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## **Management of Water Saving and Organic based Fertilizers Technology for Remediation and Maintaining the Health of Paddy Soils and To Increase the Sustainability of Rice Productivity in Indonesia**

**Tien Turmuktini** (Departement of Agrotechnology, Faculty of Agriculture, Winaya Mukti University-Jl. Raya Tanjungsari, Bandung Sumedang, KM 29)

**Tualar Simarmata and Benny Joy** (Departement of Agrotechnology Faculty of Agriculture, Padjadjaran University. Jl. Raya Bandung Sumedang, KM 21, Bandung 40900)

**Ania Citra Resmi** (Centre for Application of Radiation and Isotope Technology, National Nuclear Energy Agency, Jakarta)

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## Management of Water Saving and Organic based Fertilizers Technology for Remediation and Maintaining the Health of Paddy Soils and To Increase the Sustainability of Rice Productivity in Indonesia

### Abstract

#### Author(s)

##### Tien Turmuktini

Departement of Agrotechnology,  
Faculty of Agriculture, Winaya  
Mukti University- Jl. Raya  
Tanjungsari, Bandung Sumedang  
KM 29.

##### Tualar Simarmata

Departement of Agrotechnology  
Faculty of Agriculture, adjaran  
University, Jl. Raya Bandung  
Sumedang km 21, Bandung  
40900.

##### Benny Joy

Departement of Agrotechnology  
Faculty of Agriculture,  
Padjadjaran University. Jl. Raya  
Bandung Sumedang km 21,  
Bandung 40900

##### Ania Citra Resmini

Centre for Application of  
Radiation and Isotope  
Technology, National Nuclear  
Energy Agency, Jakarta

The rice production in Indonesia is dominated by permanent flooding or inundation system. Intensification of permanent flooding of paddy soils not only reduces the soil biological power significantly, but also restricts the roots growth. Various field studies indicated mostly of paddy soils in Indonesia has a low organic content (< 2%). Management of paddy soil health is urgently required to restore, improve and maintain the soils organic matter as heart of soil ecosystem. SOBARI (system of organic based aerobic rice intensification) as water saving technology combined with straw compost based fertilizers technology has two main goals: (1) to remediate or restore, improve and maintain the health and quality of paddy soils, and (2) to enhance rice productivity in sustainable ways (efficient water and fertilizer use). The field results using several rice varieties in Indonesia revealed that the water saving technology combined with organic fertilizers (straw compost) can produce grain yield about 8 – 12 t/ha (average of an increasing about 50 – 150% compared to anaerobic rice cultivation) and the water irrigation was reduced by at least 30 - 50% and as well as inorganic fertilizers was reduced at least by 25%. This high rice yield is highly correlated with the increasing of roots zone about 4 – 10 times, number of productive tillers about 60 – 80 tillers, number of panicles, length of panicles and number of grain/panicle, and as well as due to the increase of soil biodiversity. The reuse of straw or straw compost into soils within three years is expected to be able to remediate and improve the health of degraded paddy soils significantly.

**Keywords:** water saving, soil health, paddy soils, organic fertilizers, straw compost, remediation, SOBARI

### Introduction

Rice is one of the most important grains in Indonesia since this crop is the staple food for majority of the people. Increasing rice production to meet the population demand is one of the major issues in Indonesia's development program. Indonesia is the world's fourth largest populous country with 237 million people in the year of 2010, after China, India and United States, respectively. Despite the population growth has declined from 2.4% per annum during the late 1960s, by early 1970s

to 1.3%, and in near future expected to decline to less than 0.9%, population size is increasing continuously and it is expected to be double size by 2050 (population closely is to 480 million). The rate of rice consumption is about 139 kg rice per capita per annum belong to the highest in the world compared with Japan, Malaysia and Thailand is only about 45 kg, 80 kg and 90 kg per capita per year, respectively. The currently rice consumption is about 33 million ton per annum and expected to increase to 38.5 million ton by year of 2025 (Suryana, 2008; Simarmata, 2008; Apryanono, 2008:

McCulloch, 2008. Consequently, the rice production must be increased by at least 4 – 5 % per annum to ensure the sustainability of food security.

