MAFF
Ministry of Agriculture, Forestry and Fisheries

MANUAL OF SOIL FERTILITY IMPROVEMENT TECHNOLOGIES IN LOWLAND RICE ECOLOGIES OF GHANA

MARCH 2014

UDS
CARD
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH · GHANA ·

Table of Contents

Foreword

This handy manual – "MANUAL OF SOIL FERTILITY IMPROVEMENT TECHNOLOGIES IN LOWLAND RICE ECOLOGIES Of GHANA" has been produced based on studies conducted in lowland areas in Ghana (2009 – 2014).

It is aimed at providing farmers with low-cost soil fertility interventions using local resources such as rice straw, poultry manure, composts (cow dung, rice straw, human excreta, sawdust) and phosphate rock.

The studies were conducted at both on-station and on farmers' fields.

The document is designed to provide extension workers, other technical staff and farmers an easy reference on simple and low cost methods of improving soil fertility in lowland rice cultivation.

The wide range of materials being recommended in this manual makes the technologies easy to apply based on availability of the resources and local conditions.

Soil improvement technologies applicable to the Northern Savanna and Southern Zones have been tested and documented. For the Savanna Zone, indigenous materials like rice straw, cow dung, and human excreta have been emphasized, whereas in the Southern Sector, materials used include rice straw, sawdust, and poultry manure. In all cases, the use of phosphate rocks applies. The use of these materials as composts was also tested and documented.

Other technologies include the charring of rice husk and sawdust, which is applied to improve the carbon - nitrogen ratio in the soil. In addition, the practice of improving rice seedling growth using small quantities of inorganic fertilizer was also tested and found to be very effective.

It is our hope that, the suggested practices when applied would go a long way to improve productivity in rice-based cropping systems, increase incomes and ultimately enhance livelihoods of smallholder rice farmers.

A wider circulation and utilization of the information in this document will contribute to achieving Ghana's self-sufficiency in rice production and thereby improve the economy by way of foreign exchange savings.

On behalf of MoFA management, I wish to thank the personnel of the University for

Development Studies (UDS), Soil Research Institute (CSIR-SRI) and Japan International Research Center for Agricultural Sciences (JIRCAS) for contributing to the preparation of this Manual.

I also extend my sincere gratitude to the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan for its financial and technical assistance.

February, 2014

Hon. Dr. Ahmed Yakubu Alhassan (MP)
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Acknowledgements

Japan International Research Center for Agricultural Sciences (JIRCAS) had carried out the commissioned work from the Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, from 2009 to 2014, to contribute to the goal of CARD (the Coalition for African Rice Development). The study focused on technology development for soil fertility improvement in lowland rice systems with use of indigenous resources, which are accessible and acceptable for use by local farmers.

With several reasons, Ghana had been selected as the country of implementation of the work. It has two typical lowland rice agro ecological systems (rainfed and irrigated) and the Ministry of Food and Agriculture (MoFA), Ghana, has a strategy to achieve the goal of CARD. Also in Ghana, excellent institutions and scientists working on rice production and soil fertility, have been found as good potential counterparts.

As one of the final products of this commissioned work, this manual has been elaborated by JIRCAS and two counterpart institutions, namely, University for Development Studies (UDS) and CSIR-Soil Research Institute (SRI), to disseminate the technologies developed and evaluated in farmers' field.

On behalf of JIRCAS, I would like to express my sincere thanks to MAFF, Japan, for general direction and financial support to the work. As well, I shall be very much thankful to the members of Technical Advisory Committee in Japan for helpful assistance to the entire project.

A special word of thanks should go to all authors of the manual, from JIRCAS, UDS and CSIR-SRI, for contributing to the comprehension of scientific findings with simple words and pertinent figures/photographs.

Lastly, I am grateful to MoFA, Ghana, especially to the members of Manual Editorial Committee, and Mr. Abraham Manu Addae, for thorough editorial work on the manual.

February 2014

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List of Figures

List of Plates

LIST OF TABLES

CHAPTER 1

SOIL FERTILITY IMPROVEMENT IN GUINEA SAVANNA ZONE OF GHANA

1.1 Background

Northern Ghana is endowed with numerous valley bottoms and thus possesses good potential for rice production. Though the potential exists for rice production, yields obtained from the lowlands by small scale farmers on the whole are very low, about 1.2 tons or less per hectare. An identified major constraint is the declining soil fertility in the valley bottoms. Therefore, it is urgent to find a solution to the soil fertility problem faced by rice farmers in these regions.

Although soil fertility can be improved by chemical fertilizers, local farmers cannot afford to buy relatively expensive commercial fertilizers. This calls for development of affordable technologies which propose the use of organic and inorganic local resources.

Technologies were developed and verified with thorough considerations to the agro-environments in the Savanna Zone.

Plates 1-1-1: Typical feature of low-input rice field in Savanna Zone

1.2 Application of Rice Straw

1.2.1 General Principle

Rice straw is an essential fertilizer material which could be directly incorporated into the soil to serve as source of plant nutrients to lowland rice. Rice straw contains a rich amount of nitrogen, potassium and silicon. Unlike the use of compost[1], rice straw could be added directly and incorporated into the soil to support rice growth and production. The nutrients in the straw are released to the crop during field decomposition of the organic material.

1.2.2 Methodology:

a) Direct application of rice straw (3t/ha)

Rice straw is gathered into a heap after harvesting of rice panicles or after threshing of rice grains and stored in a shady area and protected from rains. This is to avoid the loss of nutrients from the straw due to leaching.

Plate 1-2-1: Heap of rice straw after harvesting

Plate 1-2-2: Chops of rice straw spread on the field

The straw is chopped into pieces to increase the surface area of the material to hasten the decomposition of the organic material when buried into the soil. The straw can be buried just after harvesting the rice field to allow decomposition over the dry season. Alternatively, the chopped rice straw can be buried during ploughing and harrowing at the beginning of the rains, but such land preparation must be done early in the season to allow a second harrowing before planting.

b) Alternatively, rice straw can be combined with cow dung and/or human excreta and used as compost (i.e. 2t/ha).

1.2.3 Recommendations for use of rice straw

- Rice straw applied directly at 3t/ha is highly preferred to other organic materials such as cow dung and human excreta.
- If possible, composting rice straw with cow dung or human excreta could be an alternate option to utilize these organic materials at 2t/ha of compost.
- Direct application of rice straw supplemented with small amounts of N and K, at 30-0-15 NPK/ha could also enhance rice production.

1.2.4 Advantages of rice straw and compost formulations

- It increases the soil's ability to hold water and makes the soil easier to till.
- It helps the soil to retain more of the plant nutrients.
- It supplies part of the 16 essential elements needed by the rice plant.
- It helps to reduce the adverse effects of excessive alkalinity, acidity, or the excessive use of chemical fertilizer.
- It aids in preventing soil erosion by keeping the soil covered.
- It helps in controlling the growth of weeds.

