You can easily do it!!

GUIDE for NERICA CULTIVATION

This guide is written from « training on production and extension of NERICA” for Japanese Overseas Cooperation volunteers (JOCV). It addresses those who will like to have basic knowledge and techniques on NERICA production.

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Ⅰ Basic knowledge on Rice and NERICA

1. What is NERICA?

NERICA (New Rice for Africa) is a group of interspecific hybrid rice varieties and lines between Asian rice varieties (*Oryza Sativa L.*) with high yield potential and African rice varieties (*Oryza Glaberrima* Stued.) with resistant to main constraint to rice production such as major African insect pests and disease across ecologies in sub-Sahara Africa (SSA) [AfricaRice 2008]. NERICA targets to improve the food security for small scale farmers, for women especially, who cultivate rain-fed upland rice in forest zones of SSA. NERICA was developed in 1999 by WARDA (*West Africa Rice Development Association) which became Africa Rice Center* at present. As of 2008, 18 upland NERICA varieties and 60 lowland ones were released. The upland NERICA varieties can be cultivated in the condition of upland like maize, sorghum, etc., so its cultivation will easily fit in Africa where people are used to cultivation in non-flooded and lowland areas.

2. Morphology and biological features of rice

(1) Morphology of rice

Fig. 1 and Fig. 2 show each part of a rice plant and their names.

(2) Panicle

The term “panicle” is synonymous with the inflorescence of angiosperms, and is a proper appellation used for Gramineae. The reproductive organ of angiosperm is called flower, and the group or the arrangement of the flower is called inflorescence. The inflorescence of gramineous crop is named “panicle, ear, head, and/ or spike”. The name is depended on the arrangement of spikelet on the rachis. And the one of rice is named “panicle” (or compound raceme). The panicles of rice plants are characterized by long branched rachillae (rachises). They belong to the panicle (also known as compound raceme) (Makino 1961).

Branches on the panicle are called rachis branches and a branch on each node of rachis is “primary rachis branch” and one is from primary rachis branch is named “secondary rachis branch”. A rice panicle has 8-15 primary rachis branch and secondary rachis branches are formed from some nodes on base of a primary rachis branch (Nakamura 2011).

According to an analysis of the structure of rice panicles, the branching pattern of the rachillae is monopodial branching in which the relationship between the main axil and lateral axil is clear. All of the lateral axils on the primary and secondary branches maintain an alternate order, and bilateralism can be observed in the branching direction of the secondary branches grown from the lowest node of each primary branch. In addition, spikelets are always set with their lemma side directed to the rachilla, and the direction of spikelets at the end of the rachilla is roughly the same as that of spikelets just below them (Matsuba 1978).

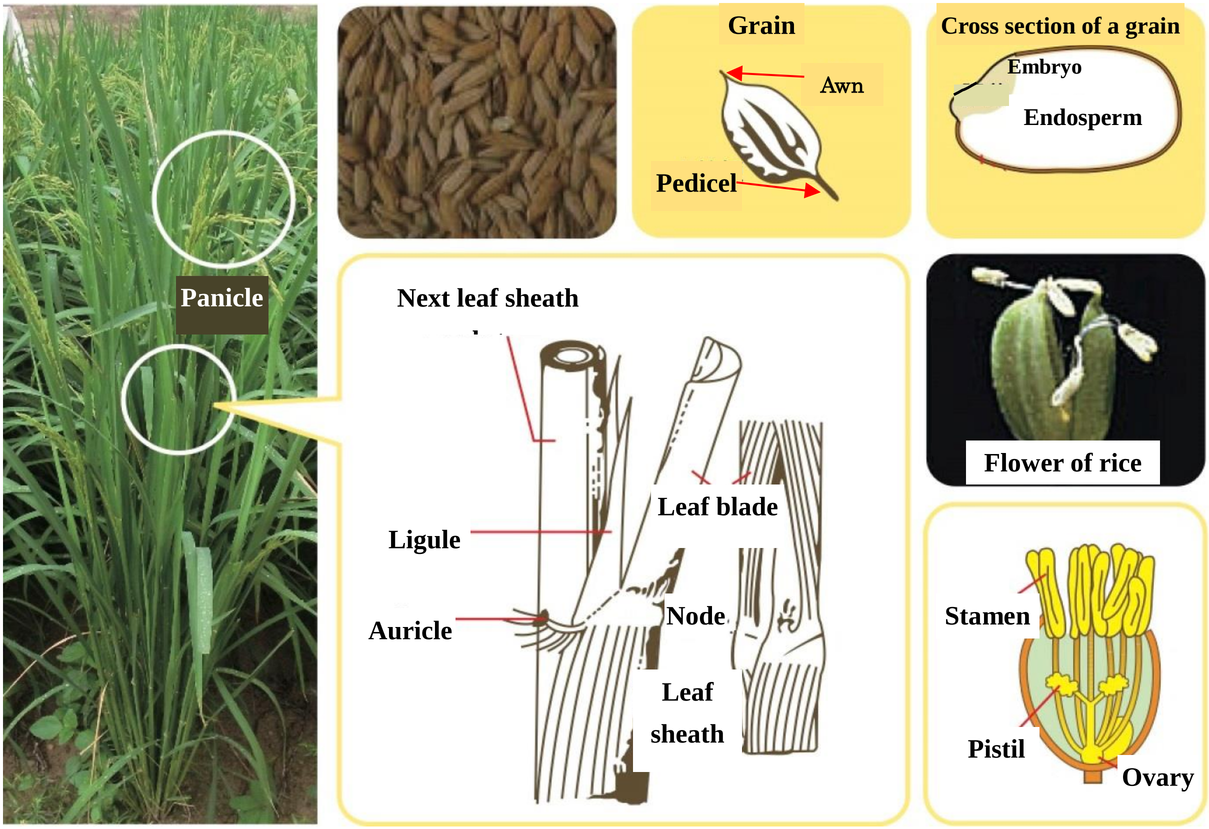


Fig. 1: Names of each part of the rice plant.

The source：米穀安定供給確保支援機構「米ネット」および Hoshikawa, K (1975)

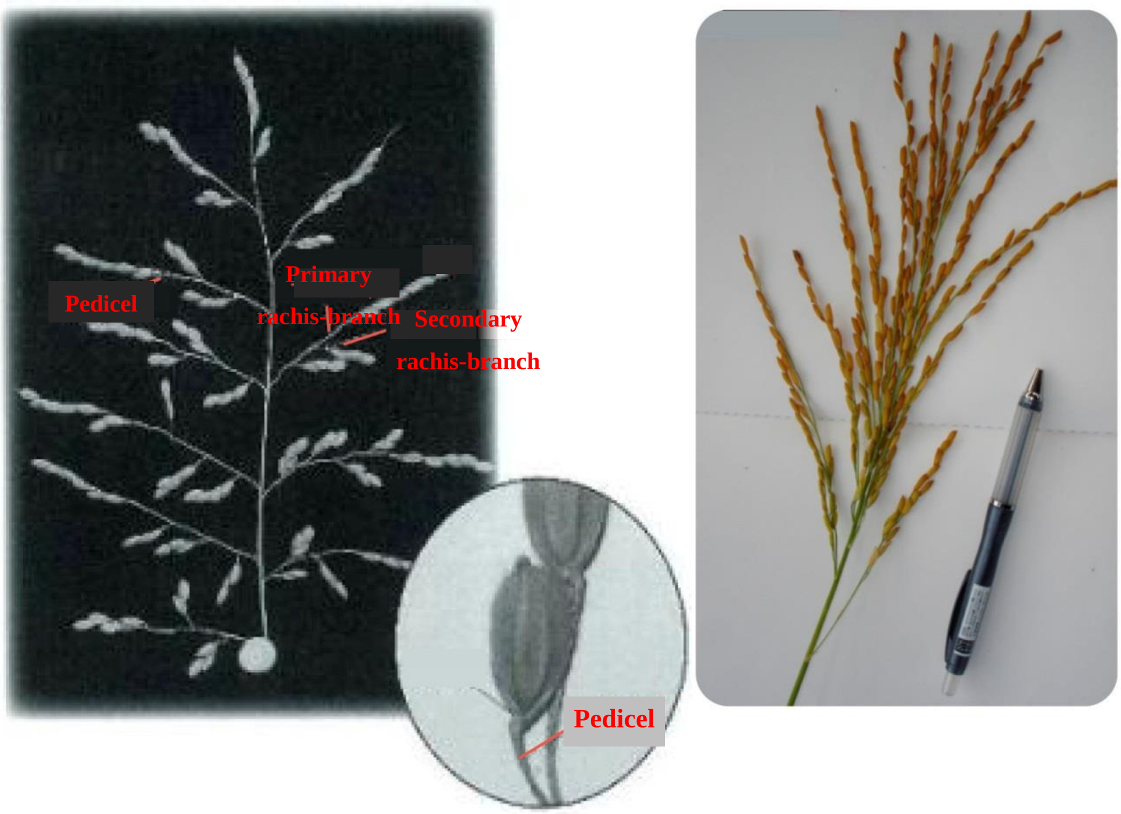


Fig. 2: Panicle of the rice.

The source：Horio 2009.『食農ネット』「イネを観る、農具を知る」

(3) Biological characteristic of rice

Upland rice or Lowland rice?

Lowland rice is cultivated on paddy field and upland rice is cultivated on upland field. And depend on agro-ecologies for rice cultivation, rice is classified as “Irrigated rice”, “Rain-fed lowland rice”, “Rain-fed upland rice”. The classification is defined by JICA in May 2008 at CARD (*1) which was launched in TICAD IV (4^{th} session of Tokyo International Conference on African Development).

*1 CARD “Coalition for African Rice Development”
CARD is a consultative group of donors, research institutions and other relevant organizations which aims to promote rice cultivation in Africa via information sharing, harmonization of existing initiatives and projects and advocacy for further investment.

The goal of CARD is to double the rice production in Africa from the present (2010) 14 million tons/ year to 28 million tons/year by 2018. As approaches to attain the goal, CARD declares “Approach by Agro-Ecology”, “Value Chain Approach”, “Capacity Development Approach”, and “South-South Cooperation Approach”. As Approach by Agro-Ecology, CARD promotes breeding and selection of improved varieties, improvement of cultivation techniques and use of inputs (water, fertilizer, etc), while recognizing the differing requirements across the three major agro-ecologies for rice cultivation, “irrigated field”, “rain-fed lowland”, and “rain-fed upland”. For rain-fed upland, CARD prioritizes intensified NERICA dissemination (Outline of CARD 2009).

