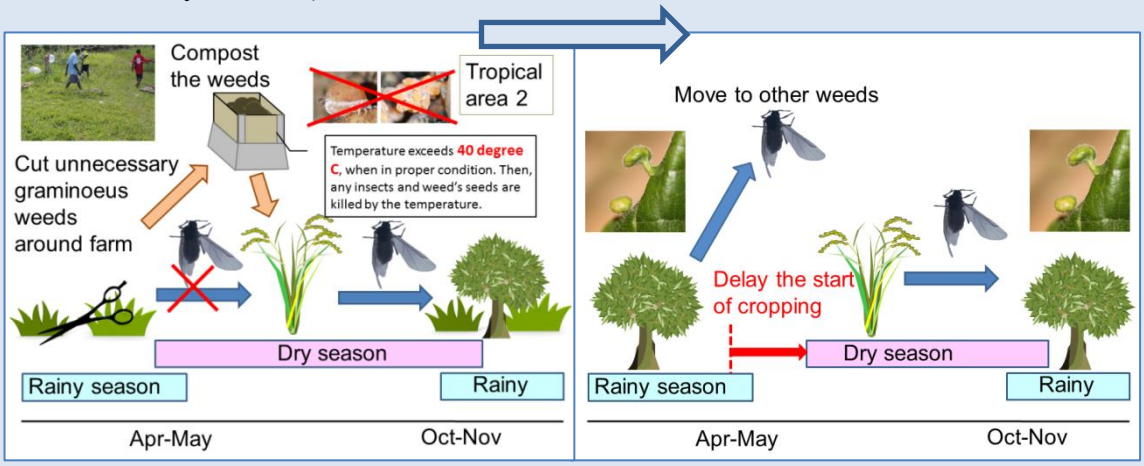


Figure 43: Illustration of insect pest control: rice root aphid

Rice root aphids, rice stem borers and rice bugs incidences and infestations can be avoided and minimized through a synchronous cropping, and proper and adequate disposal of crop residues after harvesting. The removal of weeds and brush surrounding the rice garden or rice field is one effective way to minimize insect pest pressure. Further, as the possibility has been shown in Figure 43 that this type of insect pest often occurs during the dry season and moves to other host plants including trees during the rainy season (and when the rainy season is over and the dry season begins, it comes back to the rice), it is considered that delaying the start of dry rice planting during the dry season by half a month or one month is an effective way to limit the population of aphid. The use of wood vinegar solution is also considered as one effective means of rice roots aphids.

Chinch bugs [English name: Pacific rice chinch bug]

One type of chinch bug that collectively sucks and damages the lowest part of the stocks has been identified. Rice damaged by this insect pest shows poor tillering and short stock.

Insecticide Resistance and breaking of natural enemy complex by insecticide

Spraying insecticide can be very dangerous as shown in Figure 44. The spraying method, frequency, etc., are quite technical; and the problem is that pest insects may become insecticide resistance [tolerant] to the sprayed insecticide and destroyed natural enemy complex, resulting in a higher concentration of insecticide being required, which can ultimately result in adverse effects on humans.