1.2.5 Experimental observations

Rice straw direct application showed the highest yield among ashed, charred, and composted rice straw applications. (See figure 1-2-1)

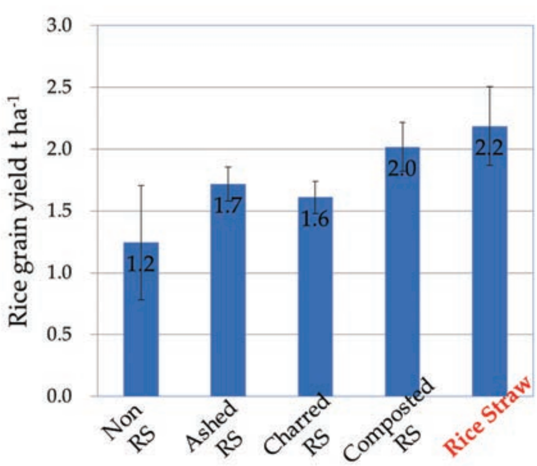

Figure 1-2-1: The effect of rice straw (RS) direct application on rice grain yield in Northern region.

1.2.6 Challenges in rice straw application

- Timing of direct application of rice straw needs to be properly clarified. But it should be incorporated at least 2 weeks before seed sowing.
- The effect of direct application of rice straw may be limited in irrigated lowland due to low decomposition rate of organic matter.

1.3 Composting (Materials & Techniques)

1.3.1 General Principle

Composting is a biological process in which micro-organisms, mainly fungi and bacteria, convert degradable organic waste into humus-like substance. Compost is high in carbon and nitrogen and is an excellent medium for growing plants.

The composts in this manual are made from three sources of organic materials; namely rice straw, cow dung and human excreta, using the compost pit method, located at a shady site. Rice straw and cow dung / human excreta at 50:50 by weight were composted into an effective, environmentally friendly and beneficial as soil amendments for fertility enhancement in lowland rice production in Northern Ghana.

Plate 1-3-1: Public latrine from which the human excreta was collected for direct application and composting.

The compost pit method or “trench composting,” is an underground method of composting. The pit method was used because it is able to contain and control the organic materials in an organized system that facilitates watering and turning for rapid decomposition of the organic materials.

1.3.2 Methodology

i) **Dig a trench for composting**. The compost trench should be about 70 cm deep. The area of the trench would be determined by the amount of organic matter to compost.

Plate 1-3-2: A trench for composting organic materials.

ii) **Pile of alternate layers of rice straw and cow dung/ human excreta materials**. The rice straw should be finely chopped and piled in the first layer and third layer with a layer of either cow dung or human excreta in the second and fourth in an alternating arrangement with rice straw. Chopping of rice straw was necessary to increase the surface area of the plant material to speed-up the decomposition process.

Plate 1-3-3: Specimen of a heap of raw cow dung used in this method.

iii) **Ratio of materials in the compost:** The weight of the organic materials was in the ratio of 50% rice straw to 50% cow dung or human excreta.

iv) **Duration and handling during composting:** The compost heaps should be watered during the first 30 days but without turning the materials. After that the piles should be turned with a foot-fork and watered periodically until about five months of composting when the compost is ready.

v) **Cover for compost pit:** Cover the compost with a thin layer of soil or plant materials.

1.3.3 Advantages of Compost:

- It increases the soil's ability to hold water and makes the soil easier to till.
- It helps the soil retain more of the plant nutrients.
- It supplies part of the 16 essential elements needed by the plants.
- It helps to reduce the adverse effects of excessive alkalinity, acidity, or the excessive use of chemical fertilizer
- It aids in preventing soil erosion by keeping the soil covered.
- It helps in controlling the growth of weeds

Plate 1-3-4: Resultant rice straw/

Plate 1-3-5: Resultant rice straw/ cow dung compost. human excreta compost

1.4 Rice Husk Biochar As A Soil Amendment

1.4.1 General Principle

Biochar is a solid material obtained from the carbonisation of biomass. Biochar may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases. Biochar also has appreciable carbon sequestration value.

The use of biochar converts agricultural waste into a soil enhancer that can increase productivity of agricultural lands, and thus boost food security as well as hold carbon. The process creates a fine-grained, highly porous charcoal that helps soils retain nutrients and water.

Biochar also improves water quality and quantity by increasing soil retention of water, nutrients and agrochemicals for plant utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution.

Sustained use of biochar can help to combat global warming by holding carbon in soil and by displacing fossil fuel use. Research shows that the stability of biochar in soil greatly exceeds that of un-charred organic matter. Additionally, because biochar retains nitrogen, emissions of nitrous oxide (a potent greenhouse gas) may be reduced. Turning agricultural waste into biochar also reduces methane (another potent greenhouse gas) generated by the natural decomposition of the waste.

As a soil enhancer, biochar makes soil more fertile, boosts food security, preserves cropland diversity, and reduces the need for chemical fertilizer inputs.

This chapter describes the charring of rice husk using a Kuntan apparatus.

1.4.2 The charring process

i) A ***Kuntan*** **charring apparatus** can be obtained from local blacksmiths at a cost of approximately 70 Ghanaian Cedis. It is too expensive for a farmer to purchase it, but it might be realistic to have one in a community.

Plate 1-4-1: A Ghanaian-made complete replica of the Kuntan-charring apparatus commonly used in Japan.

ii) **Bio-materials:** The Kuntan apparatus can be used to char 10 kg to 15 kg of rice husk at a time. An amount of 15 kg rice husk fills a 50 kg "fertilizer" bag as shown in the picture below.

Plate 1-4-2: Fifteen kilograms (15 kg) of rice husk.

iii) **Set fire.** The intensity of fire is not an exact science. Too low and charring is not achieved, and too much fire results in ashing.

Plate 1-4-3: Fire setting for charring. Secure no spread of fire around.

iv) After fire has been set, the Kuntan apparatus is used to **cover the fire**

Plate 1-4-4: A charring apparatus used to cover fire

v) **Pour rice husk** around the Kuntan apparatus.

Plate 1-4-5: Spreading of rice husk around the Kuntan apparatus

vi) Rice husk is uniformly heaped around Kuntan charring apparatus.

Plate 1-4-6: Uniformly heaped rice husk material

vii) After about 10 to 15 minutes, charring commences and materials close to the apparatus turn from brown to black. Once charring starts, the material should be turned every 10 to 15 minutes. During a good condition of charring, smoke comes out intensely with white to purple color.

Plate 1-4-7: Material should be turned when some parts become black.

Plate 1-4-8: Turning of charring material.

viii) After about 1 and half to 2 hours of charring, the material changes from brown to black and charring is complete. The material is collected and spread over a hard surface to cool.

Plate 1-4-9: Charring process completed all the material turns black.

Plate 1-4-10: Matured biochar spread to cool and stored before field application.