Early variety? Medium variety? and Late variety?

Rice varieties are classified as “Early variety”, “Medium variety”, and “Late variety” according to number of days from seeding to heading. NERICA belongs to early maturity. Each varieties has same maturity period (from heading to harvest) under same condition, but the duration of the period depends on temperature strongly and it is longer under cooler condition. Thus, the period is about for 30 days in lowland tropical like West Africa, and is more than 30 days in Cameroon due to cooler climate.

Panicle number type? or Panicle weight type?

Panicle number type is a variety which has many panicles per plant but the weight of the panicle is lighter. On the other hand, panicle weight type has relatively few panicle numbers but the weight of a panicle is heavier due to larger number of grains per panicle. NERICA belongs to panicle weight type because NERICA doesn’t have large number of tillers but less number of non-productive tillers compared to Koshihikari (Japanese variety). Koshihikari has 70-80 grains per panicle and NERICA has 80-110 grains per panicle, especially NERICA 6 has large number of grains (it possibly attains about 170 grains per panicle). Due to few number of panicle, NERICA can increase the number of panicles per unit area (m^2) by sowing with higher planting density in order to obtain adequate number of panicle for maximizing the yield. However, in general, if the number of grains per unit area (m^2) increase, the percentage of filled grains is decreased; in case a total volume of grains (grains are container to fill up the starch) exceed the quantity of total starch produced and supplied by photosynthesis.

Fertilizer application is necessary?

Some reports mention that NERICA can produce certain yield without fertilizer application (Harsh 2004, Aoyama and Yamada 2005), but fertilizer application or cultivation in fertile land is recommended for NERICA as long as possible. Continuously cultivation on same land deteriorates soil fertility. Thus, it is necessary to establish appropriate cultivation system for sustainable agriculture by adopting crop rotation with legumes, mukuna and etc.

NERICA is a drought tolerant variety?

NERICA is known as a drought tolerant variety (WARDA 2001, Harsch2004, Aoyama and Yamada 2005). However, CG 14 (*Oryza Glaberrima Stued.*), a paternal variety of NERICA, seems to be a variety which consumes much water. In addition, rice including NERICA requires much water and has less resistant to drought compared to other crops like maize, millet, and sorghum. Hence, rice reduces the yield drastically under the severe drought condition. Do not cultivate NERICA instead of maize, sorghum, millet in arid and semi-arid zone.

3. NERICA varieties

NERICA1	The apiculus color and base of the stem are violet.	
NERICA2	The grain has an awn. It resembles NERICA 5, but it is generally higher than NERICA5 in terms of plant height.	
NERICA3	It is difficult to distinguish from NERICA 4. The growth and production are stable. It has resistant to severe condition rather than NERICA 4?	
NERICA4	It is difficult to distinguish from NERICA 3. The growth and production are stable. It is the most extended variety among NERICA varieties. The result was obtained by tasting tests that NERICA 4 is more delicious than NERICA 3.	
NERICA5	The grain has an awn. The emergence is not uniformed. Period from sowing to heading is shorter. The plant height is lower than one of NERICA 2.	

NERICA6	The grain is large and slightly round. It has long plant height and less number of tillers. Period from sowing to heading is the longest among NERICA upland varieties, that is, vegetative growth stage is longer. It has less resistance to drought particularly during reproductive growth stage. It can obtain high yield under sufficient water condition.	
NERICA7	The grain is large. 1,000 grains weight is the heaviest, more than 30g. The plant height is high.	
NERICA8	The plant height is low. The color of the grain is gold. It has large number of tillers. It is difficult to distinguish from NERICA 3 and NERICA 4 in terms of color and shape of the grains.	
NERICA10	The grain has an awn. It is difficult to distinguish from other varieties like NERICA 2 and NERICA 5 in terms of the grain, but their periods from sowing to heading are different.	

This handbook is based on the NERICA Training implemented in Benin in 2010 and 2011. Thus, NERICA 4 which has been the most extended variety at tropical zone in West Africa is adopted as a sample variety for explanation. However, NERICA3, NERICA 8, and NERICA 10 are introduced and extended in Cameroon as of December, 2011. Furthermore, the characteristic such as period of vegetative stage differs according to cultivated condition and/or climate.

Ⅱ. Growth stages of NERICA

The growth period of the NERICA varieties depends on the varietal characteristics, cultivate method, Agro-environment (especially temperature), and so on. In case NERICA 4 is cultivated under tropical lowland area in West Africa (WA), its growth period from seeding to harvesting is approximately 100 days but it takes around 115 to 120 days in Central Region of Cameroun. The result of series of the variety trials at IRAD Yaoundé shows that the growth period of NERICA 3 and NERICA 8 around 110 to 115 days and 105 to 110 days, respectively. However, there is still not enough information on NERICA in Cameroun where it is lower temperature than in WA. Therefore, it is necessary to accumulate more data of NERICA varieties such as growth period in each Agro-ecology in Cameroun.

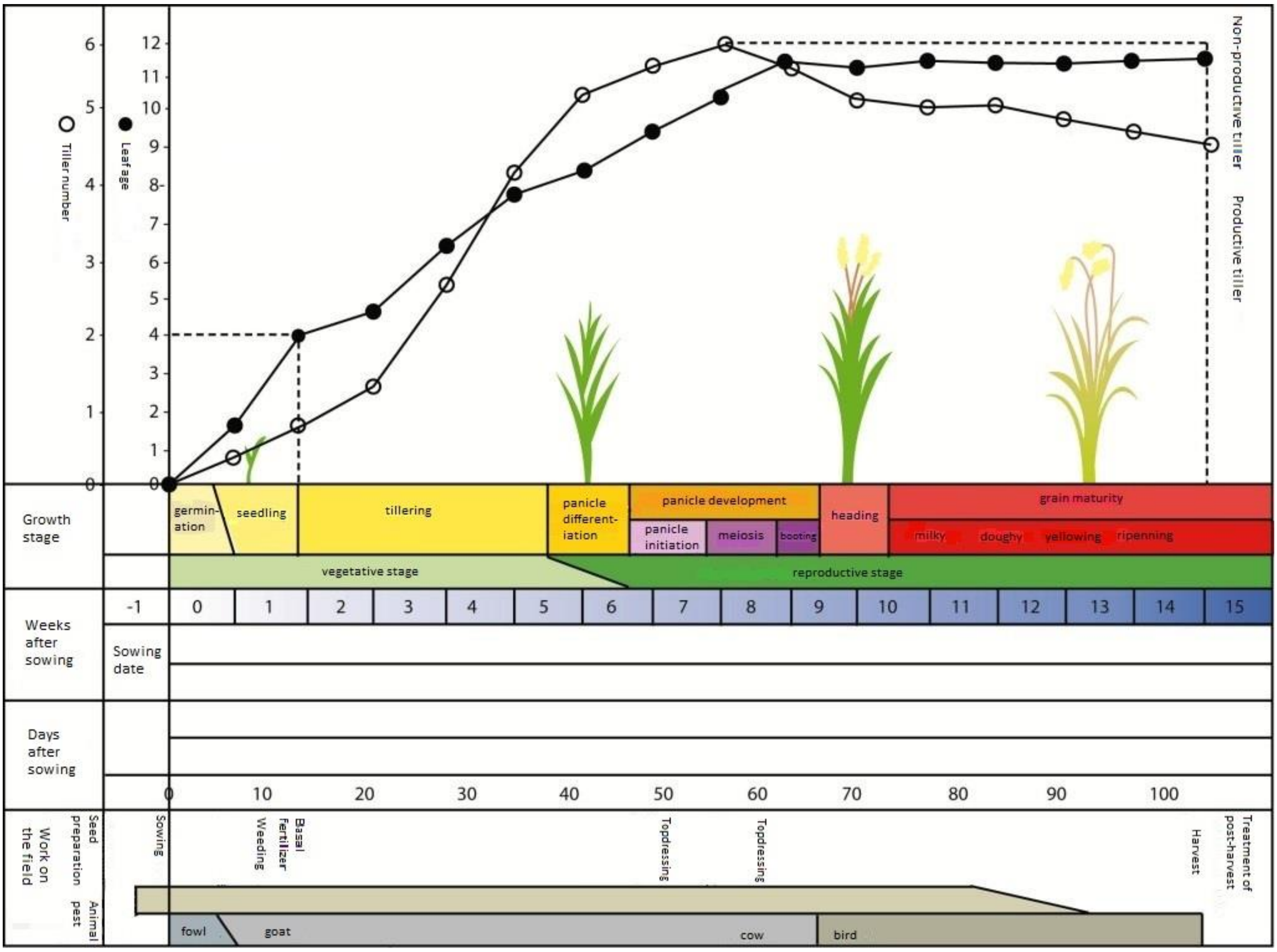


Fig. 3: Growth cycle of NERICA 4 in West Africa

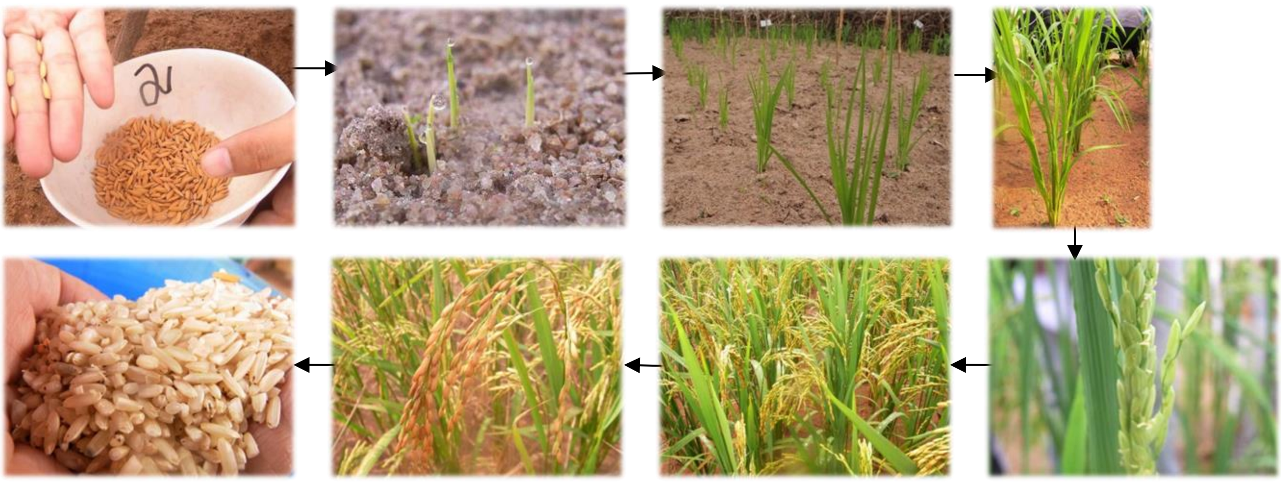


Fig. 4: Photos of each growth stage (from seed to brown rice)

The fig. 3 shows each growth stage of NERICA 4 according to the time in WA. The days after sowing to each stage are changed by the cultivation condition (Agro-ecology). So please fill out the blank spaces on the figure based on the data collected in your field.