Rice cultivation covered a total of around 10 million hectares throughout the archipelago consisted of about 7,9 million ha paddy soils (lowland rice) and the rest is belong to upland rice. Paddy rice growing in Indonesia has changed dramatically during the last five decades. Either rice production or rice productivity had increased significantly from 9 million ton rice (productivity about 2,5 ton per hectare) in early 1970 to 29 million tons in 1989 (4.23 ton per hectare) to 60 million ton in 2009 (4,6 ton per hectare). The increasing of rice production was highly correlated with the adoption of new technologies, mechanization, chemical use (fertilizers, plant protection agents) and luxurious use of valuable water irrigation (ISB, 2004; ISB, 2009; Simarmata, 2009; FAO, 2004).

The challenge for agriculture is to increase the production to meet demand for food in a sustainable way. Declining soil health and soil quality, scarcity of water and mismanagement of plant nutrients have made this task more difficult. Can agriculture provide enough food for Indonesia and how is the sustainability of the rice productivity and food security?. The recent data revealed that the highly intensive of fertilizer use that has been introduced over the past five decades probably has reached a point of diminishing returns or levelling off (Simarmata and Joy, 2011; Abdullah et al. 2006; Anthofer, 2004).

The rapid growing of population in Indonesia not only led to an intensive agricultural practices, but also accelerate land conversion of agricultural land to non-agricultural use and to sped land degradation and environment hazard. The intensive uses of inorganic fertilizers and agrochemical products during the green revolution (at beginning year of 1960) have given a great impact on the decline of soil health and soil quality. Based on recently research, the soil organic content of agricultural soils has been decreased within 30 years sharply. It is estimated about 70% of paddy soils in Indonesia have a low organic content (<

2 % of org-C) and low nutrients availability. This paddy soil is belong to degraded soil and can be categorized as unhealthy soils or sick soils and fatigue soils (Simarmata and Joy, 2011). The extent of sick paddy soils is increasing continually due to inefficient use of inorganic fertilizers, especially nitrogen and mismanagement of soil organic matter. The excessive use of nitrogen has accelerated the decomposition of soil organic matter (Ingham, 2001; Simarmata, 2009; Abbott and Murphy, 2004; Gupta and Rog, 2004; Sullivan, 2004). A lot of attempt has been done to anticipate and to solve this problems. The adoption of environmentally friendly agriculture (organic based agricultural and good agricultural practices) becomes more important and growing rapidly. An effort to remediate or restore the health and quality of degraded agricultural soils has been done since the last 10 years by using organic fertilizers and soil ameliorant.

The success key of soil remediation (restoring) and maintain of paddy soils health is highly correlated with soil organic matter management and good agricultural practices in sustainable ways. Organic based fertilizers by using the rice straw or straw compost as a main source of organic fertilizers for paddy soils not only restore and improve the soils health, but also reduce inorganic fertilizers significantly. The use of straw compost not only remediates and increases the soils health, but also can reduce application inorganic fertilizers by at least 25% - 50%. Particularly, the supply of silica nutrient and potassium can rely on straw compost application. Every 5 ton straw contain about 70 – 100 kg urea, 50 – 60 kg Super phosphate and 100 – 150 kg KCl (Dobermann and Fairhurst 2002; Husnain et al. 2008; Simarmata, 2009; Turmuktini et al. 2010).

Paddy rice cultivation (irrigated rice fields) largely depends on the water supply (irrigation) and it consumes about 3000 – 5000 L of water to produce 1 kg of grain rice. The increasing scarcity of water threatens the sustainability of the irrigated rice production system and hence the food security and livelihood of rice producers and consumers. The task becomes more difficult due to global climate change. Therefore, a more efficient use of water is

needed in rice production. Several strategies and management are being pursued to reduce rice water requirement, such as alternate wetting and drying, ground cover systems, system of rice intensification (SRI), aerobic rice and raised beds (Uphoff 2004, Yuan et al. 2004, Yang et al. 2004; Wikipedia 2009; Namara et al. 2004; Ho 2004; Simarmata and Yuwariah, 2009).