CHAPTER 2

IMPROVING SOIL FERTILITY TECHNOLOGIES IN RICE PRODUCTION IN FOREST ZONE OF GHANA

2.1 Background

For effective and efficient use of local fertilizing materials to improve rice production, water management is essential. The 'Sawah' technology is proposed to be the first step in improving rice production and soil productivity. The 'Sawah' technology involves bunding, puddling and leveling of the rice field with inlets for irrigation and outlets for drainage. Transplanting at a spacing of 20 x 20 cm with 2 or 3 seedlings per hill is recommended.

Technologies have been developed with use of local organic and inorganic resources and verified with thorough considerations on the agro-environments of the Equatorial Forest Zone.


Plates 2-1-1: The "Sawah" technology showing bunding, puddling, leveling and transplanting of rice fields.

2.2 Poultry Manure

2.2.1 General Principle

Poultry manure (PM) is manure (fertilizer) obtained from chicken/fowl droppings. It is an organic fertilizer and relatively abundant in the Ashanti and Greater Accra regions. These two regions produce almost 50% of total poultry manure in the country. The nutrient content of a typical poultry manure (especially layers) from the Ashanti region is 2.6% TN, 0.61% P, 1.09% K, 8.5% Ca and 7.0% Mg (this may vary depending on method of storage). Currently, PM is used extensively in maize and vegetable production in Ashanti, Brong Ahafo and Greater Accra regions. However, it is also very good for rice production.

2.2.2 Advantages of using Poultry Manure

- It is rich in plant nutrients (especially N, Ca and Mg)
- It is cheaper and easier to obtain.
- It is less expensive than inorganic fertilizer. (1 tipper truck load=GHC100)
- It has a longer lasting effect as it releases nutrients slowly and over longer period
- It improves both physical and chemical condition of soil
- It is environmentally friendly

2.2.3 Challenges in using Poultry Manure

- Bulky and large quantities required
- Not easy to transport over longer distances
- For efficiency and effectiveness, must be applied 1-2 weeks before transplanting.

2.2.4 Rate of application

Poultry manure can be applied to any rice field. It can be applied to both lowland and upland rice fields. On new rice field (under fallow for more than 2 years) 1.0 t/ha of manure can be used. Under continuous cropping conditions, at least 2.0 t/ha manure should be applied.

Table 2-2-1. Estimating quantities of manure to be applied:

Rate (t/ha)	Number of mini bags (50kg fertilizer sack)	
	Acre	Hectare
1.0	10	25
2.0	20	50
4.0	40	100

A mini sack full of dry manure is approximately 40kg.
The mini sack (50 kg fertilizer bag) can be used as the standard of measurement. Example: If the field is half an acre, to apply 2.0 t/ha, divide 20 by 2 = 10 bags

Note: Top dressing needs to be done when the application rate is 4.0 t/ha and below. At 6.0 t/ha and above top dressing may not be necessary.

2.2.5 Method of application

PM should be applied by broadcasting onto the field. At application rates of 2.0 t/ha and below, PM should be applied before or during ploughing (1st puddling) with little or no water on field. Broadcast manure evenly/uniformly on the field, preferably 2 weeks before transplanting.

At application rates of 4.0 t/ha and above: PM should be broadcast onto the field long (1-2 weeks) before ploughing. This will allow partial decomposition before land preparation is done.

Application of PM should be done closely to the ground to prevent being blown by the wind. Note: Under both conditions, fresh PM should be applied at least 3 weeks before seeding/ transplanting.

Table 2-2-2. Expected paddy yield under different rates of poultry manure application

Rate of application (t/ha)	Top Dressing	Expected Yield (t/ha)
2.0	30 kg N/ha	4.0
4.0	30 kg N/ha	5.5
6.0	-	5.5

**Under good agronomic practices (water management, weeding, and pests and disease control)*

Excreta of chicken are collected from the ground of farm.

The resultant poultry manure.

Plates 2-2-1: Poultry manure derived from poultry farms is a good source of plant nutrients.

2.3 Composting

2.3.1 General Principle

Rice straw and sawdust abound in the Ashanti region. These materials need to be composted to improve their quality. The quality of the compost is further enhanced when poultry manure is added.

Preferably composting should be done at the end of the season (November/December) when there is plenty rice straw and farmers are less busy.

Quantities of rice straw or sawdust to be used in combination with poultry manure may vary, depending on the availability of the manure. The quantity of manure to be used may vary from 15 – 25% of total compost.

Table 2-3-1. Quantities of plant materials and poultry manure needed for composting

Plant material	Quantity of plant material		Quantity of poultry manure	
	(kg)	(mini bags)	(kg)	(mini bags)
Rice straw	75	17	25	0.5
Saw dust	75	2	25	0.5

Note: This compost gives a ratio of 3:1 plant material to poultry manure

- A mini bag of straw (compressed) is approximately 5.0 kg
- A mini bag of sawdust (freshly collected from saw mill) is approximately 40.0 kg
- A mini bag of poultry manure (compressed) is approximately 40kg

2.3.2 Procedures

i. Select a location for composting, preferably closer to where the compost is to be used. Smaller lots of compost piles are better than one huge pile. Bigger piles require extra labour to convey compost to points of application.

ii. Weigh rice straw or sawdust according to the ratio above. Soak rice straw (after chopping into 4-6 cm pieces) or sawdust over-night. Sawdust can be soaked in sacks. Remove and allow excess water to drain off.

iii. Measure 2 – 3 full length of a cutlass (1.2 – 1.8m) as the width and approximate the length (this will depend on the size of compost to be made). This should be done under a tree or any place where there is shade.

iv. Dig a trench of one full length of a cutlass. Fill the trench to about 30 cm with the plant material and add 10 cm (divide full length of a cutlass six times) of poultry manure. Add a handful of wood ash. Repeat the process till all the materials are used. The pile can be built up to one cutlass length high.

v. Cover the compost with banana, plantain, palm fronts or any available plant material.
vi. Water compost every 3 to 5 days, depending on the environmental conditions
vii. After 3-4 weeks open and turn the compost (bottom materials should be moved to the top). For rice straw this should be done once. For saw dust (hard wood) compost which takes more than 8 weeks to decompose, turning should be done at least twice. Compost can be allowed to stay in the pit until it is needed.
viii. Before application, remove the compost and allow it to cool (1 week is enough). In case the material will not be used immediately protect it from rain.

2.3.3 Method of application

After composting, the resulting material is approximately 30% of the original plant material. The amount of materials required to obtain a particular quantity of compost can therefore be estimated.

Example: How much materials (rice straw and poultry manure) are required if 50 kg of compost is needed?

To obtain 30 kg compost, 100 kg rice straw & manure are required (since compost is about 30% of the original materials)

Therefore 50 kg compost = (100/30) x 50
= 167 kg

If the ratio of straw and manure is 3:1

Then rice straw = 126kg and manure = 42 kg (values are approximated)

1. Broadcast compost before ploughing (1st puddling)
2. For effectiveness and efficiency, application rates of 4.0 to 6.0 t/ha, may be necessary.
3. Top dressing (using urea or ammonium sulfate) is normally required.