1. Chronological growth cycle of rice

The chronological growth cycle of the rice plant, from a morphological point of view, starts with germination, and goes through shoot development (comprising leaf emergence and tillering), internode elongation, panicle emergence, flowering, grain filling, grain maturity (which is accompanied by a withering of the stem and leaves), to the termination of life. The life of the rice plant is separated into the vegetative and reproductive growth phases, representing growth before and after panicle primordial initiation, respectively. The two phases are considered to be qualitatively different from each other (Maruyama 1995). Each phase is divided more precisely according to the growth conditions of the rice plant.

The growth of NERICA is divided into two phases : vegetative phase and reproductive phase

- ***Vegetative phase***: Sowing → Germination/Emergence → Tillering → Panicle differentiation
- ***Reproductive phase***: Panicle differentiation → Panicle initiation → Meiosis/ Booting → Heading/ Flowering→ Grain maturation → Harvest.

Vegetative growth phase

Primarily, the vegetative growth phase is separated into the period in which the young rice plant depends on nutrients in the endosperm only and the succeeding period of the autotrophic rice plant. This phase is characterized by germination of seeds, active tillering, rooting, elongation of plant height, and emergence of leaves at certain intervals (Maruyama 1995).

Reproductive growth phase

The reproductive growth phase is divided into two stages, before and after heading/ flowering. The former period is for panicle development and the latter for grain filling and ripening of panicles. The reproductive growth phase starts with the differentiation of panicle primordial (hereinafter it is shown as panicle differentiation, P.D.) and is characterized by panicle development (hereinafter it is shown as panicle initiation, P.I.) and the elongation of the culms, sometimes called the internode elongation stage. Panicle development is further subdivided into some stages extending from differentiation of the primordia to heading and flowering (Matsushima 1957). Panicle differentiation begins with the development of the third leaf before the flag leaf (Akimoto and Togari 1939). Goto *et al*. (1990) reported that when the length of the third leaf before the flag leaf attains 30 to 50% that of the previous leaf, the bract primordial in the panicle differentiation stage would have been reached. Therefore, identification of the third leaf before the flag leaf is important for determining when to apply nitrogen fertilizer as a top dressing in order to increase the number of grains per panicle.

The panicle differentiation (P.D.) stage, which is the beginning of the reproductive growth phase, can be identified through the morphological observation in the field (Fig. 3). The longer leaves appear above the canopy within a plot at the stage (See at 38 DAS in the Fig. 3). And the P. I. stage follows the P.D. stage (after 7 to 10 days of the P.D. stage)

2. Vegetative growth phase

(1) Germination and Emergence of seeds

It takes 5 to 7days from seeding to emergence if seeds are sown around 3cm depth in sandy to silty soil. If the seeds are sown deeper than 3cm and/or in clayey soil, it usually takes more than 7 days to emergence.

Germination : Emergence of plumule. Emergence of radicle, i.e., the so-called pigeon-breasted status in which germination can be considered to have already started

Emergence : when any parts of plant appear from the soil.

(2) Tillering stage

Tiller is branch which is developed from axillary bud in botanical but it is called ‘tiller’ in case of rice. A tiller arises at the axil of each leaf. The tillers arising on a main stem are called ‘primary tillers’. A primary tiller, similar to the main stem, produce a tiller at the axil of each leaf. The tillers developing on a primary tiller are called ‘secondary tillers’. Tertiary tillers develop on ‘secondary tillers’, and higher order tillers such as quaternary tillers and others develop on each mother stem. So, the main stem of a plant produces a large number of tillers. The tillers which develop in an early growing stage of a plant usually grow vigrously, produce panicles at the tips of the stems and finally contribute to the yield as productive tillers. The number of panicles depends largely on the number of tillers. The development of tillers during the tillering stage, therefore, is important for the yields of rice.

The growing stage during which the number of tillers increase vigorously is called the ‘most-active-tillering stage’, and the stage when the number of tillers reaches maximum, when the number of tillers begins to decrease, is called the ‘maxmum-tiller-number stage’.

(3) Leaf emergence and Flag leaf

Leaves arise on a main stem at the phyllotaxis of 1/2. Each leaf is called the first leaf, second leaf, ・・・・, Nth leaf from the coleoptil. The last leaf is called the flag leaf. The length of late developping leaf (leaf + sheath) is usually longer up to the 3rd leaf before flag leaf and after this, it is gradually shorter toward the flag leaf. In general higher temperature, faster development of the leaves.

The shape of leaves differs depending on the position where they are located on the shoot axis. In the lower position of the plant, the coleoptile appears first and in the tillers, the prophiyll appears first. The first leaf on an embryo is an incomplete leaf. The uppermost leaf on a shoot is called a flag leaf. The leaf length increases according to the higher positions on a plant. The shape of the leaves does not differ much with the inserted position although minor changes can be observed. When grown under weak light intensity, the leaves elongate conspicuously.

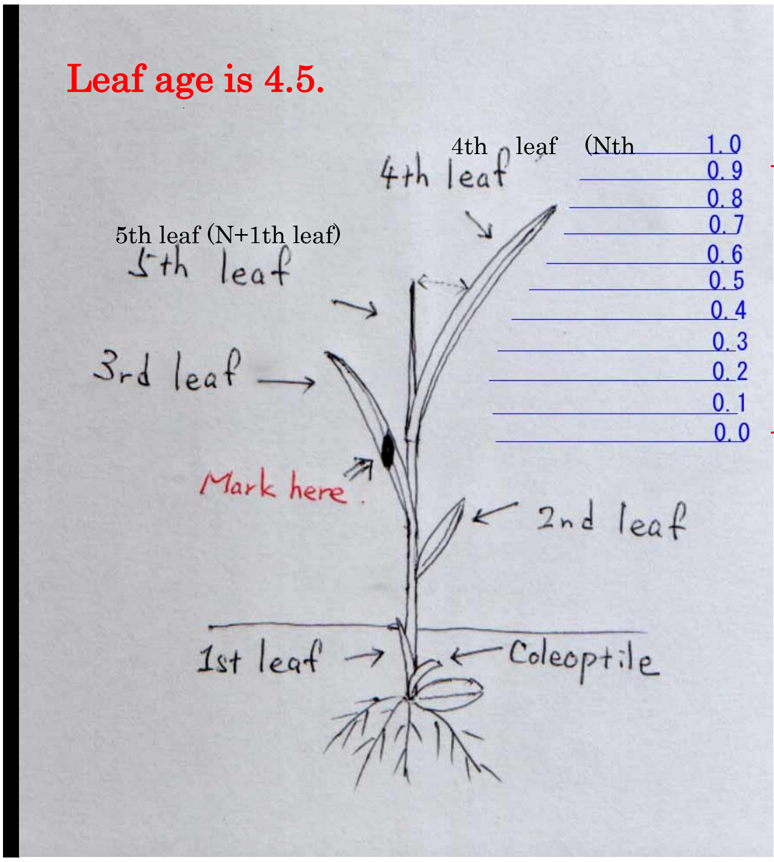
(4) Leaf age

Leaf age development can be determined by counting the number of leaves, from the first leaf to the flag leaf, produced by each principal culm. If you want to know when the panicle differentiation stage has been reached and the speed of leaf development, it is advisable to observe the leaf age weekly.

Example 1(Leaf age 8.4): Leaf No.8 is divided into 8 portions. One portion represents 0.1 leaf age. If the length of the youngest leaf, i.e. leaf No.9, is about half that of leaf No. 8 (or 4 out of 8 divisions), the leaf age is 8.4.

Note: If the emerging leaf is longer than the developed leaf, you should read 8.9 or 9.0, depending on the length of the young leaf in relation to the developed leaf.

Example 2: (Leaf age 4.5)



Leaf No. 4 is divided into 8 equal portions. One portion is equivalent to 0.1 leaf age. The length of the last leaf, i.e. leaf No. 5, is about the 5th portion of leaf No. 4. The leaf age is 4.5.

The 5th leaf is 5/8 of the 4th leaf.
So the leaf age is 4.5.

Fig. 5: Determining the age of a leaf

(5) the number of leaves developed from the principale stem

The number of leaves developed from a principale stem of every variety of rice is almost fixed although it is somewhat variable depending on the agro-environment. A result of the experiment in the IRAD shows that the number of leaves developed from the principale stem of NERICA 3 and NERICA 8 were around 11 in ferilizing condition and 10 in non-fertilizing.

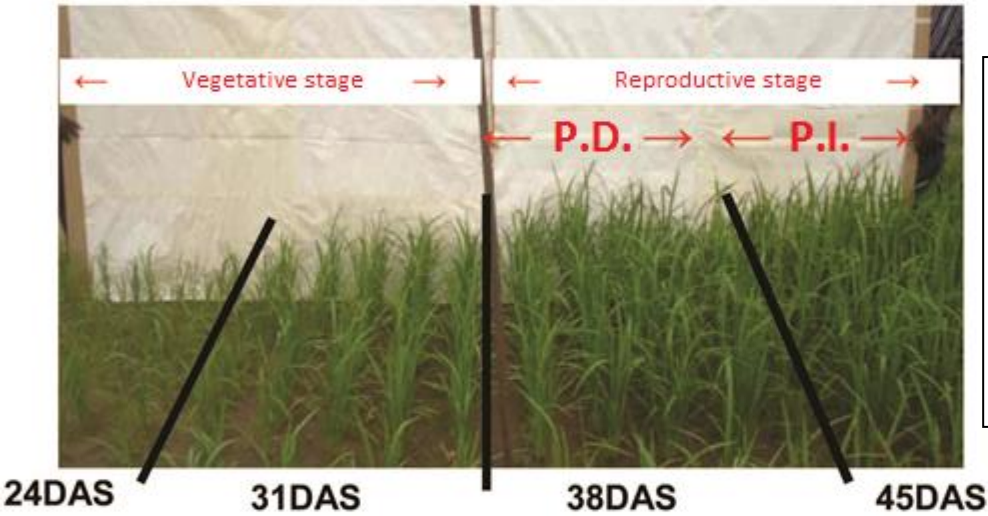
In case rice is cultivated under a low planting density and/or in fertile soil, the number of leaves increase. In contrast, under a high planting density and/or in unfertile soil, it decreases. In general the number of tillers increase as the number of leaves of the principal stem increase.