Since 2006 we have developed system of organic based aerobic rice intensification (SOBARI) to promote the soil biological activity (biodiversity) and to provide a favourable condition for rice roots growth and to increase the growth and yield of paddy rice (Simarmata 2008). This technology is a holistic rice production system by using and integrating the soil biological power, plant, fertilizers and water management according to the plan and design. The main goals of SOBARI as a water saving and organic based fertilizers technology are (1) to remediate, improve and maintain the health and quality of paddy soils and (2) to increase the productivity of paddy rice in sustainable ways, (3) to promote efficient and eco-friendly paddy soil cultivation and (4) to reduce the inorganic fertilizers application by at least 25%.

The implementation of SOBARI now is beginning widely adopted in several provinces of Indonesia (West Java, Banten, East Java, Central Java, North Sumatera, South Sulawesi, and North Sulawesi, East Nusa Tenggara, Bali and etc.) and it shown a promising and higher rice yield about 50 – 100% compared with traditional methods of continuous flooding (permanent anaerobic) and able to save the water irrigation significantly. This high rice yield is highly correlated with the increasing of roots zone about 4 – 10 times, number of productive tillers about 60 – 80 tillers, number of panicles, length of panicles and number of grain/panicle, and as well as due to the increase of soil biodiversity (beneficial organism) under aerobic condition. Experience with SOBARI technology combined with the recycling of straw as organic fertilizers or straw compost was able to reduce inorganic fertilizers up to 25 - 50%, to reduce water irrigation to 30 – 50%, to enhance the soil biodiversity and nutrient availability and to increase the rice yield by at

least 25 % compared to conventional methods or resulted about 6 – 11 ton grain yield of rice per hectare (Simarmata 2008; Simarmata 2009). This paper is a review of SOBARI as a water saving and straw compost based technology for restoring or remediation, improving and maintaining of the health of paddy soils to increase rice productivity and ensure food security in sustainable ways

## **System of Organic Based Aerobic Rice Intensification**

### **Definition**

System of organic based aerobic rice intensification (SOBARI) is a holistic rice production system by integrating the soil biological power, plant, fertilizers (organic, biofertilizers and inorganic) and water management to achieve targeted main goal (by design). The main goals SOBARI are to achieve and to sustain high rice productivity, promotes and enhances agro-ecosystem health (soil quality & soil health), including biodiversity, biological cycles and soil biological activity. Therefore, the maximize of local input, especially organic fertilizers (straw compost, cow dung or others) and biofertilizers becomes the main priority and called as low external inputs for sustainable rice cultivation (LEISRC) (Simarmata 2008).

The management of local inputs is designed to optimize the biological processes in achieving the desired rice productivity (outputs) and environmental quality. System of organic based aerobic rice intensification is working with the nature by optimize of organic- and biofertilizers application, water and culture of management to promote soil biological power and minimized the use of inorganic fertilizers.

### **Pillars of SOBARI**

The key success of system of organic based aerobic rice intensification (SOBARI) in increasing rice growth and soil biological activity (soil biological power) in soils are highly depend on the four basic concepts or pillars of SOBARI, as follows: (1) the of paddy soil ecosystem, (2) living soil as natural fertilizers factory (biofertilizers plant) or

bioreactor, and (3) biological power of rice and (4) integrated nutrients management

### Paddy Ecosystem Change

Traditionally paddy rice ecosystem is characterized by permanent flooding or inundation. Consequently, all aerobic organisms cannot life in soils due to oxygen depletion, which is required for aerobic respiration. Depletion oxygen leads to anaerobic conditions (anoxic conditions) and give a significant negative effect on the beneficial organisms activity and roots growth. By changing the rice ecosystem from anaerobic (permanent flooding) to aerobic conditions resulted a dramatically change in soils, especially on soil biological activity and the roots growth. The moist soils up to muddy condition provide oxygen for the respiration of soil organism. Meso- and micro fauna play an important role to create and to build a tunnels system, which is very important for air and oxygen supply under muddy condition. It seems, these tunnels support the biological activity in soil and it produced a lot of cast on soil surface. This cast is containing either macro- or micronutrients and as well as essential growth substances, like vitamins. In contrast under inundation or permanent

flooding, there is no activity of aerobic and produced no cast on paddy soil surface (Uphoff 2004; Hengsdijk, and Bindraban 2001; Simarmata 2008; Bouman et al. 2002). In addition, the roots growth and microbial activity was increased significantly under aerobic to muddy condition (Figure 2.1)