Make a trench

Chop rice straws

Put the materials into the trench

Cover the materials by leaves or sheet

Plates 2-3-1: Procedures of composting rice straw

2.4 Charring Of Sawdust

1. General Principle

Sawdust is common in the Ashanti, Brong-Ahafo, Eastern and parts of the Western regions. The material can be charred (burning under very limited oxygen supply). Charred sawdust improves the physical properties of the soil. Char may be used to improve the physical condition of sandy fields or to open-up very clayey soils.

A lumber mill in Kumasi

Sawdust is a waste but useful to enhance soil fertility.

Plates 2-4-1: Sawdust is obtained from timber factory.

2.4.2 Procedures

i. Collect sawdust from a saw mill to the field. Spread the material thinly for it to dry.
ii. Make a small fire with twigs.
iii. Place the lower part of the charring (Kuntan) equipment over the fire. When smoke starts coming out profusely fix the second part on the first
iv. After 5 minutes spread some sawdust on the lower part of the equipment. Add more sawdust
v. Stir the charring sawdust slowly until the entire material is charred. Collect the charred material on a hard surface or on an old roofing sheet. Quench (put out) the fire and allow the charred material to cool for some time. The process needs practical demonstration!

Note: Open burning can result in the production of ash and not char. Ash has little benefits compared to char.

Make a small fire

Place a Kuntan apparatus on the fire

Pour sawdust around the apparatus

Charring process is going on for 1 to 2 hours

The resultant sawdust char, a kind of biochar.

Plates 2-4-2: Using the Kuntan apparatus to char saw dust.

2.4.3 Application

Charred sawdust should be broadcast uniformly on the field during puddling in soils with sandy or loamy texture. In clay soils with very low rates of infiltration, application should be during ploughing (1st puddling). Rate of application can vary from 1.0 t/ha to as high as 10.0 t/ha depending on availability of charred saw dust. Some notes as below.

- Very sandy soil with high rate of infiltration will require high rates of application
- Clayey soils with very low rate of infiltration will also require high rates of application during ploughing. This is to help open up the soil so as to improve infiltration. (Paddy soils with hard clay layers which prevents/retards infiltration, normally give poor yields. All agronomic practices (fertilizer and weeding) should be done.

2.5 Application Of Phosphate Rock

2.5.1 General Principle

Rock phosphate is not common in Ghana. This material, however, abounds in Togo and Burkina Faso. With the low phosphorus status of most Ghanaian soils, rock phosphate will gradually become important in Ghana

Burkina Faso rock phosphate (25% P_2O_5) is effective when applied directly to rice.

2.5.2 Rate of application

Application rate is usually higher compared to triple supper phosphate. Application rate of 135 kg P_2O_5 /ha (540 kg or approximately 11 bags of 50 kg weight) may be used for one hectare (2.5 acres) with a good residual effect for at least two years.

Table 2-5-1. Amount of rock phosphate required for application

Rate (kg/ha)	Number of mini bags (50kg fertilizer sack)	
	Acre	Hectare
540 (135 kg P_2O_5)	4.5	11

Note: A 1.5 L bottle of rock phosphate weighs approximately 1.8 kg. This bottle may be necessary when dealing with smaller areas.

2.5.3 Method of Application

Rock phosphate is powdery and may be blown away by wind during application. After determining the quantity of rock phosphate to be applied, measure the same quantity of dry loam or sandy soil. Mix with the rock phosphate before broadcasting on the soil surface.

This will minimize the effect of wind significantly. Application should be done before or during puddling.

2.6 Top Dressing

2.6.1 General Principle

After basal application of organic or mineral fertilizers, the quantity of nitrogen required for good plant growth after a period of time may be inadequate. As the driving force of plant growth, adequate amount of nitrogen should be applied at 5 or 6 weeks after transplanting. Addition of nitrogenous fertilizer after the application of basal fertilizer is termed topdressing. In Ghana urea and sulphate of ammonia (SA) are the common straight fertilizers used for topdressing. Excess application of nitrogenous fertilizer may produce more vegetative growth at the expense of grain yield. Lodging is also enhanced when more than adequate amount of nitrogen is applied.

2.6.2 Quantity of Urea or Sulphate of ammonia to apply

Generally, application of 30 kg N/ha is recommended. Depending on the initial fertility level of the soil, the rate may be reduced. There is the need therefore to examine the growth and colour of the plants before deciding to apply the full rate or a reduced rate.

Table 2-6-1. Application rates and quantities of urea or SA

Rate of application	Urea		Sulphate of Ammonia (SA)	
(kg N/ha)	**(kg/ha)**	**(kg/acre)**	**(kg/ha)**	**(kg/acre)**
10	22 (half a bag)	9 (1/5 of a bag)	47 (1 bag)	19 (1/4 of a bag)
20	43 (1 bag)	17 (1/3 bags)	95 (2 bags)	38 (3/4 of a bag)
30	65 (1 and ¼ bags)	28 (half a bag)	143 (3 bags)	57 (1 bag)

Urea: 46% N; SA: 21% N. Number of bags required is in brackets.

Note: A 1.5 litre volume of urea is = 1.0 kg; a similar volume of SA = 1.5 kg

CHAPTER 3

IMPROVING RICE SEEDLING GROWTH USING SMALL QUANTITY OF CHEMICAL FERTILIZER

3.1 Background

For reducing the loss and increasing use efficiency of chemical fertilizers per planting area in rice cultivation systems, the utilization of small quantity of fertilizer for coating rice seed and soaking rice seedlings are suggested to minimize the loss found upon traditional fertilizer application methods, for example broadcasting and point application. Rice seed coating and seedling soaking can boost early growth of seedling and enable delayed supply of fertilizers at early cropping season.

In this manual, it is described about the two technologies, seed coating method for the direct seeding practice in the Savanna Zone, and seedling soaking method for the transplanting practice for the Forest Zone, respectively.

3.1.1 Advantages of adding small amount of fertilizer to seed and seedling

- Methods are simple and easy to handle.
- Methods help to improve plant growth and replenish the soil fertility like fertilizer micro-dosing method.
- Extending the growth of seedling when seeds and seedlings are grown on non-P fertilized soils.
- Delaying fertilizer application at early cropping season.
- Reducing the quantity of chemical fertilizer used and farmers making saving on fertilizer purchasing.
- Farmers possibly select locally marketed available inorganic/chemical fertilizer at that moment or organic fertilizers such as animal manure available on farms.
- The fertilizer management by small-scale farmers can be flexible about sources and doses of both inorganic and organic fertilizers (Figure 3-1-1).
- Saving the cost of fertilizer consumption when fertilizer solution is re-used with numbers of seedlings and fertilizer solution residue is re-applied to the rice field.
- Since, the P compounds within TSP are mostly in the forms of calcium dihydrogenphosphate; Ca(H2PO4)2.2H2O, returning these elements to the field would also give a beneficial effect of calcium to the plant grown in the field. When the fertilizer such as NPK has been selected and utilized by farmers some beneficial

fertilizer effects of N and K fertilizers must also involve with the growth of plants and soil fertility replenishment.