3. Reproductive grow phase

(1) Panicle differentiation stage and Panicle initiation stage/ panicle formation stage

The reproductive grow pahse begins at the panicle differenciation stage. So it is important to identify "the panicle differentiation stage" for the appropriate timing of the fertilization application. This stage is usually found between 5 and 6 weeks after sowing (WAS) for NERICA 3 grown under the optimum condition. It is also possible to distinguish through observation of the plants. In NERICA (especially NERICA3 and 8), a much longer leaf begins to exceed the previous one at about 5 weeks after sowing (38DAS in the figure). This is the panicle differentiation stage. And then a week later, the next leaf reaches the same height of the long leaf. This is the period of the panicle initiation stage (45DAS in the figure).The nitrogen application during the panicle initiation stage increases the yield through multiplying the number of grains per panicle.

Upland rice growth may delay in farmers' fields of the rain-fed upland cultivation due to scarce of rainfall. In case of that the weeks after seeding and/or days after seeding cannot be available for the appropriate timing of fertilizer application. Therefore, your observation in the field is much more important to increase the yield through right timing of the fertilizer application.

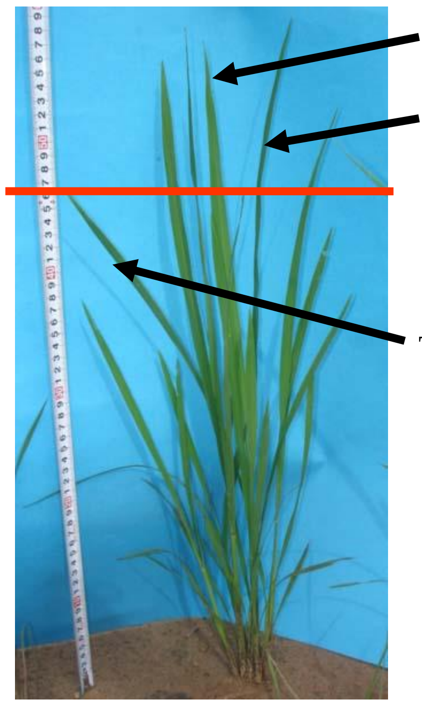


P.D.: panicle differentiation

I.P.: panicle initiation

DAS: Days after sowing

Fig. 6: Visual indicators at panicle differentiation (P.D.) and panicle initiation (P.I.) stages.



The second leaf before the flag leaf

The third leaf before the flag leaf

The third leaf before flag leaf is much longer than the fourth leaf

The fourth leaf before the flag leaf

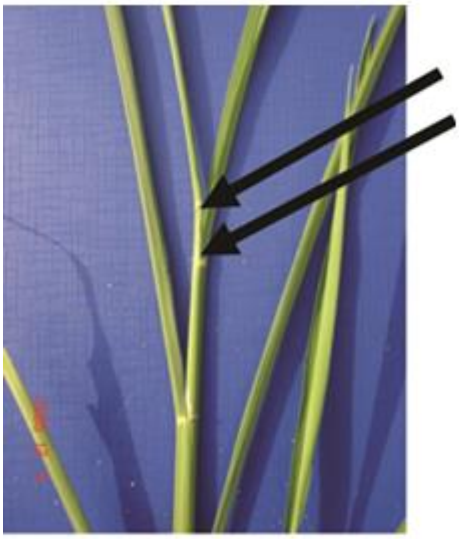
When the second leaf before the flag leaf is as the same as that of third one, the young panicle can be visible in many case.

Fig. 7 : Determing the start of the panicle formation stage

Sokei et al. (2010[a])

(2) Meiotic stage and booting stage

This stage is usually observed about a week before heading (see the photo at the below left side).The nitrogen application at this stage, if there is a surplus of urea, can also improve yield through increasing the rates of filled grains.



Most active time of meiotic stage is when both auricles of the flag leaf and one of the 1st leaf before the flag leaf are same height.
Meiotic stage starts when the auricle of the flag leaf reaches 8 cm below the auricle of the 1st leaf before the flag leaf and terminate when the auricle of the flag leaf reaches 8 cm above the auricle of the 1st leaf before the flag leaf.

Young panicle at meiotic stage

Fig. 8: Visual indicator at the meiotic stage (Developed by Dr. Seizo Matsushima *et al*. in 1955)

Matsushima *et al*. (1955) have shown that the meiotic stage starts when the auricle of the flag leaf is 10 cm below the auricle of the first leaf before the flag leaf, and ends when the auricle of the flag leaf reaches 10 cm above the auricle of the first leaf before the flag leaf. The most active time is when both auricles are the same height.

(3) Heading stage

The heading date is one of the most important agronomic characteristics. Heading occurs when panicles start emerging from the sheaths. The panicle that emerges first within a plot is known as the precocious panicle. The date when 10% of the stems in a plot have headed is called the “first heading date”, while the date when heading takes place in 50% of the stems is called the “heading date” and marks the heading time of each plot. The date when more than 90% of the stems in a plot have panicles is called the “full heading date”. The heading period is the period from the first heading date to the full heading date. This period is shorter when the number of panicles per plant is small and longer when the number is large. It is usually longer under low temperatures than under high temperature conditions (Hoshikawa, 1993). Each heading date is determined by the ratio of the number of headed panicles to the total number of panicles of the plot.

(4) Grain maturity stage

At the time of heading and anthesis, both rachises and rachis-branches are all upright. Anthesis and and ripening start from upper rachises, and around five days after, starch begins to be accumulated in the caryopses on the upper rachises which have flowered earlier. This means that the weight of the caryopses on the upper rachises increase earlier. As a result the panicles start to droop from the upper rachises. Since the rachises are located lower on the panicle flower or are just after anthesis at this stage, they are still upright.

By 5 to 7 days after heading, all glumous flowers on the panicle have completed anthesis, and brown rice grains have already developed in the paddies on the upper rachises to such an extent their longitudinal length has been determined. Thus, the panicles further droops. 10 to 15 days after antheses, the increase in total panicle weight becomes greatest. The panicles which has almost completed ripening droops lower than the neck node of the panicles.

Within a rachis, the caryopsis on its tip flowers first and becomes heavy earliest. Then, ripening occurs in other caryopses in the order of anthesis. In general, the caryopses on the upper rachises are mostly superior spiklets, and the lower the caryopses are located, the higher the ration of inferior spikelets is. Consequentry, in a poorly ripend panicle, the upper rachises droop but the lower ones do not. A well ripened panicles is characterized by the good drooping of all rachises, including lower ones.

III. Cultivation of NERICA

The standard procedure for a upland cultivation up to eat is followings : (1) a land selection, (2) a land preparation, (3) seed prepration, (4) Seeding, (5) 1st weeding, (6) NPK fertilizer application, (7) 2 nd weeding, (8) Top dressing (Urea application), (9) Animal & Bird Control, (10) Harvest, (11) Threshing, (12) winnowing, (13) dehusking & milling, (14) cooking. Important point(s) of each procedure is(are) shown below.

1. Land selection

Suitable conditions for the cultivation of NERICA

- Select a sunny land. If it is not flat, it is better to be leveled.
- Select a fertile land.
  - ✓ Virgin land or1st year land of new crop rotation system after fallow.
  - ✓ Avoid continuous cropping of upland rice in the same field (once or twice at most, but it depends on soil fertility).
  - ✓ Avoid cultivating the upland rice after the cassava.
  - ✓ Avoid the barren land (e.g. land where soil color is white because of the salt).
- The field is desirably far from grazing land. If damages by the domestic animals are anticipated, it is recommended to be surrounded the field with fence.
- The field should be easily accessible from your house for the daily field management and communication with the rice

- Select a sunny land!!
- Sow perpendicularly against the direction of the slope!!

Fig. 9 : Example of a land selection and seeding method.

2. Land preparation

(1) Slash and burn and land measuring

Fig. 10 : Land clearing : slashing the bush or forest and burning.

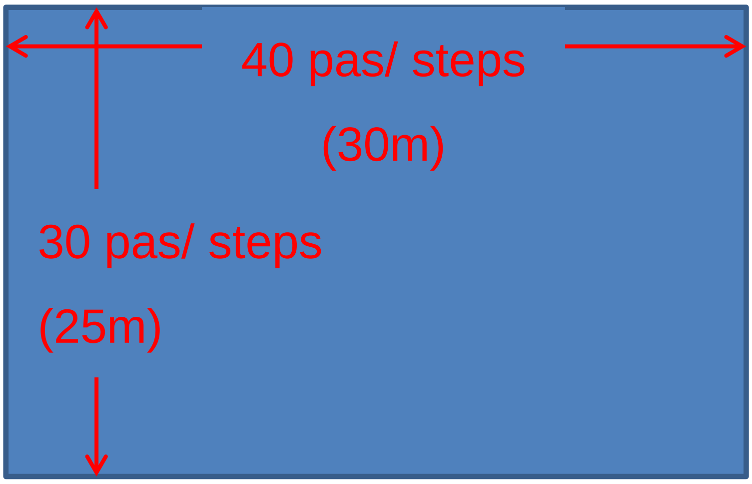


Fig. 11 : Measure the area corresponding to the amount of seed

(2) Plowing and leveling

Plowing the field

Leveling the field

Fig. 12: Example of the plowing and leveling the field.

Field demarcation (this is just for your information)

N.B. Method for making a rectangle

If you want to demarcate your field exactly after land preparation (plowing, harrowing, and leveling), please do as follows:

Step 1: Decide on the proposed field layout.

Step 2: Mark out the outline of the trial field.

Step 3: Mark out a right-angled triangle at one corner of the field.

(i) Lay out the two adjacent sides of the triangle.

(ii) Map out the right-angled triangle using the "Pythagoras Theorem" method ($a^2 + b^2 = c^2$, usually $3^2 + 4^2 = 5^2$).