The population of beneficial microbe (nonsymbiotic nitrogen fixers such as *Azotobacter sp* & *Azospillum sp* and phosphate solubilizing bacteria) and roots growth were increased highly significantly compared with anaerobic conditions (Simarmata 2008). The rice roots system under aerobic to muddy condition was about 5 – 10 times greater than flooding ecosystem. It has been revealed only about 30% of rice roots growing well. Consequently, the potential obtained yield of various rice varieties is the work of only 30% rice roots. If roots system growing optimally in step with the rice production, the potential yield of various rice variety may increase by at least 2 three times. Therefore to change permanent flooding rice ecosystem to aerobic conditions (field capacity to muddy) is absolutely necessary to increase the rice production and to save water irrigation significantly.



Figure 2.1: Roots system and tiller number of SOBARI rice under muddy condition (aerobic) is about 3 – 5 greater than permanent flooding rice (anaerobic) (Simarmata, 2007)

### **Living Soil as Natural Biofertilizers Factory**

Paddy soil ecosystem under aerobic to muddy condition is living system and highly complex system characterized by several of biological, chemical and physical processes, which markedly influenced by environmental factors. Microorganisms inhabit the soil and together with exocellular enzymes and the soil meso fauna and macro fauna conduct all known metabolic reactions. A hectare of fertile healthy topsoil contains approximately 1200 kg of bacteria, 1200 kg of actinomycetes, 2400 kg of molds, 120 kg of algae, 240 kg of protozoa, 51 kg of nematodes, 120 kg of insects, 1200 kg of worms and 2400 kg of plant roots. One per gram moist soil in rhizosphere contains approximately  $1,200 \times 10^6$  of bacteria,  $46 \times 10^6$  of actinomycetes,  $12 \times 10^5$  of fungi and  $5 \times 10^3$  of algae (Sullivan 2001; Ingham 2001). All these organisms from tiny bacteria up to the large earthworms and insects will eat, grow and interact in the soil ecosystem to form food web that influence paddy soil ecosystem significantly. Food web is the community of organisms living all or part of their lives in the soil and it named as the living component of soil. Therefore under aerobic to muddy condition, paddy soil is life and **act as natural fertilizers** factory or **biofertilizers plant**. Contribution of soil beneficial organisms for nutrient availability was well known. The nonsymbiotic nitrogen fixers may contribute up to 50 – 100 kg N per hectare, phosphate solubilize microbes may increase the availability of P up to 50%. In addition, the mineralization rate of added straw was faster and provided more nutrient and energy for biological activity to support the rice growth. Flooding permanently or under anaerobic condition will lead to close of natural valuable fertilizers factory, mean while the farmer spend a lot of money to buy in organic fertilizers (Uphoff 2004; Simarmata 2008).

Paddy soil as natural fertilizers factory (bioreactor) need a sufficient energy sources to allow the machine working properly. Energy source for biological machine is mainly depends on organic availability. Organic material is entry point of chemical energy to paddy soil ecosystem. Consequently, the activity of heterotrophic microbes, like bacteria, fungi and actinomycetes are relying on organic

supply. The present of microbe as first trophic level allow the energy flow to next trophic level in soil food web. As organisms decompose complex material, or consume other organisms, nutrients are converted from one form to another form, and are made available to plants and to other soil organisms. Soil-dwelling organisms release bound-up minerals, converting them into plant available forms that are taken up by the plants growing on the site. Organisms which are not directly involved in decomposing plants wastes may feed on each other or others wastes products or the other substances they release. Among the substances released by the various microbes are vitamin, amino acids, sugars, antibiotics, gums, and waxes, which are very important to sustain the soils remain alive and healthy. It is not surprisingly that aerobic to muddy condition of paddy soils are tilled and fertilized by soil organisms (Ingham 2001; Sullivan 2004).