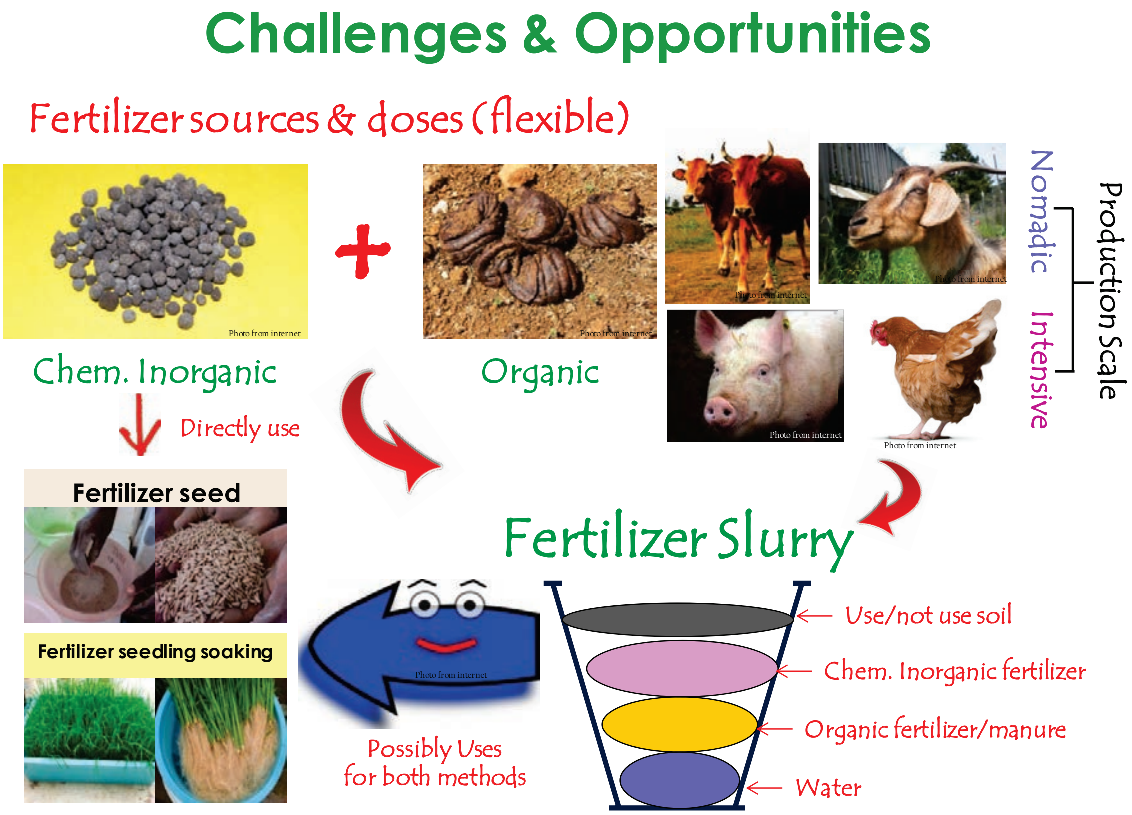

Figure 3-1-1: Challenges and opportunities of small-scale farmer for using locally available inorganic and organic fertilizers from various sources

References

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3.2 Fertilizer seed coating

3.2.1 General Principle

In low P soil, replenishment of soil P can be achieved rapidly through a large P application at rates adequate to increase P availability or seasonal P application. However, delayed chemical fertilizer application or timing of application may happen due to the difficulties of access to fertilizer and credit. A method of fertilizer seed coating has been introduced as another option of reducing the quantity of fertilizer and labor input.

Plate 3-2-1: Fertilizer-coated seeds

3.2.2 Procedure of fertilizer seed coating

A fertilizer seed coating can be prepared by using a small quantity of water-soluble P fertilizer such as triple superphosphate (TSP). Briefly, mix 100 g dried-soil with 10 g fine-ground (powdered) TSP, 100 g rice seeds, and approximately 30 mL water, blend the mixture (soil-TSP-seed-water) together; check that most of the seeds are coated by fertilizer mixture. Then, air-dry wet-coated seeds over a flat-container for 30 minutes, and now TSP-coated seeds are ready for use (Plate 3-2-1). The ratio for seed: soil: TSP is 10:10:1, while amount of water applied is adjustable. Proportion of materials used for seed coating is showed in Table 3-2-1 and Plate 3-2-2.

Coating rice seeds by using small quantity of powdered chemical fertilizer is easy and this method is recommended for broadcasting rice cultivation system.

Table 3-2-1. Preparation of TSP-coated seed

Materials used for coating			
Coated seed needed (kg)	Seed (kg)	Soil (kg)	Ground-TSP (kg)
0.1	0.1	0.1	0.01
(=100 g)	(=100 g)	(=100 g)	(=10 g)
1.0	1.0	1.0	0.1 (100 g)
2.0	2.0	2.0	0.2 (200 g)
5.0	5.0	5.0	0.5 (500 g)
10	10	10	1.0
20	20	20	2.0

Plate 3-2-2: Materials used for fertilizer seed coating; 1) Ground TSP, 2) Soil, 3) Rice seed, 4) Water, 5) Coated seed during wet and air-dried conditions, and 6) TSP-coated seed ready for use.

3.3 Fertilizer seedling soaking

3.3.1 General Principle

The benefits of adding P fertilizer to the seedlings by soaking of seedlings in P solution may be attributed to high concentration of P that remains in available forms for plant, and a greater gradient of P concentration is created close to the roots and that would allow better diffusion to the roots. Soaking of rice seedlings by using small quantity of chemical fertilizer in a form of solution is easy and this method is recommended for transplanting rice cultivation system (see **Plate 3-3-1**).