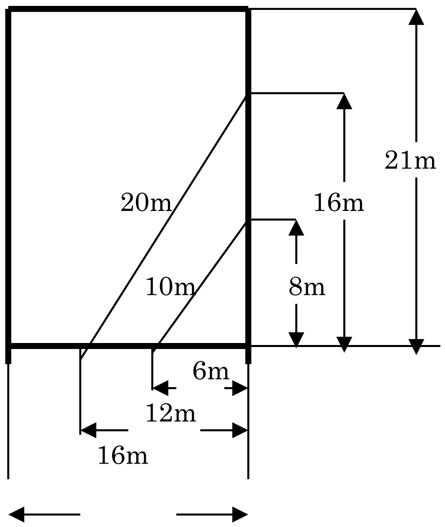
(iii) Confirm your measurement by using another point (Figure 2).

(iv) Mark out a rectangle by pegging at the four corners of the field.

(v) Confirm the other right-angled triangle (length of both sides and their diagonal again).

Step 4: Peg out the replicates according to your field plan.

Step 5: Peg out the plots and footpaths according to your field map.



$a^2 + b^2 = c^2$

- $6^2 + 8^2 = 10^2$
- $12^2 + 16^2 = 20^2$

Fig. 13: Mapping out trial plots using right angled triangles

3. Rice seed preparation

(1) Separation of filled grains and empty grains by winnowing

Fig. 14: Example of winnowing for separation filled grains and empty grains.

(2) Germination test

1. Choose 50-100 rice seeds.
2. Cover the seeds with a tissue paper or a damp cloth.
3. Count the number of germinated seeds after 5 days to determine the rate of germination.

Note: If the rate is low, increase the amount of sowing seed.

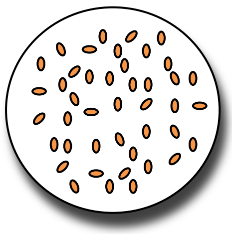


Fig. 15: Example of germination test.

4. Sowing

Seeding should be done after the rainy season started. It is better to sow when rain becomes regularly at the beginning of the rainy season. If there is a risk of seed run off by heavy rains, the seeds should be sown in depth of 3-4cm, especially in sandy soils.

Upland rice farmers use three different methods of direct seeding - dibbling, drilling, and broadcasting.

Sowing by drill (recommended method to producers)

Drilling method

In drilling (Fig. 16 and 17), rice seeds are sown in rows with regular inter-row spacing but intra-row spacing may not be regular. Planting with wide inter-row spacing is called row seeding while sowing with narrow inter-row spacing is called drilling. Drilling requires much less seed than broadcasting, enhances field management work (such as weed control), and results in homogenous plant growth. Drilling is easier than dibbling but takes more time than broadcasting. Compared to broadcasting, drilling also permits better accessibility to sunshine and aeration for the plants. Consequently, drilling is recommended for use in farmers' fields.

- In a sloping land, seeding must be made perpendicularly against the direction of the slope to prevent rice plants from running off due to heavy rains.

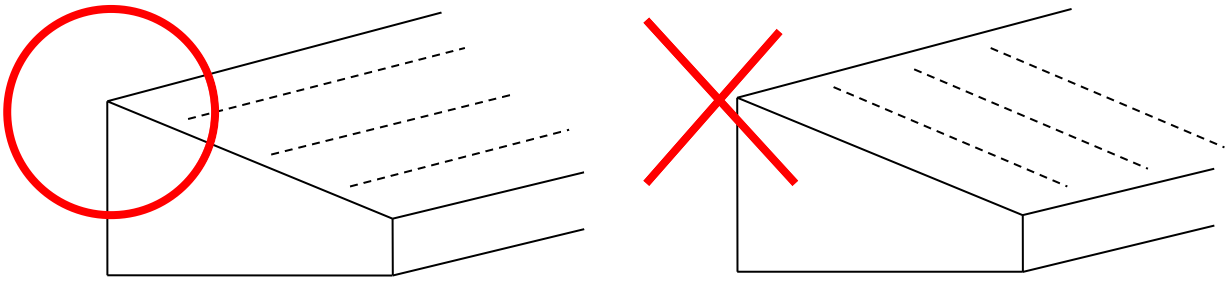
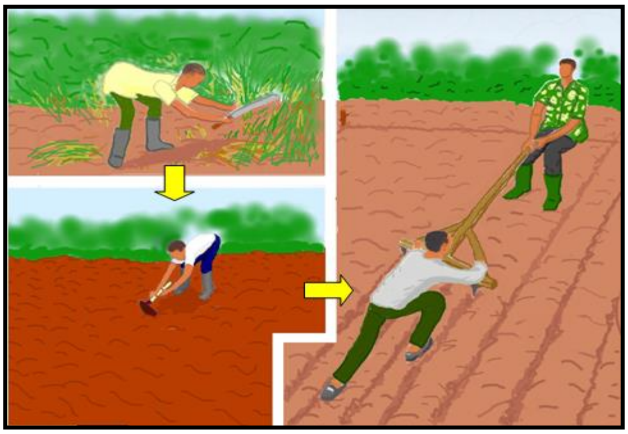


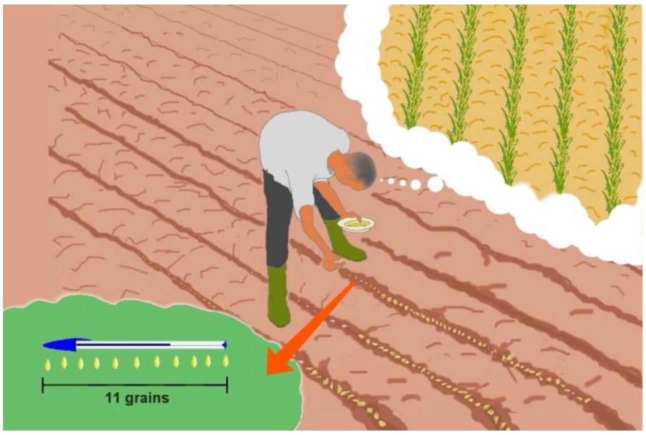
Fig. 16 : How to seed in a sloping land.

a. Row drawer (seeding rake) for drilling

b. Drawing rows for drilling



c. A image of land preparation to seeding.



d. Adequate density for seeding.

Rice seeding: example of high density.

Rice seedlings of drill seeding in a plot.

Fig. 17 : Example of drill seeding method – how to seed in drilling -.

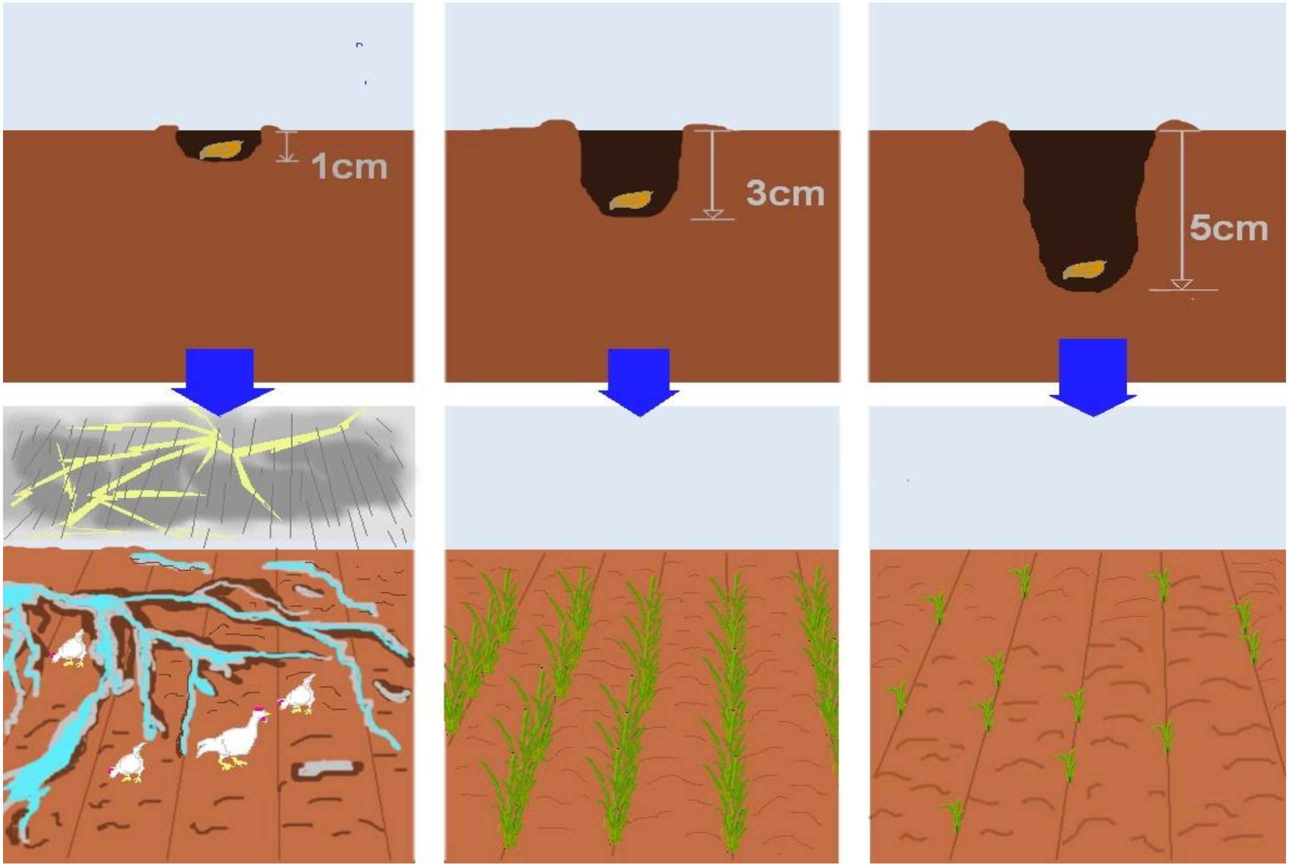
Do not miss the appropriate seeding time!! If you don’t have a time to plow by hands, do dibbling method at random shown like below.

Sow 4 to 5 seed grains in the pocket after digging the sowing hole by the hoe.

Rice seedlings at random dibbling method

Fig. 18 : Example of the broadcasting method when you do not have enough time for seeding.

Too shallow (about 1cm) Optimum (about 3cm) Too Deep (amore than 5cm)



Bird damage, flowing out seeds. Good emergences. Insufficient emergences

Fig. 19 : Optimal seeding depth for good plant establishment.

Fig. 20 : A bad example of seeding depth. Too deep!!