### **The performance of Natural Fertilizers Factory (Biofertilizers Plant)**

is highly depending on water management and organic supply (organic fertilizers). The water management or irrigation supply is aimed to maintain the paddy soil condition under field capacity to muddy conditions and to meet the water requirement of rice. Water conditions or water level is regulated through water canal. The distance between of water canal may range from 5 – 10 m depend on the level of paddy soils. The rice straw is used as a main source organic material to supply chemical energy the soil ecosystem and essential nutrient (macro- and microelements) for rice plant. The application of composted straw or other organic fertilizers play an important role to stimulate the growth of beneficial microbes (N-fixers, phosphate solubilizing and phytohormone producing bacteria) and to secure the of organic matter supply for soil fauna, which are act as soil engineers. The application of improved organic fertilizers (high content of humic substances, relative high of nutrition contents and other bioactive substances such amino acid, sugar and vitamins are highly recommended. The benefits of this products includes easily handling and application, relative lower in application rate (dosage), the standardized quality, relative free from contaminants (weed



seeds and soil born diseases) and lasted longer in soils.

### Biological Power of Rice

Since long time ago, people and scientist believe that rice is an aquatic plant and grows best in standing water. But recently was known that rice is not an aquatic plant. Although rice can survive when its roots are continuously submerged under water but does not thrive under hypoxic conditions. Rice does not grow as well in standing water as when its roots are able to get oxygen from direct contact with air.

Under submerged conditions the roots grow is limited and rice plants spend lot of its energy and some of the roots' cortex disintegrates to form air pockets (*Aerenchyma tissue* pockets (aerenchyma) so that oxygen can reach root tissues. In addition, under flooded conditions up to 3/4 of roots may die by the time of flowering (panicle initiation) (Uphoff 2004; Simarmata 2008). Field results revealed that wider space combined with good water and nutrient management increased the tiller number and growth significantly (Figure 2.2).



**Figure 2.2: The tiller number about 60 – 80 per clumps and growth performance of SOBARI rice (variety of Ciherang), while the flooding rice produced only 20 -30 tillers (Doc. Simarmata, 2006 – 2007).**

Water management is focusing to maintain an aerobic to muddy condition in paddy rice ecosystem. Young seedling 8 – 12 days old are planted twin (two of singly seedling are planted in line with 5 cm distance) combined with wider plan space (30 cm x 30 cm or 30 cm x 35 cm is highly recommended) to allow the roots of singly seedling grow independently at the beginning stage. Output oriented of organic based fertilizers is aimed to secure the supply of nutrient sufficiently and to maintain the optimum biological activity in soil ecosystem

### Nutrients Management

The intensive rice practices lead to the excessive nutrients removing from the paddy soils ecosystem. Fertilizers application of traditionally rice cultivation is focused only on primary nutrients such as N, P, and K, especially nitrogen (very cheap due to subsidized price). Consequently lead to nutrients depletion in soils. In addition, the