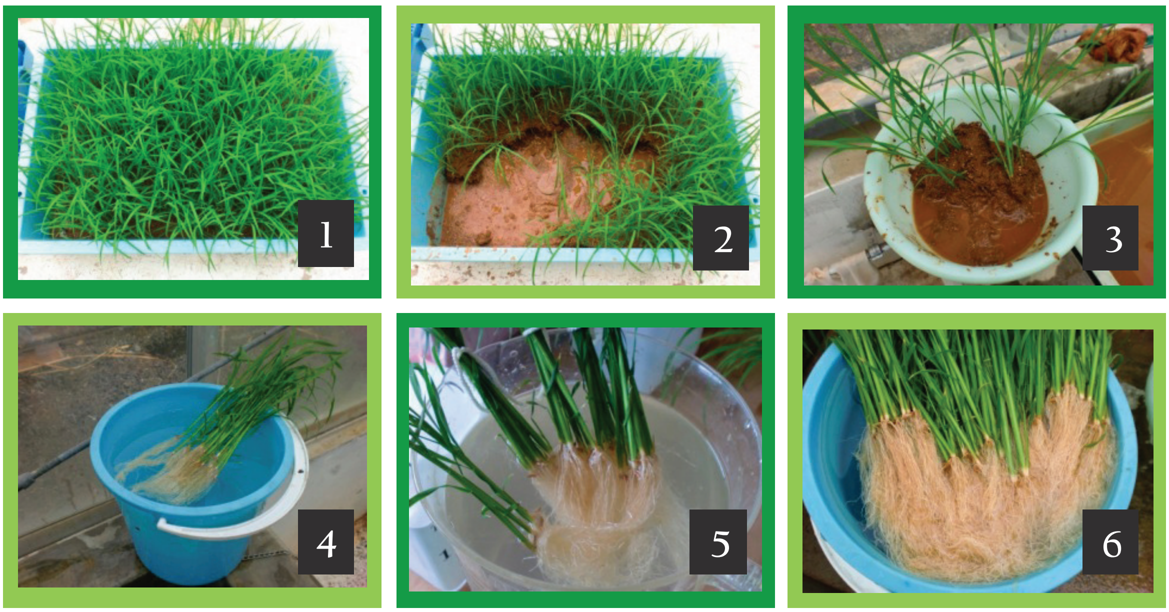

Plate 3-3-1: Seedling soaking procedure; 1) rice seedling nursery, 2) & 3) Separating seedling, 4) Washing to remove soil and debris, 5) Soaking seedling in fertilizer solution, and 6) Increasing numbers of seedling soaked in solution in order to improve fertilizer use efficiency

3.3.2 Procedure of seedling soaking

i. Nurse the rice seedling in a conventional bed to get suitable rice seedlings.
ii. Take the seedlings out of the bed and wash the roots by water to remove all soils and debris.
iii. Wash and prepare numbers (see **Table 3-3-1**) of seedlings that must be used.
iv. Keep washed seedlings by soaking in clean water before using these seedlings for soaking in the nutrient solution.

v. Hold the seedling up straight, let the clean water dropped by gravity, or slightly/ gently/ softly swing to remove water drop a little faster. We don't need to hang the seedling too long in the air. When most of water is drained, we can soak the seedling in TSP-solution.
vi. Soak the root & Culm of seedling in 5% TSP solution for 30 minutes (see **Table 3-3-2** for preparation of TSP solution).
vii. Hold the seedling up straight, let the TSP-solution dropped by gravity into a container, or slightly/gently/ softly swing to remove solution drop faster. These soaked seedlings can be used for transplanting to the field directly and we don't need to dry the roots.
viii. Use large numbers of seedlings per a unit of fertilizer solution.
ix. Re-apply residual fertilizer solution to the paddy field finally.

Table 3-3-1. Expected number of seedlings for 1 acre-field

Plant spacing	Number of plants/hill		
(cm x cm)	1	2	3
20 x 20	2,500	5,000	7,500
25 x 25	1,600	3,200	4,800
30 x 30	1,100	2,200	3,300

Table 3-3-2. Preparation of TSP solution for soaking rice seedlings

Needed fertilizer solution	Materials used for solution making	
(Liter; L)	Water (L)	Ground-TSP (kg)
1	1	0.05 (=50 g)
2.0	2.0	0.1 (=100 g)
5.0	5.0	0.25 (=250 g)
10	10	0.5 (=500 g)
20	20	1.0
50	50	2.5

3.3.3 Modifications of fertilizer soaking method

For farmers' convenience, some modification of seedling soaking method can be implemented. Dipping the rice seedling in phosphate slurry is another option. For examples, in India, the P slurry is prepared by mixing superphosphate with puddled soil and water at the ratio 1:3.5:5 for one hour before use (ANGRAU, 2011). In china, P fertilizer is mixed with soil or compost in a proportion of 1:1 to 1:5 and water added to make a paste or slurry. Before transplanting, the rice seedlings are dipped in this slurry.

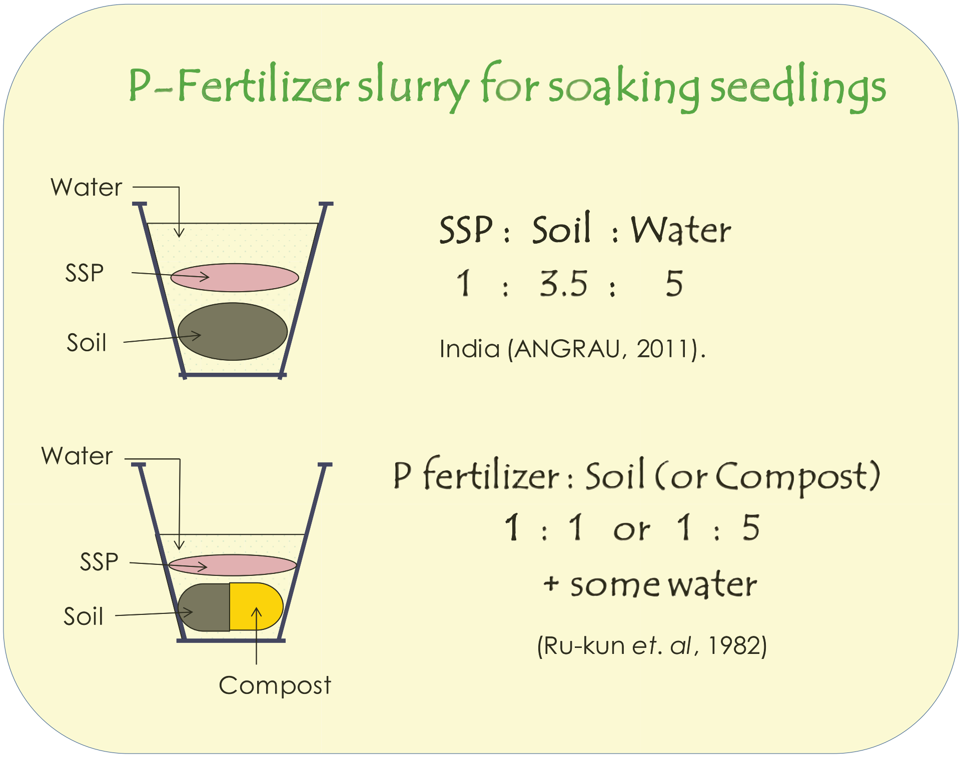

Figure 3-3-1: How to prepare phosphorus fertilizer slurry for soaking seedlings

Approximately 40-60% saving on phosphate fertilizer by dipping seedling roots is expected (Ru-kun et. al, 1982). Directly dipped rice seedling in P slurry is an easy way because it needs not to wash the roots resulting in less time consuming (**Figure 3-3-1**).

CHAPTER 4

BURKINA FASO PHOSPHATE ROCK SOLUBILIZATION

4.1 Background

Phosphorus is one of the major elements for crop growth. However, it is normally insufficient in the soil, especially in Sub-Saharan Africa (SSA). In Asia, 14.9 kg P/ha of chemical fertilizer is applied on the average, but merely 1.6 kg P/ha is applied in SSA.