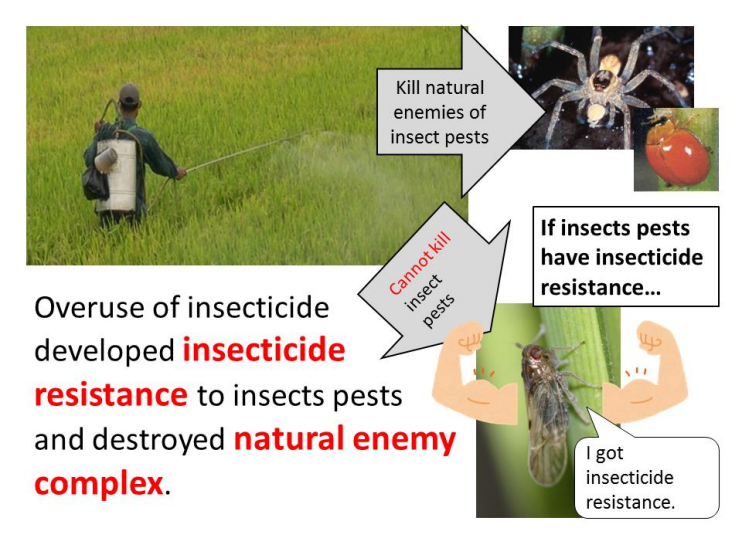


Figure 44: Insecticide Resistance

Wood/ bamboo vinegar

In PNG, the utilization of wood/bamboo vinegar is recommended. Wood/bamboo vinegar is made in such a way that highly moist wood is smoked, and in a chimney, as shown in Figure 45, the moisture-laden liquid forms condensation, which produces the vinegar to be collected. When the vinegar is diluted by 10–100 times and sprayed onto plant beds, grove soil, or paddy stalks, it is effective for insect control.

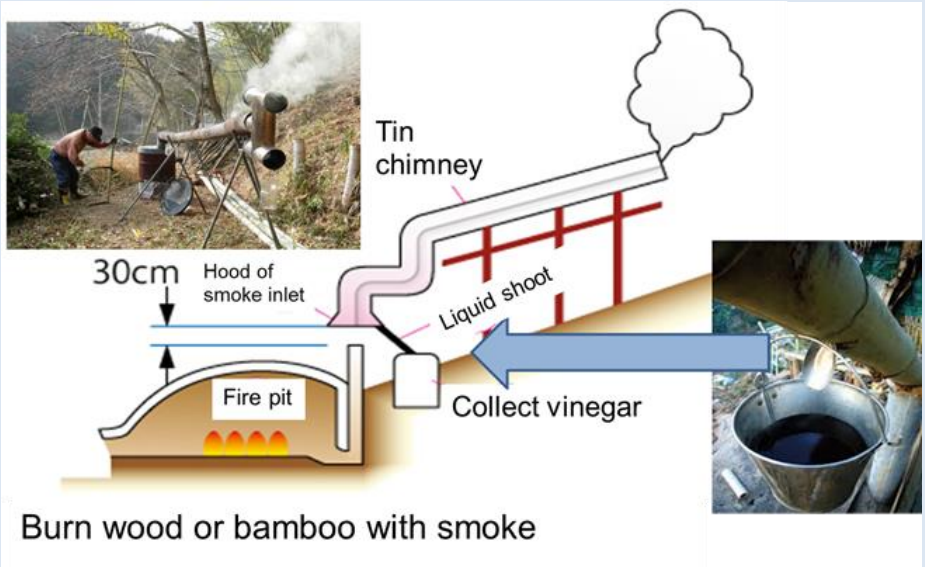


Figure 45: Making Wood Vinegar

Cultural control

- Understanding **life cycle** of insect pests is most important to adopt proper control methods.
- **Monitoring** of insect pests is essential to decide whether control them or not.
- **Cultural control methods** such as synchronous cropping, crop rotation and weed control are effective to **cut out of life cycle** of insect pests.

No by individual farmers but **community-wide adoption** is most effective for cultural control.

Shown in Table 1, insect pest control by main rice insect in PNG is summarized.

Table 1: Summary of insect pest control

	Stem Borer	Rice Bug	Plant-hopper
Synchronized cropping	Yes	Yes	Yes
Crop rotation	Yes	Yes	Yes
Weed control	Yes	Yes	No
Remove stubble/Straw and burn them	**Yes**	No	No
Plow the field after harvest	Yes	No	No
Collect eggs by observation	Yes	No	No
Collect adults by sweeping	No	**Yes**	No
Early maturing variety	Yes	No	Yes
Resistant/tolerant variety	Yes	No	**Yes**

2 Harvesting and Soil Treatment After Harvesting

2.1 Harvesting

There are three basic method of determining the harvest time for your rice crop. One is by counting the number of days between planting and harvesting. Each rice variety has a crop-duration measured in the number days from planting to harvesting, when the optimum ripening age is reached and the crop can be harvested. This number varies from 110 to 135 days-after-planting.

Another method for determining the harvest time is the percentage of grains that have turned yellow and are full at ripening. It is harvest time when about 80% of grains turned yellow regardless of the weather conditions. The ripening grains should never be allowed to fully ripen at 100% level because at this stage the rice grains and crop starts deteriorating and can be devour by birds and wild animals.