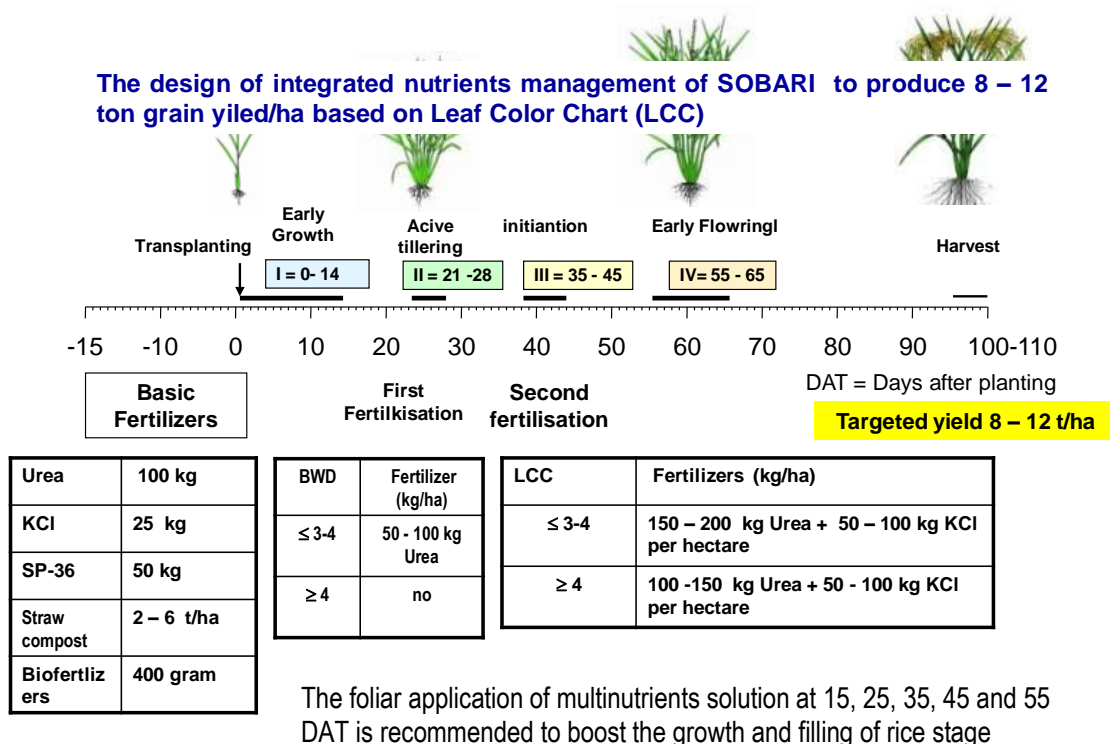
excessive of nitrogen application will accelerate the decomposition of soil organic matter and harm the environment (soil quality, water and air pollution). At least sixteen and possibly nineteen elements are known to be essential for plant growth. All nutrients have to be present in adequate amounts according to plant development or stage of growth to ensure the high rice productivity. Therefore, the management nutrition or fertilization of SOBARI is based on outputs oriented (Figure 2.3).

The amount nutrients supplied into agro-ecosystem as inputs are calculated according to the plants requirement for supporting plant development and growth to achieve the targeted productivity (*outputs by design*). The plants needs of nutrients as raw materials based on the plant development. The nutrients availability in soils and agro-ecosystem (soil properties, landscape and climate) condition and as well as



on the characteristic of applied fertilizers (solubility, salt index, reaction, etc.) must be integrated in designing of inputs management (raw materials management). It is necessary to keep the balance between inputs and outputs in order to avoid either nutrients depletion or excessive of nutrients supply, nutrients disorder

in soils and to maintain the sustainability of natural resources. In the long run, it is possible to obtain high yield on sustained basis only when the nutrients balance is positive (when the input is larger than removal). Thus all removed nutrients from the soil by plants must be replaced in an ecologically responsible way.



**Figure 2.3: Design of integrated nutrients management output oriented of SOBARI based on leaf color chart (LCC)**

In SOBARI is recommended the use of a balance application of organic and mineral fertilizers. The widely used of fertilization methods in SOBARI to produce about 8 – 12 ton rice grain yield (targeted production) are as follow; (1) the incorporation of rice straw or straw compost is done during the land preparation, (2) one day or before transplanting about 50 kg of urea, 25 kg KCL and 50 kg SP-36 (as alternative is 50 kg urea and 100 kg NPK) were applied into soil, (3) application of about 50 - 100 kg urea is done at 18 – 21 days after transplanting or after the first weeding

(leaf colour chart can be used as indicator to determine the nitrogen rate), (4) 50 - 100 kg urea and 25 - 50 kg KCl or 50 kg urea and 100 – 150 kg NPK (16:16:16) is applied 35 – 38 days after transplanting. In addition, enriched organic liquid fertilizers or multinutrition solution is sprayed to plant at 15, 15, 25, 35, 45 and 55 days after transplanting (Figure 2.3).