The others seeding methods

1) Dibbling method

Dibbling (Fig. 21) is the seeding method normally used for varietal trials in research institutes in West Africa. This is the process of planting seeds in pockets at a given spacing, usually 20 cm x 20 cm between plants and between rows (regular planting). The recommended seed rate for this spacing is about 35 kg ha^{-1}. The calculation of seed rate depends largely on the weight of the seeds of the variety. Different varieties have different kernel weights, usually depicted as the 1000 grains weight. At about 10 to 14 days after seeding, which is roughly the 3rd leaf age, the number of seedlings per hill can be adjusted to meet the objectives of the trial.

Note: If we want to know the tillering ability of a variety (which is related to the number of panicles at harvest), we need to establish a single plant per hill. However, it should be noted that early maturity varieties (panicle weight type), such as upland NERICA varieties, may not attain their maximum yield under trial conditions because the number of panicles per hill and spikelets per unit area may be less than maximum.

a. Dibbling using planting rope in a trial plot   b. Rice seedlings in a dibbled trial plot

Fig. 21: Rice dibbling seeding method.

2) Broadcasting method

Broadcasting (Fig. 22) involves scattering seeds in the field. This method is very popular with farmers in West Africa because it saves time that can be spent on other activities, such as planting other crops (maize, sorghum, legumes, etc. However, it is difficult to seed uniformly and to maintain homogeneity of growth. Broadcasting requires much more seeds (100 to 150kg ha^{-1}) than dibbling and drilling. It is also makes field work (weed control and data collection) difficult. Broadcasting is, therefore, not normally used for the variety trials

a.Broadcast seeding in the forest zone in The Gambia   b.Rice seedlings in a plot sown by broadcasting

Fig. 22: Planting rice by broadcasting in West Africa (example in The Gambia)

Finally farmers may decide sowing method by themselves. However, among the three methods, sowing by hill is adopted in experiment fields because it is easier to control the plants and collect data. But data collection is not necessary for ordinary farmers, sowing on line seems to be better for them because it is easy compare to sowing by hills.

NB : « competition »

It is tempted to believe that there is possibility to obtain more yields depending on the quantity of more seeds and much fertilizer with high plant density. However, it can cause competition (fight among the plants for nutrients and water) which may reduce the yield. Drought is the most important enemy of rice and high density increases the number plants and leaves. There is possibility to lose much humidity because of transpiration from leaves. And then, according to data of experimental research, at high density, the number of panicle per unit area will increase while the number of grains per panicle will decrease. Therefore, the control of seed density is very important. Dibble seems to be more efficient. However, finally farmers may decide sowing method by themselves.

5. Weeding

Competition by weeds for nutrients always results in significant yield losses. It is, therefore, necessary to inspect the field regularly and to weed as necessary to minimize competition for nutrients, especially before fertilizer is applied, and to maintain field sanitation. Weeding around the trial plot will also reduce the threat of damage by rodents.

a. easy weeding with liner seeding (drilling and dibbling)

b. difficult weeding with broadcasting

Fig. 23: A comparison of weeding in drilling and dibbling to broadcasting seeding method.

6. First apprication of fertilizer (Basal fertilizer)

Basal application (N: P: K)

It is advisable to apply basal fertilizer (N: P: K) to the field 10 to 14 days after seeding (DAS) to avoid the loss of fertilizer due to heavy rainfall in SSA, in the sloping land especially. Basal fertilizer application can still be done until the early seedling stage, around the 3rd leaf development stage, especially for sandy soils (where seeds are sown at a depth of 3cm, but preferably before the

4th leaf has developed fully.

7. Top dressing

The application of urea (top dressing) increases yield. It is recommended to apply it at the panicle initiation stage (between 6th and 7th week after sowing) and meiotic stage (between 7 to 10 days before heading). Please see the page 13 and 14.

N.B.

- Basal fertilizer is not always necessary on the field where it is fertile like virgin land (there is no cultivation in the past), 1st land in a new crop rotation cycle after fallow, etc. However if we can apply it, we can expect better growth.
- Regarding topdressing, it is not necessary to apply as same as the basal fertilizer application where rice grows quite well because soil is fertile. Fertilizer application in such land may cause lodging due to over-luxuriant growth.
- Generally, nutrients in seed are enough to grow until the third leave development. After that, the plant needs additional nutrients. If they will lack, the leaves color will gradually turn into yellow.
- Apply the two-thirds portion as homogeneously as possible over the entire plot, and apply the remaining one-third much more homogeneously across the plot.

Fertilizer	Application Timing	Recommended quantity	Objective of application
NPK (20-10-10)	10-14 days after seeding	200 kg/ ha	To increase the number of tillers
Uréa	Panicle initiation stage (60-65 days after seeding)	50 kg/ ha	To increase the number of grains par panicle
Uréa	Meiotic stage (70-75 days after seeding)	50 kg/ ha	To increase percentage of filled grains

Fig. 24: Example of the fertilizer application (method, description, dose, and timing of the application).

Nutrients which are indispensable for the plant's growth

Nitrogen (N), phosphorous (P) and potassium (K), Nitrogen makes protein, phosphorous makes nucleic acid with genetic information and potassium has strong relation with the osmotic pressure. As chemical fertilizers are made of these elements, it is better to use them correctly.

If it is difficult to obtain chemical fertilizers, we can preserve nitrogen by growing legumes. Rhizobium is the micro-organism in charge of nitrogen fixation in the soil. But, nutrients are necessary for legumes to grow at first. Then, legumes cannot substitute chemical fertilizers. It just maintains soil fertility.

Calculation of fertilizer rates

Correct calculation of the amount of fertilizer to be applied in each field is recommended to maximize the effect and to minimize economic loss. However, in many case, there is no balance in villages. We show below the method that a PET bottle is used to weigh a necessary amount of fertilizer (this is approximative). If you have or can use a balance to weigh fertilizer, please use it.

(1) How to weigh by PET Bottle.

Step 1. Make a 1L bottle

1) How to make the 1L bottle.

a) Prepare one 1.5L PET bottle and two 0.5L PET bottles.

b) Fill both of two 0.5L bottles with water.

c) Pour the water from the 0.5L bottles to 1.5L bottle (Total 1L of water).

d) Mark the water level on the bottle.

e) Cut the bottle on the mark.

Step 2. Fill the fertilizer at the end (see photos).

1 L of NPK → about 1kg.

1 L of Urea → about 0.75 kg

Fig. 25: Example how to weigh the fertilizer (NPK=20:10:10 and Urea)

(2) Calculation of a necessary amount of fertilizer

Example 1 (N: P: K application)

We want to apply fertilizer at the rate of N: P: K = 30: 30: 30 kg ha^{-1} in a plot of 500 m2 using the compound fertilizer N: P: K = 15: 15: 15. How much fertilizer formulation is to be applied to the plot?

Step 1: Calculate the amount of fertilizer to be applied per ha.

(1) We are using compound fertilizer of N: P: K = 15: 15: 15.

(2) 100 kg of compound fertilizer (2 bags of N: P: K = 15: 15: 15) contains 15 kg of N.

(3) We can use the following formula, where x is the amount of fertilizer to be applied per ha:

(100 kg of NPK : 15 kg of N = x kg of NPK : 30 kg of N)

100 : 15 = x : 30

15x = 3000

x = 200

(4) 200 kg of NPK compound fertilizer per ha will supply 30 kg of N per ha.

Thus, to apply 30 kg of N per ha using compound fertilizer of N: P: K = 15: 15: 15, we need to apply 200 kg of that fertilizer per ha.

Step 2: Calculate the amount of fertilizer to be applied per plot from the result of (4) in step 1.

(1) We can use the following formula, where y is the amount of fertilizer to be applied per plot of 500 m2 (1 ha = 10,000 m2).

10,000 : 200 = 500 : y

10,000y = 100,000

y = 10 kg

(2) Thus we should apply 10 kg of NPK=15:15:15 fertilizer per plot (500 m2).

Example 2 (Urea application)

We want to apply urea [CO (NH2)2] to a 700 m2 at the rate of 30 kg of N per ha. How much urea is to be applied? (C = 12.0, N = 14.0, O = 16.0, H = 1.0)

Step 1: Calculate the molecular weight of urea per mol.

Step 2: CO (NH2)2 = 12 +16 + (14+1 x 2) x 2 = 12 + 16 + 32 = 60

Step 3: Calculate the proportion of N in the urea

28 / 60 = 46.666666…… (%)

We can use the value of 46 % for the calculation (I believe that you know the number).

Step 4: Calculate the amount of urea applied per ha.

(1) 100 kg of urea contains 46 kg of N (because urea contains 46% of N as calculated above).

(2) Therefore, we can use the following formula where x is the amount of fertilizer to be applied to 1 ha.

(100 kg of urea : 46 kg of N = x kg of urea : 30 kg of N)

100 : 46 = x : 30

46x = 3000

x = 65.17…..

(3) Thus 65.2 kg of urea is needed to apply 30 kg of N per ha.

Step 5: Calculate amount of quantity of urea to be applied per plot from the result of (3) in step 4.

(1) Using the following formula, where y is the amount of urea to be applied per plot of 700 m2:

1 ha = 10,000 m2
10,000 : 65.2 = 700 : y
10,000y = 45640
y = 4.564 kg
(2) Thus we need to apply 4.6 kg of urea per plot

N.B. Method of mesurment of plot area

Trigonometry : Area of a triangle obtained from Hero's formula .

$$\Delta\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

$$*s = \frac{(a+b+c)}{2}$$

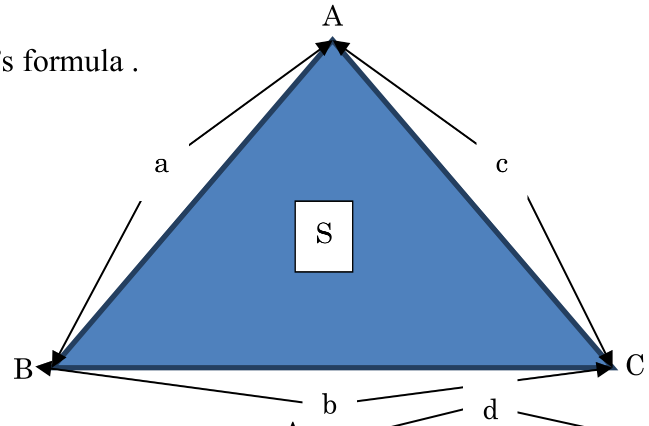
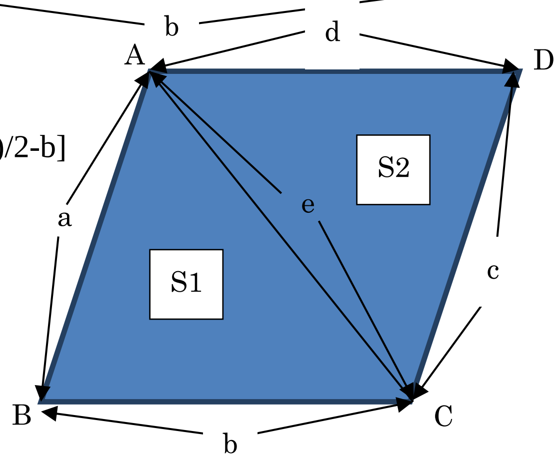


Fig. 26 : Formula of Héron.