Local phosphate rocks (PR) are attractive alternatives for chemical fertilizers in Sub-Saharan Africa (SSA), as we have a lot of PR deposits over the African Continent (see Map 1 next page). Unfortunately, Ghana has no PR mining activity at this moment, but regional PR may become available from neighboring Burkina Faso or Togo.

Generally, it can be directly applied to lowland rice cultivation for enhancement of rice yield (see elsewhere in this manual). But in case the effect of phosphate rock direct application is inferior to chemical P fertilizer, there are several ways to enhance the availability of PR; i.e. biological, chemical and physical ones (FAO, 2004). The PR solubilization technologies, i.e. PR enriched rice straw composting and PR calcination through saw dust or rice husk charring, were introduced so that PR can be utilized in various conditions.

This chapter describes the technologies to be applied to Burkina Faso phosphate rocks (BPR) from Kodjari as in the Map.

Phosphate rock powder commercial in Burkina Faso

Fig 4-1-1: Phosphate rock deposits in SSA (after Bationo, 2009)

4.2 Phosphate Rock solubilization through organic matter composting

4.2.1 General Principle

Composting is biological technology to improve physical and chemical properties of organic materials through biological organic matter decomposition process. Composted organic matter can improve soil fertility and rice production. Moreover, it can contribute to enhancement of PR solubility.

4.2.2 Advantages of PR solubilization with rice straw composting.

- Solubility of PR can be improved, and then effect of PR application would be enhanced.
- Solubilized phosphorus from PR can contribute to rice yield enhancement.
- It can be cheaper P fertilizer than chemical fertilizer.
- P-enriched rice straw compost can be expected to improve soil physical properties.
- P-enriched rice straw compost supplies various plant nutrients such as Nitrogen, Potassium, and especially Phosphorus.

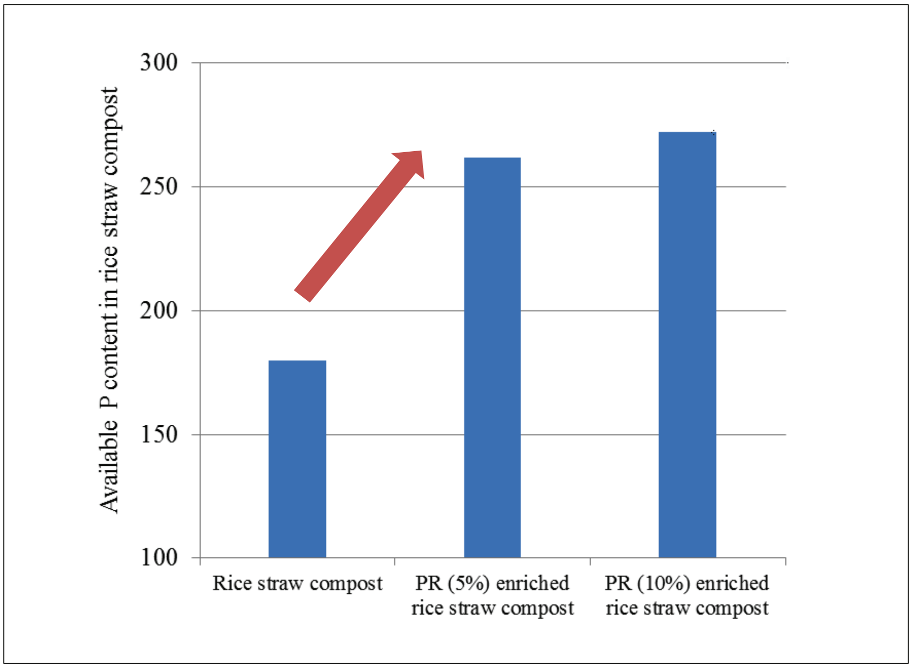

Fig. 4-2-1: Phosphorus content increased in PR enriched compost

4.2.3 Challenges in PR solubilization with rice straw composting

- Not easy to procure local PR in Ghana
- Composting process takes about three months to receive significant effectiveness on PR solubilization

4.2.4 Procedures

i. Select a location for composting, being closer to where the P-enriched compost is to be used so that users can reduce labor power to carry the compost to the field.

ii. Rice straw should be shredded into roughly 15-30 cm long.

iii. Weigh rice straw, PRs, and ammonium sulfate (AS) in the ratio as stated below.

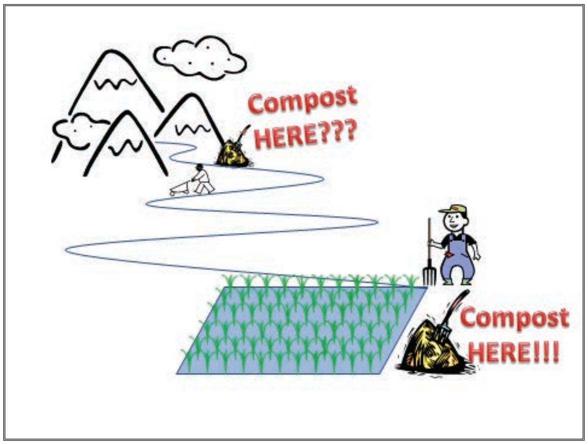

Fig.4-2-2 Location of the composting

Table 4-2-1. Quantities of rice straw, phosphate rock and Ammonium Sulfate for making P enriched rice straw compost.

Rice Straw	Phosphate Rock	Ammonium Sulfate
7.5 kg	0.4 kg	0.15 kg
50 kg	2.7 kg	1 kg
100 kg	5.4 kg	2 kg

iv. Place the rice straw in the composting trench and add water.

v. Add the PRs and Ammonium Sulfate on the rice straw and mix it well.

vi. Cover the compost with a plastic sheet or plant leaves.

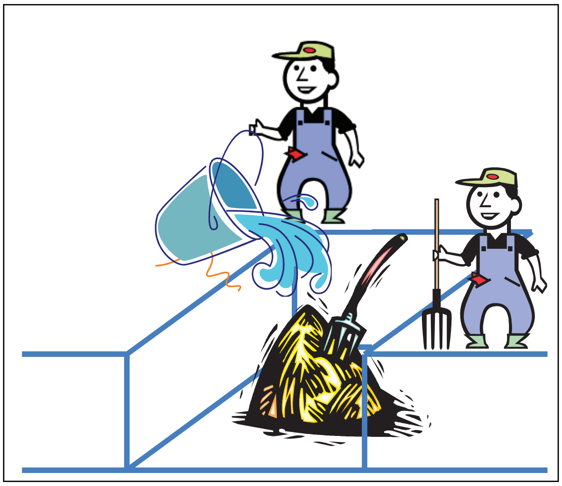

Fig.4-2-3 Water is necessary for the composting process.

vii. The compost heap should be watered every 3 to 5 days depending on the environmental conditions.
viii. After 3-4 weeks open and turn the compost (bottom materials should be moved to the top).