**Summary of SOBARI Field Results**

SOBARI is now widely adopted by incorporating the rice straw during land

preparation. Young singly seedling is transplanted at 8 – 12 days old with wider spacing (30 cm x 30 cm or 30 cm x 35 cm) in square pattern. Seedling is planted at the marked intersection of planting space (25 x 30 cm, or 30 x 30 cm or 30 x 35 cm). A single seedling is planted in twin methods (two single seedling is planted in line about 5 cm distance from each others at point of planting cross section, called as Twin Seedling Method : “**SOBARI-TS**” ) to allow the roots system of seedling growing properly at the beginning stage. The seedling is planted by slipping in sideways rather than plunging it into the soil vertically and it makes the shape of the transplanted seedling more like an L than like a J. With an L shape, it is easier for the tip of the root to resume its growth downward into the soil.

Water applications or irrigation is required to regulate the soil moisture under field capacity to muddy conditions until the beginning of grain ripening stage. The water regulation is necessary to allow rice roots growing properly and to stimulate the growing of soil organisms and as well as its biodiversity. One or two days before weeding (manually or mechanically), the rice field is irrigated with 1- 2 cm depth or a thin layer to allow the removing of weeds the easily and to improve the soil aeration. Usually, weeding is done 3 times (2, 4 and 6 weeks after transplantation).

The field results of SOBARI from several Provinces or districts in Indonesia are summarized in Table 1. As shown in Table 1, adoption of SOBARI with various rice varieties under different planting season in several provinces of Indonesia are fairly easily to achieve 40 – 60 fertile tiller plant and contains about 150 – 250 grains per panicle. The average yield was ranged from 8 to 10 ton grain yield per hectare (about 50 – 100% higher than traditional flooded paddy rice). The highest yield about 12 ton per hectare in 2008 was obtained in SOBARI Experimental Research Station of SOBARI of Agriculture Faculty of Padjadjaran University, Bandung. SOBARI method raises not only the yield of paddy (kg of unmilled rice harvested per hectare) without relying on improved varieties, but also to increase the outturn of milled rice by 5 – 10%.

This „bonus“ on top of higher paddy yields is due to having fewer unfilled grains and fewer broken grains. In addition, based on field results and report of farmers groups and extension services have verified that SOBARI crops are more resistant to pests and diseases than and as well as more resistance to abiotic or climatic stress (drought). The length of the crop cycle (time to maturity) is also reduced by 5 – 10 days. The earlier harvested time is highly correlated with no seedling stress during transplantation and after planting the roots can grow optimally without lag phase.

The key success of SOBARI depends on water irrigation and fertilizers management. The water supply by irrigation is focusing to maintain the soils under moist to muddy conditions to allow the roots system and soil biota growing optimally. Based on field experiences, the SOBARI method may reduce the water irrigation use by at least 30 % - 50 %. Output oriented integrated fertilizers application of SOBARI is aimed to provide a sufficient nutrient to meet the plant requirement based on targeted yield by design and to improve the soil quality and soil health. Therefore, the application of organic fertilizers and biofertilizers are need to increase nutrients availability and biological activity in soils. SOBARI is focusing on the application of rice straw as a main source of organic fertilizers. Actually, organic fertilizers in the form of rice straw are the main product of paddy rice cultivation. It well known that ratio between straw and grain yield ranged from 1.0 – 1.5 times. Straw is the only organic material available in significant quantities to most rice farmers.

About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity (Dobermann and Fairhurst 2002).

Nutrient content of every 5 ton rice straw is equal to 50 kg N, 10 kg P<sub>2</sub>O<sub>5</sub> and 120 kg K<sub>2</sub>O. Straw is also an important source of nutrients such as zinc (Zn) and silicon (Si). By incorporating the rice straw during land

preparation combined with biofertilizers may reduce the application inorganic fertilizers significantly. Based on field report, the application of 2 – 6 ton/ha of compost straw combined with the application biofertilizers and enriched organic liquid fertilizers as multinutrition solution (Nazarudin et al. 2010; Simarmata 2009) reduce the usage of inorganic

fertilizers by 50%. SOBARI recommends the inoculation of piled straw with decomposer (sellulolitic and lignolitic combined with *Trichoderma, sp*) about 2 – 3 weeks before spreading in the rice field and incorporation during the land preparation to accelerate decomposition of straw and to suppress the pathogenic microbes in straw.