The third method of determining the harvest time is by the grain's moisture content. The ideal grain moisture content for harvest is between 18 and 22%w.b. Grains should be firm but not crumbly when bite or press between the teeth.

When harvesting, it is important to harvest all the grains together at once. If the crop is big and cannot be harvested in one day, you must organize a hired or pooled labour and harvest the crop in a day or two. Never leave your rice crop to another week or fortnight to harvest. Doing so will cause your crop to degenerate and allow insect pests, vermin and birds to thrive eating off your ripen grains. Leaving your crop to a delayed harvest may generate through crop lodging, grain shattering, and mouldy or pre-germination whilst still in the field. Therefore, the use of correct timing to harvest will help reduce crop losses as described above.

Delayed harvesting will also cause grains to fluctuate in its moisture content over the period they are still in the field, casing grains to deteriorate in physical integrity. Harvesting too early will result in a larger percentage of unfilled or immature grains, which will lower the yield and cause higher grain breakage during milling. Generally the ideal harvest time lies between 130 and 136 days after sowing for late-maturing varieties, 113 and 125 days for medium-maturing varieties, and 110 days for early-maturing varieties.

As tools for harvesting, you should have bush knife or sickle to cut the base of the stem. You should have hoes and shovels to treat soil immediately after harvesting.

Before harvesting the entire crops, you have to harvest best rice seeds to use for next cropping. It should be harvested in the middle of garden because the rice at the edge of the garden could have been affected easily by surrounding environment and seeds might not be ideal. You have to select and harvest healthy and full mature rice panicle for seeds and separate from other grains.

After harvesting best rice seed panicles, you should harvest all the rest of grains by cutting the base of the stems.

Figure 46: Training youth harvesting rice crop using the harvesting knives or sickles.

2.2 Soil Treatment Just After Harvesting

After completion of harvest, you have to remove all the weeds and stumps from the roots and plough them back into the soil by ploughing with hoes or any other gardening tools, to prepare for next cropping. Soil treatment should be done together with harvesting, to remove all the habitats of pests, put green manures back to the soil, and give enough time for green manure to de-compost for next cropping.

Figure 47: Soil tillage using hoe before planting and soon after harvesting.

Check box for Confirmation:

3 Post-Harvesting

Post harvesting is an important process to obtain and keep good quality of rice. The basic steps of post harvesting are indicated in the followings.

3.1 Selecting Best Seeds

You should select best seeds from the selected panicles as seeds for next cropping. Pick healthy, fully-matured, and uniform seeds in size especially from the center of the panicles. Try to select 40% of your selected panicles as seeds and the rest for usual consumption in order to obtain better germination ratio and uniform quality.

Check box for Confirmation:

3.2 Threshing

Threshing is a mechanical process of separating the ripen grains from the panicles or from the straws, either manually or by the use of threshing machines. Threshing of rice must be done on the day the rice crop is harvested either by panicle-harvest or by straw-harvest. When the rice crop is harvested and grains are separated from the pedicels and dried, the grains should not be wet again. Repeated condition between drying the rice grain and absorbing them of moisture will cause grains to crack and break during the milling process.

If the rice crop is harvested while there is light rainfall and/or a drizzle, the harvested grain-straws should be allowed to dry off the rain drop-lets on a canvass or by hanging them on raised stake or on bamboo or wooden pole scaffold.

Rice can be threshed using hands as shown in Figure 48 or by a more commonly and effective way of threshing by beating the grain-straw against a wooden frame as shown in Figure 49. One important method of threshing rice when rice is panicle-harvested is the use of both foot, with the circular and wringing motions using the foot's sole.

Figure 48: Panicle-harvested rice may require hand-rubbing to separate grains.

Figure 49: Straw-harvested rice is threshed by beating against wooden frame an on canvass.

Check box for Confirmation:

3.3 Drying

Drying the harvested grains to the appropriate moisture content is important to prevent the growth of fungi, moulds and prevents the attack of stored-grains pests such as grain weevils. Rice grains must be carefully dried and over-drying must be avoided as it causing the moisture content to fall below 12% that leads to grains cracks and resulting into broken grains when milled.