How to culculate the area of a field.



Plot ABCD is divided into two triangles, S1 and S2.
ΔArea(S1)=√ (a+b+e)/2 ×[(a+b+e)/2-a]×(a+b+e)/2 ×[(a+b+e)/2-b](a+b+e)/2 ×[(a+b+e)/2-e]
S=(a+b+e)/2

Similary, area of Δ(S2) can be obtained as Δ(S1)
From the above, area of plot ABCD is equa to : S1+S2

8. Fight against diseases and pest insects

Regarding diseases, NERICA is comparatively resistant to diseases such as leaf rust (rice blast), and for the moment, it is not necessary to take countermeasure.

There are some pest insects like "termite", "stem borer", "the stink (bug)" etc.

- Countermeasures against the insects are not required until a certain level. It is better to think of insecticide application when there is damage at about 20 percent of whole field.
- The cultivation of plants that stem borer prefers rice as corn can attract them and reduce damage to some degree.

NERICA attacked by the rice borer

Stink bug

9. **Fight against predatory animals**

- The closure of the domestic animals like fowls, goats, cows, etc., is effective to prevent the damages caused by.
- Damages caused by rodents (rats and hedgehogs) are also considerable in upland rice cultivation. It is important to prevent the first intrusion. The clearing around the field to prevent their intrusion because they fear exposing themselves to their enemy like owl. It is better to think of the application of a rodenticide when the damage occurs.
- One of the biggest problems on upland rice cultivation is damage caused by birds at just after seeding and during ripening period (Fig. 27). Thus, **it is necessary to take countermeasures against birds.** The countermeasures are follows;

  - **Chasing birds** – it is the most effective method. Someone should stay on the field to guard particularly in the morning and evening, the time when birds appear frequently.
  - **Changing the field every season** – once those birds discover the rice field, they remember the place and will come back every season. So it is better to change the field every season.
  - **Cultivating at same time in large scale –** organizing a group and cultivating in large scale can avoid intensive damage. And sowing at the same time can reduce the period for chasing birds.
  - **Installation of materials for scaring birds** – settling a scarecrow, and hanging CDs (see photo) because birds dislike reflection of sunlight, and tinplate with a stone which makes noise by blowing in the wind and scares birds may be effective at the beginning. But the birds will get used to them for a moment.
  - **Avoiding cultivation in a season many birds appear** – the magnitude of the damage is depending on the season in some area (for example, larger number of birds is observed in 1st season rather than one in 2nd season in Batouri). It is important to know which season is less damage and cultivate in the season.

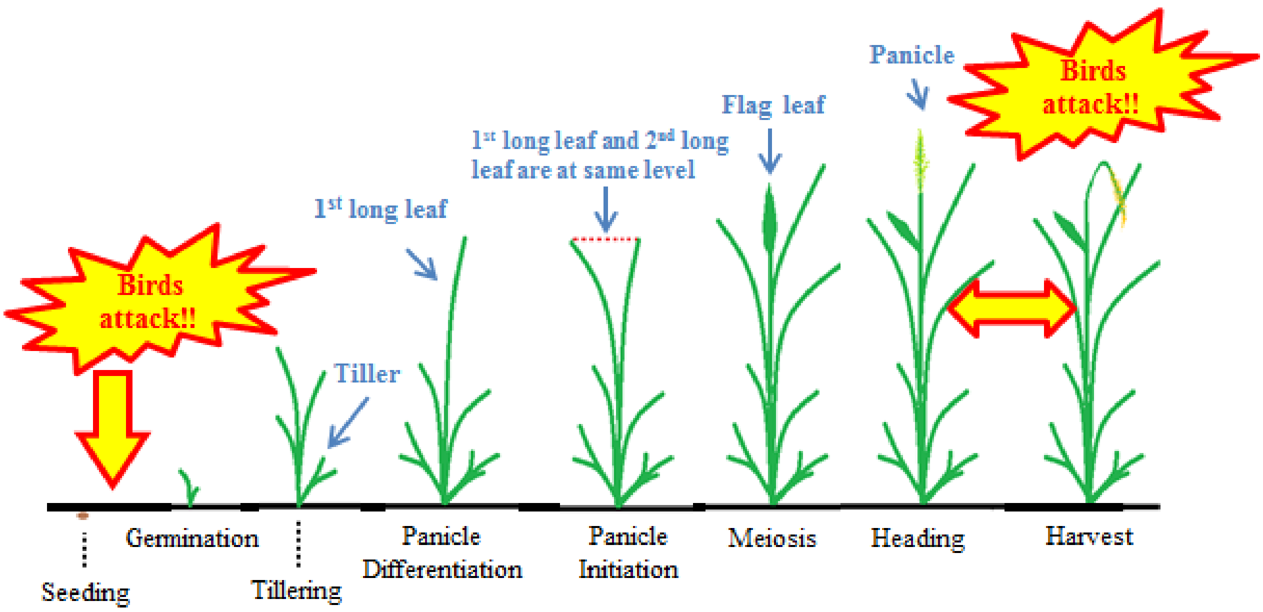


Fig 27: Rice growth stage vs. the period of damage caused by birds.

Photo1. A tinplate with a stone makes noise.

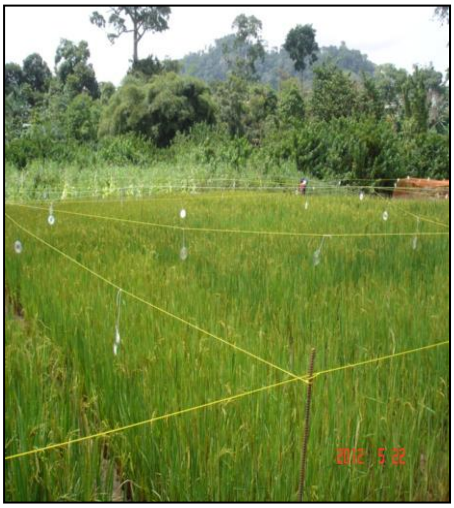


Photo 2. CDs are hung on ropes.

Photo 3. Hanging various things on a rope.

Fig. 28 : Example of countermeasures against birds.

10. Harvesting

Timing:

The most appropriate timing for harvest of early maturity upland varieties is when the color of all grains changes from green to yellow gold, and 1/3 of rachis changes the color from green to brown (Photo).

- **Harvesting too early**: the yield will be reduced due to many immature grains which have lower weight, and those grains are not threshed easily and remained on the panicle which will be thrown away.
- **Harvesting too late**: the quality of milled rice will be deteriorated by late increasing number of cracked grains and preharvest sprouting grains.

Moment:

The grains should be dry at harvest. Therefore, it is recommended to start harvesting after 10 am because grains are wet in early morning with dew. In case of after rain, it is better to wait until grains become dry. If it rains every day, dry them immediately after harvest. Wet rice grains are perishable in a bag, while too dry grains break easily after milling.

Method:

There are mainly two methods for harvesting. One is by harvesting panicles, and another is by harvesting with stems with a sickle or machete. It is recommended to harvest with stems in large scale since labor can be saved and it is easier to thresh after harvest. The plants should be cut off 10-15cm from ground to avoid harvesting with foreign matters like soil. The method by harvesting panicles is recommended for collecting the seeds for the following season.

Photo 1. The field attains appropriate timing for harvest.

Photo 2. The color of all grains becomes yellow gold.

Photo 3. The color of 1/3 of rachis becomes brown.

Fig. 29: Appropriate timing of harvest.

The appropriate period for harvesting on early maturity variety is when color of all of grains changes green to golden, or almost all primary rachis-branches changes from green to brown but rachis of the panicle is still green (see a photo left side).

The grains should be dry at harvest. Therefore, it is recommended to harvest after ten o'clock because grains are wet in early morning with dew. In case of after rain, it is better to wait until grains become dry. If it rains every day, dry them well after harvest. Wet rice grains are perishable in a bag, while too dry grains break easily.

Photo 1. The timing of harvest is still too early

Photo 2. The timing of harvest is too late

Photo 3. Harvesting panicles for seeds

Photo 4. Harvesting rice plants by cutting the stems

Fig. 30 : Example of harvsting methods.

IV. <u>**Yield and postharvest treatment**</u>

1. Yield and yield components

Breeders and agronomists are usually interested in the yield of a variety. Yield components include the number of hills per area (1 m^2 is normally used), number of panicles per hill, number of spikelets per panicle, percentage of ripened kernels, and kernel weight (1000 kernels weight is normally used).

① **The number of hills per square meter in the field (hills / m^2)**

The number of hills per square is determined at planting (at seeding). In case of « sowing by broadcasting method » and « sowing by drilling method »: harvest and count a sample per square meter in the field.

Note. How to count the number of hills per square meter in the field in case of «sowing by dibbling method »,

The number of hills per square meter should be counted as shown in frame A in Figure 16. The sides of the frame should be half way between rows. Thus, in a 20 cm x 20 cm plot, the sides of the frame should be 10 cm between rows and 10 cm between hills while, in a 25 cm x 20 cm plot, the sides of the frame should be 12.5 cm between rows and 10 cm between hills. The number of hills per square meter is also used to measure yield at harvest.