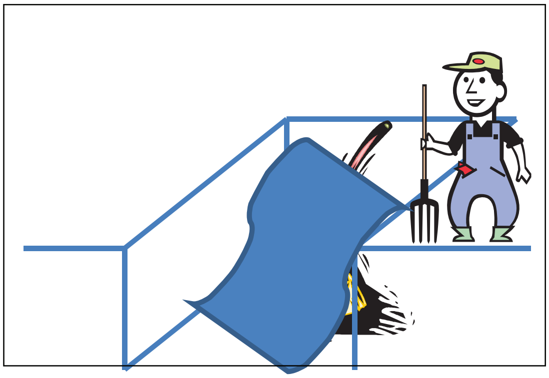

Fig.4-2-4 Cover the compost.

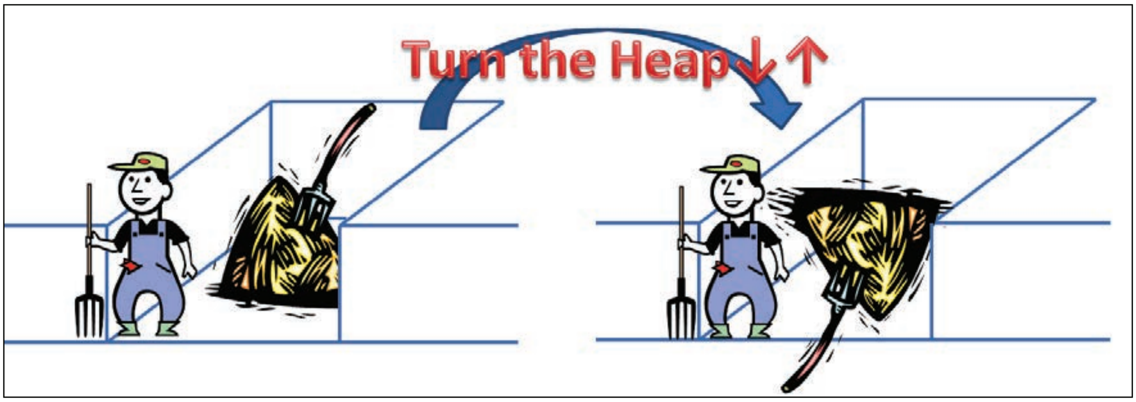

Fig.4.2.5 Turn the compost heap every 3-5 days.

ix. Before application remove the compost and allow it to cool for one night.

4.2.5 Remarks

P-enriched rice straw compost should be incorporated during ploughing, to reduce labor cost. And so, composting process should be started at harvesting time. Top dressing (using urea or ammonium sulfate) is normally required.

Composting can be considered as effective technology for Ghanaian rice production, because of several reasons, that is not only for PR dissolution, but also for other general effects such as mineral nutrient concentration, decreasing of C/N ratio, and avoidance of pest and disease risk.

4.3 Phosphate rock solubilization through low temperature calcination.

4.3.1 General Principle

There are the biological, physical, and chemical procedures for solubilization of phosphate rock (PR). And it is well known that PR elusion characteristics can be substantially increased by high temperature calcination. And the high-heat processed phosphorus (P) fertilizer is widely used, and that is called “calcinated phosphate fertilizer” and/or “fused phosphate fertilizer”. In Japan, fused magnesium phosphate fertilizer has been widely produced.

However, these calcination and fusion treatment need the facilities and advanced techniques similar to other chemical procedure for PR solubilization. So, it cannot be applicable directly to farmers. On the other hand, there are several reports about the enhancement of low grade PR solubility through low-temperature calcination. Low- temperature calcination technology has a possibility for local farmers to apply technology for PR solubilization.

In our experiment, the effect of low temperature calcination on PR solubilization was evaluated, and it was suggested that the calcination under 350~400°C can enhance the solubility of PR approximately 8%. And saw dust charring through Kuntan method was tested as farmer-applicable technology for low-temperature calcination. The potential of rice husk and/or sawdust charring was evaluated as applicable Kuntan method in Ghana.

4.3.2 Advantages of PR solubilization with Kuntan biochar making.

- Solubility of PR can be slightly improved to enhance its application and effectiveness.
- Solubilized phosphorus from PR can contribute to rice yield enhancement.
- It can be cheaper source of P than chemical fertilizer.
- It can be expected the same effect of biochar application such as improvement of soil physical property, nutrient supply, etc.
- Kuntan application will improve crop growth through root development enhancement.
- Kuntan application will improve soil biological properties thorough being good habitat of microorganisms.
- Kuntan application will contribute to neutralization of acidified soil.
- Kuntan application will improve soil physical properties such as ventilation and water retention.

4.3.3 Challenges in PR solubilization with Kuntan biochar making

- Not easy to purchase local PR in Ghana
- Kuntan application rate for lowland rice has not been properly studied.
- Too much application of Kuntan has a negative effect for crop production.

4.3.4 Procedures

i. Select a location for charring. It should be closer to where the PR enriched biochar is to be used.
ii. Collect the powdery organic materials such as sawdust or rice husk from saw mill or rice mill, and spread it thinly for it to be dry.
iii. Add the PRs on the sawdust or rice husk in the ratio as stated below, and mix it well.

Table 4-3-1. Quantities of rice husk or sawdust and phosphate rock, to make P enriched *Kuntan* biochar.

Rice husk/ Sawdust	Phosphate Rock
7.5 kg	2.5 kg
25 kg	8.3 kg
50 kg	16.6 kg
100 kg	33.3 kg

iv. Make a small fire with twigs or grasses.

Plate 4-3-1: Twigs gathered for fire

v. Place the charring apparatus over the fire.

Plate 4-3-2: Fire is covered by a charring apparatus.

vi. Make the heap around charring apparatus, with mixture of PRs and sawdust or rice husk.

Plate 4-3-3: Pouring the mixture of PRs and sawdust.

vii. Wait about 2 hours until black spots will be appeared on the surface of heap

Plate 4-3-4: Black spots appeared on the surface of the heap.

viii. Stir the charring Kuntan slowly until the material is mostly charred.

Plate 4-3-5: Charring process is going well with increasing of black parts in sawdust.

ix. The Kuntan changes from brown to black and charring is complete. The material is collected and spread. Then add the water to extinguish fire completely.

x. Collected Kuntan contains enriched and solubilized phosphorus. It can be used to enhance chemical and physical properties of the soil.

Plate 4-3-6: Resulted P-enriched biochar made from sawdust.

4.3.5 Remarks

Open burning can result in the production of ash and not char. Ash has little benefits compared to char.

Prepared by
Japan International Research Center for Agricultural Sciences (JIRCAS)
in collaboration with
CSIR-Soil Research Institute (SRI)
and
University for Development Studies (UDS)

Funded and directed by
Ministry of Agriculture, Forestry & Fisheries (MAFF), Japan