The drying of freshly threshed grains should be done on opened canvass in sheltered area or in a shed which is protected from direct sunlight and any expected rain-fall as shown in Figure 50. Intermittent drying can be done under direct sun-light but this must be done under 30 minutes to less than an hour each day or in each drying season as shown in Figure 51. This drying method is called air-drying. The grains spread onto a canvass should have a spreading thickness of 4-5 cm (but not more than 5 cm) and occasionally turned over and re-spread until ideal moisture content of 14-15%w.b is consistent achieved. Never use concrete or iron sheets like corrugated roofing iron sheets as surface to spread your grains onto for sun-drying as this material can trap sun's heat and raise the temperature to the detrimental level.

Grains moisture content can be determine by biting-method or by using an electronic moisture reading meter supplied through REU and the provincial DAL.

It may be difficult to determine the duration of grain drying period or timing due to most rice harvesters not knowing the initial grain moisture content and when to step drying when the appropriate MC is achieved. The speed and the effectiveness of grain drying are influenced by the surrounding air temperature, humidity level, wind or breeze velocity, and general weather conditions. It might take just half day or more than three days to completely dry the rice grains to storable moisute content. When drying the grains, rice grains must be turned-over every 30 minutes by using a rake or by hand.

Figure 50: Rice grains being sun-dried spread on canvass.

Figure 51: The same rice grain being dried in sheltered area or shed.

Check box for Confirmation:

3.4 Winnowing

Winnowing is a mechanical means of separates chaffs from the rice grains. It is a very simple work but very important process and can be done manually or by a using a winnowing machinery. If you

don’t winnow or separate chaffs, stones, and foreign matter from your rice grains, the chaffs and foreign matter will cause grains to break while milling, increase the cost of milling rice, increase the wear-and-tear in the milling machine components responsible for husking and polishing.

There are two means of winnowing, (1) by natural breeze or wind and by, (2) electric motor fan driven wind. You can use the breeze to blow the chaffs away from rice by dropping the grains from an overhead position to the ground on the canvas several times as indicated in the Figure 52. Avoid contaminating the hill of grains with soil particles, stones or grits. You can also throw up the rice grains to blow away the chaffs, empty grains and foreign matter using the bamboo-strip winnower several times in a circular and rolling motion as shown in Figure 53.

Figure 52: On spread canvass, rice grains can be winnowed with prevailing winds or breeze while being dropped from a height either by small bowls or container.

Figure 53: The same rice grains can be winnowed using round winnowing trays made from weaved bamboo-strips.

Check box for Confirmation:

3.5 Storing

After winnowing, the rice grains can be milled right away for consumption or the grains bagged into sacks and stowed away. Rice grains in storage should be stowed away in dry, well secured and protected shed, away from the family dwelling house or home.

Rice grains dried in direct sun-light conditions would have high grain temperature soon after its re-bagging and sacks brought into the storage room must have their sack mouth left open to allow air movement and grains temperature to reach the room temperature as shown in Figure54. Fairly well prepared rice grains can be stored for much longer storage period and later milling for consumption.

Rice should be stored in sealed sacks and should be placed in a protected place to avoid damp, rats and insects. The rice should not touch the ground to avoid the possibility of absorbing moisture from the floor and causing high-moisture relating spoilage to the rice grains.

It is also important to store seeds for next cropping appropriately. Life of the seeds will be halved for every 1% increase in moisture content or below 36°C in grains temperature. The rice seeds can also be stored in sealed sacks and should be placed in dry sheltered storage rooms as shown in Figure 54 and 55.

Figure 54: Rice grains in sacks whose sack-mouths are left open to allow the heat to escape soon after sun-drying and allowed to settle to the room temperature.

Figure 55: Sack-mouths with grains left to settle to the room temperature and not allowing the hot air to condense if the sack mouths are closed soon after sun drying.