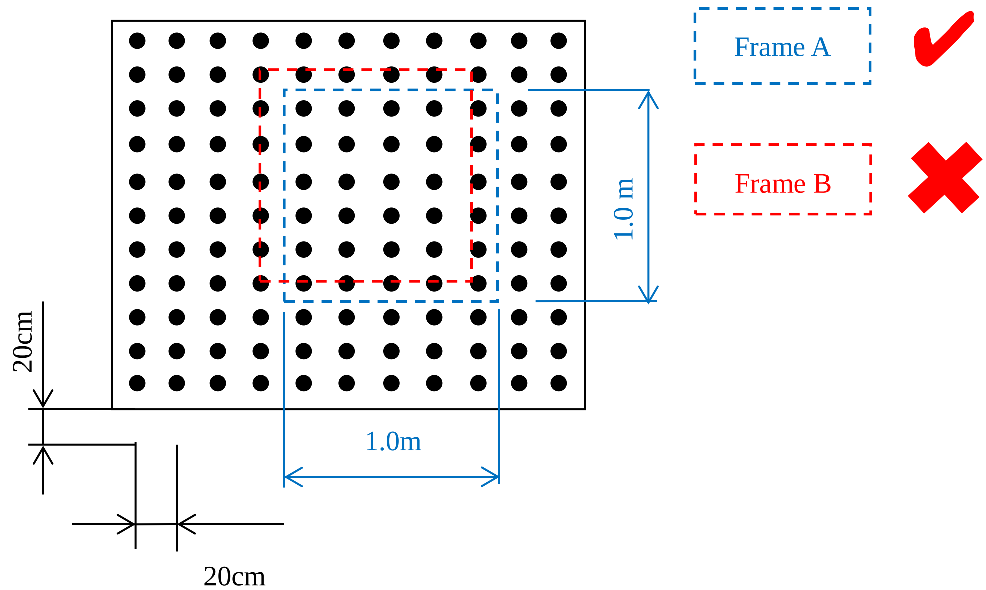


Fig. 31: Example of how to count the number of hills per unit area (square meter)

② **The number of panicles per hill (panicles / hill)**

In case of « sowing by broadcasting method » and « sowing by drilling method »: we first count the total number of panicle that have been harvested and then divide by the number of plant. In case of sowing per hill: we count the number of panicle and then divide it by the number of plants

③ **The number of spikelets per panicle (spikelets / panicule)**

It is the number of grains attached to a panicle. It is not necessary to take into consideration the sowing method. We just have to count the number of grains and divide it by the number of panicle.

④ **The percentage of ripened kernels (%)**

It is the ratio between spikelets having a grain and the total number of spikelets. The procedure to obtain the above mentioned percentage is as follow:

- Put all the grains threshed into the water and separate ripened kernels from infertile (floating)

grains
- Count the number of floating (infertile) kernels
- Count also the number of kernels remaining at the bottom (ripened kernels)
- Divide the number of filled kernels by the total number of kernels

$$\text{« percentage of the ripened kernels (\%) »} = \frac{\text{«the number of ripened kernels»}}{\text{«the number of floating kernels »+ «the number of ripened kernels»}}$$

N.B. In case where we are checking the percentage of ripened kernels

When putting rice seed in water, let's make sure that all the grains are well scattered. If not, some of the unfilled grains present in the lot will remain at the bottom as filled grains. In such a case, estimation will be biased.

⑤ The kernel weight (g / 1000 grains)

1000 kernels weight is normally used. But normally, we can count three or five time the number grains that correspond to the indicated weight (for example 5g or 2g) and estimate the mean and the weight of a grain. After that, we can convert to have the weight of 1000 grains.

Also, that weight is influenced by percentage of humidity contained in the grains. As 14% relative humidity is generally used, if it is possible to verify the weight of water contained in the specimen, the weight can be adjusted according to the following formulae:

$$\text{Grain weight with a moisture content of 14 \%} = \frac{\text{Actual weight of 1000 grains} \times (100 - \text{measured moisture content (\%)})}{100 - 14}$$

＜Exemple＞calculate the weight of 1000 grains from the number of grains and using 2g as the reference

Number of time	Weight (g)	Number (grains)
First	2,02	74
Second	2,06	78
Third	2,01	73
Mean	2,03	75

To estimate the weight of 1000 grains, we will use the average values of "75 grains for 2,03g".

(75 grains) : (2.03g) ＝ (1000 grains) : (Xg)

$$\text{« The weight of 1000 grains » X (g / 1000 grains)} = \frac{2.03\text{g} \times 1000 \text{ grains}}{75 \text{ grains}} = 27,\overset{1}{\cancel{0}}6666\ldots$$

=27,1

« Why do we use 2g? »

Initially, the reference was 5g. But, if the weight is more than 3g, the number of grains will be more than 100 in most cases and then, the risk of mistake.

If from the first to the third time, the number of grains does not differ, it is possible to count and be right. But, if it differs, we have to count again. If the sample is small or if we are confident in our counting, we can use 5g as reference.

⑥ Calculation of the yield components

Let's multiply the above mentioned five yield components and determine the crop yields of 1m^2 (g/m^2). By dividing that production by 100, we obtain the production per hectare.

$$\frac{\cancel{\text{Hills}}}{\text{m}^2} \times \frac{\cancel{\text{Panicules}}}{\cancel{\text{Plant}}} \times \frac{\cancel{\text{Grains}}}{\cancel{\text{Panicule}}} \ \% \times \frac{\text{g}}{\cancel{\text{1000 grains}}} = \frac{\text{g}}{\text{m}^2}$$

Per「1ha = 10,000m^2」、「1 ton = 1,000,000 g」

$$\frac{\text{ton}}{\text{ha}} = \frac{\text{g}}{\text{m}^2} \times \frac{1\cancel{0,000}}{1,00\cancel{0,000}} = \frac{1}{100} \times \frac{\text{g}}{\text{m}^2}$$

N.B.   Example of yield estimation

- Number of hills per m^2: 25
- Number of panicles per hill: 8
- Number of spikelets per panicle: 120
- Percentage of ripend kernels: 65%
- 1000 grain weight at 14%: 26/1000 grains

The production per m^2 (g/ m^2) = 25×8×120×0.65×26/1,000＝405.6g/m^2

The production per ha（t/ha）＝405.6×1/100＝4.05t/ha

2. Post harvest treatment

1) Threshing

Threshing small quantity of rice can be done by hand. In case the quantity is quite large, it is faster by beating the panicles by a stick or directly on a plastic sheet. A drum and a log on the plastic sheet for beating are recommended.

Photo 1. Threshing with a drum.

Photo 2. Threshing with a log.

Photo 3. Threshing with a stick.

Photo 4. Threshing with a local machine.

Fig. 32. Example of type of threshing methods.

2) Drying and Winnowing

After threshing, the grains should be dried immediately but not rapidly to prevent the deterioration of the quality. Winnowing can be done while drying the grains when there is wind.

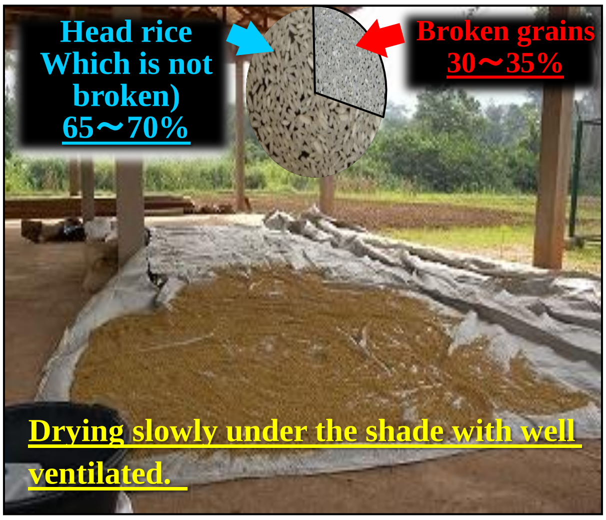
Drying: Drying is very important to produce quality rice and keep high germination rate. But exposing the grains to strong sunlight for long time causes increasing number of broken grains due to excessive dry or rebound of moisture by the rapid decrease of humidity (the grains absorb the moisture again during the night). Therefore, dry under shade or, spread the grains with 4-5cm thickness on the plastic sheet and mix them every 1-2 hours if dry grains under sunlight.

Winnowing: Put the grains in a bucket, basin, or plate, when a wind comes drop the grains to the sheet and winnow away the husks and trashes. If you bring your paddy without well winnowing to a rice miller, the operator will refuse to mill because such paddy with trashes will damage and destroy the machine.

Photo 1. Drying grains under sunlight.

Photo 2. Winnowing with a plate and bucket

Fig. 33: Example of drying and winnowing paddies after harvesting.



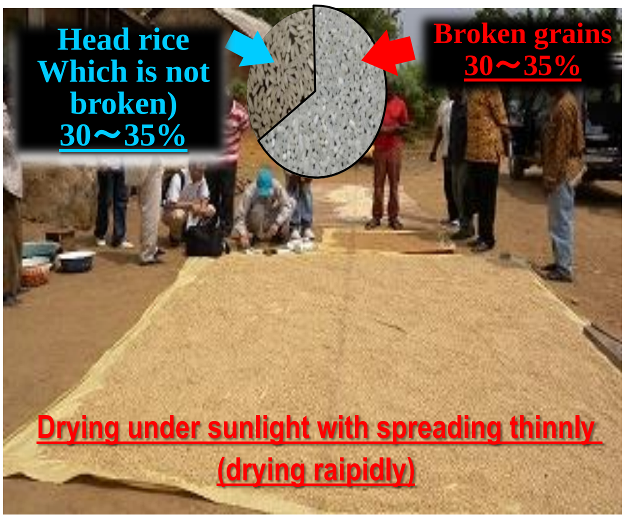


Fig. 34: Differnt proportion between head rice and broken rice dipending on the method of drying.

Photo 2. Well winnowed paddy.

Photo 1. Bad winnowed paddy.

Fig. 35: Good and bad examples of paddies after winnowing.

3) Dehusking and Milling

Milling machine is very useful. But in case the machine is not available or rice miller is far from your place, it is possible to make a dehusking mortar with local wood as follows. The seeds for the next season should be stored in cooler and dry place to keep them from decreasing germination rate and the damages by rice weevils or rats.

A milling machine for husking & whitening.

White rice milled by the machine.

Fig. 36: Some photos of rice milling by a milling machine (SB10).

<u>How to dehusk rice grains without machines</u>

1) Dehusking: Put the grains into a mortar and pound them with a pounder. With these methods, the percentage of broken rice tends to be high

2) Winnowing: Spread them on a tray, hold it with both hands, and blow gently while shaking in all directions to remove the husks or trash.

Photo1. An improved mortar.

Photo 2. A traditional mortar

← A wooden mortar for husking (left).

&

Brown rice dehusked by the wooden mortar (below)

Fig. 37 : Sample of wooden mortars, duhusking, and brown rice.

V. Annexes

1. Références

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*) In Japanese with English summary or abstract
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Bon appétit!

Grow rice,

Grow life!