Check box for Confirmation:

3.6 Milling

The final step before consumption is the milling of rice. You can bring your rice to the nearest milling station. If milling station is not available in your neighborhood, you can mill your rice manually using *kisér* or *tong-tong*. Basic instruction on how to construct rice milling tools such as *kisér* and *tong-tong* can be sourced from "Basic Rice Farming in Papua New Guinea –Let's Grow and enjoy our own rice" by DAL and JICA. You can also enquire about suitable motorized rice mill to DAL.

Check box for Confirmation:

4 Important Practices

4.1 Synchronous cropping and Crop calendar

You need to crop rice at the same time with other farmers in the same area to avoid concentration of pests and to prevent the yield losses. You also need certain period of time when no farmer crops rice in the same area by synchronizing the rice cropping season to cut the life cycle of pests and diseases as explained earlier. You should implement the synchronous cropping of rice with other farmers to protect your farm from pests and diseases by creating community-based crop calendar for rice cropping. See the example of crop calendar in Appendix 1

Create common understanding and set the rules about rice farming in your area. The problem of pests and diseases cannot be solved by individuals. They need to be tackled by the community.

Check box for Confirmation:

4.2 Crop Rotation

If you continue to cultivate rice in the same field, there will be a growth injury due to continuous cropping of the same crop. The yield will be smaller and smaller every time you cultivate in the same field as illustrated below.

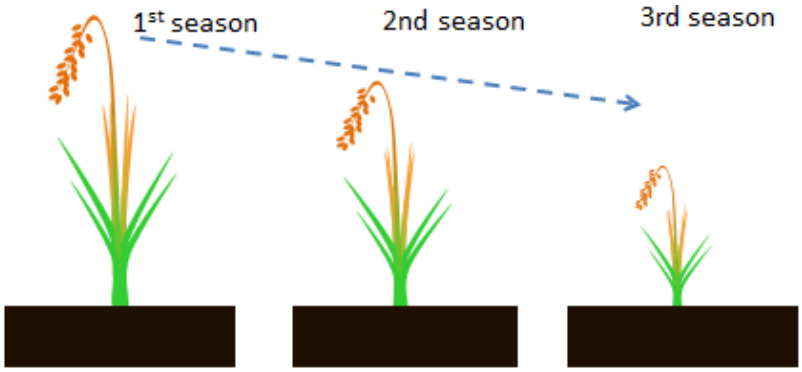


Figure 56: Schematic illustration to show decline in rice yield if cropped on the same land repeatedly.

If you try to cultivate a new field every time to avoid a growth injury, it causes deforestation, damages the ecological system and gives the permanent damage to the environment. Shifting cultivation needs to be avoided. (See Figure 57: Illustration of Crop Rotation)

What works best is crop rotation. There should be one year interval for the same crop to be planted to prevent a growth injury, but you can cultivate different types of crop during this one year interval. So if you are going to plant and harvest rice twice a year, you should think of two other crops, which are not similar to rice or each other such as peanut and carrot and are not likely to cause monoculture injury, and rotate the garden for each crop in the field every season as indicated in the picture below. (See Table 2)

Green manure crops are those which should not be harvested for consumption but should be utilised as organic fertilizers. Peanuts and pigeon peas are good as green manure crops. So If you chose to crop peanuts for crop rotation, you can apply back to the soil approach to peanuts just like weeds

(but much more effective) by ploughing the peanuts back to the soil and make your farm much more fertile.

Crop rotation does not have to take place in the same area. You can do it in different locations. If you want to plant rice for one season per year, you can plant peanut and/ or pigeon pea in between rice cropping and make your farm fertile.

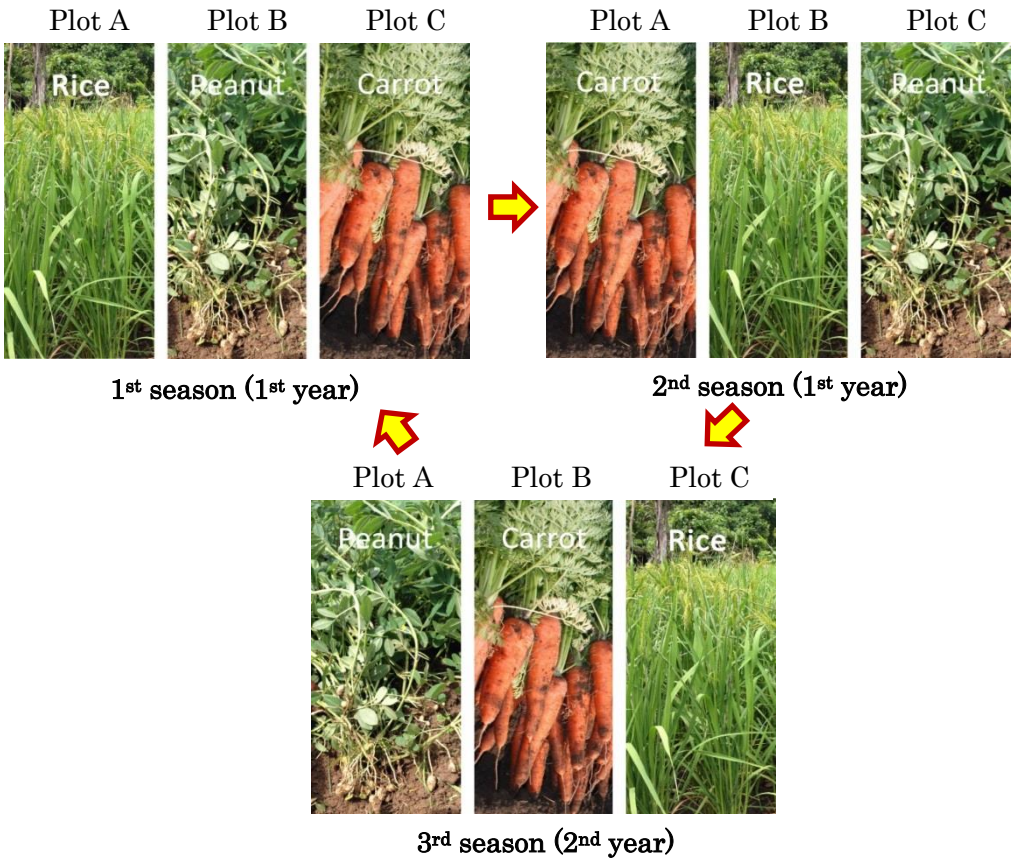


Figure 57: Illustration of Crop Rotation

Further Explanation:

Crop rotation is a practice of growing a series of dissimilar types of crops in the same area in sequential seasons. This practice is also to diversify cultivated products. Growing the same crop in the same place for many years in a row disproportionately depletes the soil of certain nutrients and such a soil condition gets concentrated and reduces production, increasing the risks of pests and diseases such as wire worms (a kind of nematode which comes to rice grains). This is called **'injury by continuous cropping[1].'**

Crop rotation is necessary to prevent injury by continuous cropping. A crop that leaches the soil of one kind of nutrients should be rotated by a dissimilar family crop that returns that nutrient to the soil or draws a different nutrient for next cropping. For example, rice can be rotated by peanut and peanut can be rotated by tomato. There needs to be a one year interval to go back to rice cropping. See the different types of crop family which can be cultivated in PNG below.

[1] Injury by continuous cropping: The negative impact of continuous production on soil productivity has been demonstrated but is less well researched and understood. In the history of cropping, farmers continuously combat their way to avoid injury by continuous cropping.

Table 2: Interval the next cultivation of agro-products by Order and Family

Taxonomic affiliation		Crop	Interval to the next cultivation (year)
Order	Family		
Poales	Poaceae	Maize	1
		Paddy upland	1
		Paddy irrigated	Low injury but need to take measures
Apiales	Apiaceae	Carrot	1 (low injury)
		Parsley	1-2
Asterales	Compositae	Lettuce	1-2
	Asteraceae	Garland chrysanthemum	2-3
		Sunflower	1-2 (low injury)
Brassicales	Cruciferea	Broccoli	1-2
		Cabbage	2
		Napa cabbage	2-3
		Turnip	1-2
		White radish	1 (low injury)
		Leaf mustard	2-3
Brassicales	Cruciferea	Melon	2-3
		Pumpkin	1 (low injury)
		Water melon	4-5
		Zucchini	Low injury
Caryophyllales	Chenopodiaces	Spinach	1-2
Fabales	Fabaceae	Chickpea	2-3
		Alfalfa	3-5
		Pigeon pea	Low injury
		Mucuna	Low injury
		Peanuts	No injury
Lamiales	Lamiaceae	Peppermint	No injury
Liliales	Liliaceae	Green onion	1-2
		Onion	1-2
		Garlic	1-2

		Asparagus	1 (low injury)
Malvales	Malvaceae	Okura	2～3
Scrophulariales	Pedaliaceae	Sesame	1 (low injury)
Rosales	Rosaceae	Strawberry	2-3
		Pear	2-3
		Peach	2-3
Brassicales	Solanaceae	Green pepper	3-4
		Paprika	3-4
		Potato	2-3
		Tomato	3-4
Solanales	Convolvulaceae	Sweet potato	1 (low injury)

Crop rotation allows farmers to keep their fields under continuous production, instead of letting them fallow, and also reduce the need for applying artificial fertilizers, both of which can be expensive.

4.3 Mixed planting and intercropping

Mixed planting is the practice of planting two or more crop species in the same area, either at the same time or in sequence to allow for insect pest control, and weed control, to allow for beneficial insects to thrive while maximizing the use of the land space. Mixed planting is a form of multi-cropping that can be used for cultivating rice while the nearly planted cash crops such as cocoa, coconuts, rubber, oil palm are establishing.

Intercropping is the practice of growing one or more crops in the same area in addition to the main crop. For example, you can grow rice in the palm oil, cacao, or banana plantation. The most common goal of intercropping is to produce a greater yield on a fixed size of land by making use of resources that would otherwise not be utilized by a single crop. For intercropping, careful planning is necessary not to have crops competing with each other for physical space, nutrients, water, or sunlight.

Mixed planting and intercropping are the alternative cropping methods in addition to crop rotation to avoid the ecological destruction through slash-and-burn farming.

Figure 58: Rice being inter-cropped with a banana crop.

Figure 59: An establishing oil-palm have spaces in-between each palm that can be cropped with rice or other short-term crops.

4.4 Terraced Fields

A terraced field is a piece of sloped fields that has been paved, graveled, raised or reinforced with strong timbers to make a flattened area for farming and prevent the soil to erode. It is ideal to cultivate rice in the flat land, but if you cannot find the flat land and need to use sloped fields, you need to construct a terraced field first.

Figure 60: A sloping land can be cropped using land-terracing techniques and sloping land technologies.

A raised terrace field keeps water in the soil and avoids draining of nutrition from the soil. The terraced field will have higher yield than non-terraced field in the slope. With terraced fields, you can avoid shifting cultivation as you can continuously crop in terraced fields with good soil treatment, and reduce the abandoned fields which are the source of pests and insects.

Construction of terraced fields should be done gradually over time from the small area of low-pitched slope. Regarding terraced fields, where the slope is steep, it is preferable for cultivation to make each terrace flat over duration of two years, as the soil can fully spread itself. (On the contrary, if a slope is made flat immediately, it is not good for planting because the surface layer becomes formed from less fertile soil.)

4.5 Keeping Demonstration Plot Diary

You should keep record of your observation and care provided at your demonstration plot in the Demonstration Plot Diary. See the template in Appendix 2. You can record the date of your visit, weather, condition of soil and rice, and care (if any care is provided). It should take only a minute to keep such a diary. Demonstration Plot Diary is a useful tool you can use to teach others about rice production based on your own experience.

Check box for Confirmation:

Appendix

Appendix 1: Example of Crop Calendar

Appendix 2: Demonstration Plot Diary

Appendix 1: Example of Crop Calendar

Crop Calendar template

Item/ Month	January	February	March	April	May	June	July	August	September	October	November	December
Weather Pattern												
Soil Preparation 												
Sowing at nursery 												
Transplantation 												
Weed Control 												
Pest Control 												
Harvesting 												

Fallow period of rice garden except for nursery bed

Appendix 2：Demonstration plot Diary

Date	Weather	Condition of soil and rice	Care (if any care is provided)
ex.	sunny	Soil is dry. I cannot make a mass with the soil.	Sprinkled water