**Table 1: Unmilled Rice Yield Summary of the System of Organic Based Aerobic Rice Intensification (SOBARI) in Different Province/District in Indonesia (Planting Season 2007 – 2009)**

| Location   | Yield (t/ha) | Control (t/ha) | Increment (%) |
|--|--------------|----------------|---------------|
| SOBARI Experimental Fields and Demo Plot (Faculty of Agriculture of Padjadjaran Univ. Bandung), planted Rice (Ciherang, Dyahsuci, IR 64, Mekongga) | 6 – 12       | 4 – 7          | 50 –150%      |
| Demo Plot in Research Institute for Rice of Indonesia, harvested on July 2008 (Ciherang, Mekongga and Sintanur                                     | 7 – 10       | -              | -             |
| West Java (Bandung, Garut, Sumedang, Bogor, Bekasih, Subang, etc.) with various rice variety   | 6 - 11       | 4 – 6          | 50 –100 %     |
| Banten (Serang)  | 6 – 10       | 4 – 6          | 50 –100 %     |
| East Java (Tulung Agung, Jombang, Madiun, Blitar, Mojokerto, Nganjuk, etc.)  | 6 – 10       | 4 - 6          | 50 –100 %     |
| Central Java (Sragen, Sukoharjo, Wonogiri, Karang Anyar, Purworejo, Magelang, Semarang, etc. )   | 6 - 10       | 4 - 6          | 50 –80%       |
| Nort Sumatera (Sergei, Tebing Tinggi, Tapanuli, etc)   | 5 – 10       | 3 - 7          | 50 –100 %     |
| South Sulawesi (Gowa, Luwu, etc.) conducted by Famer Groups in 16 Subdistrict (Various Rice Variety)   | 6 – 10       | 3 – 6          | 50-200%       |
| North Sulawesi (Minsel, Minut, etc. ) conducted by Famer Groups with Various Rice Variety  | 6 – 10       | 3 – 7          | 50 –200 %     |
| Nusa Tenggara (Kupang, Ende, Bajawa, Nagekeo, Rote Ndao) conducted by Famer Groups with Various Rice Variety                                       | 6 - 10       | 2 – 6          | 50 –300 %     |
| West Kalimantan (2 ha)   | 8,9 ton      | -              | 100%          |

**Sources:** Agricultural Services Agency of Bogor (2008), Agricultural Services Agency of South Sulawesi (2009), Agricultural Services Agency of Bajawa and Ende (2008), Agricultural Services Agency of South Minahasa (2008), Rice Institute for Rice of Indonesia, 2008, PT. SMS, 2008-2009

## Management for Remediation the Health of Paddy Soils

### Basic Concept

The concept of restoring or remediation of soils health is based on basic function of healthy soils under natural ecosystems, such as (1) to provide an excellence growth media for roots

system and soil organisms (2) regulating and partitioning water and solute flow; (3) filtering and buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition; (4) storing and cycling nutrients and other elements within the earth's biosphere (5) to sustain and maintain a

diverse community of soil organisms (soil biodiversity) which are important to control plant disease, insect and weed pests, to form beneficial symbiotic associations with plant roots, (6) to improve soil quality, water and nutrients holding capacity, (7) improve crop production (Seybold *et al*, 1998 and Ingham, 2001).

**Straw Compost for Restoring Health of Paddy Soils**

Briefly, the main function of organic fertilizers like compost straw in soils will act as: (1) a revolving nutrient bank account. Rice straw is derived from plant residues and it contains all essential plant nutrients (macro and micronutrients) and chemical energy resulted from photosynthesis. Therefore, biomass of straw as organic matter is the storehouse for nutrients and chemical energy. Either nutrients or energy are released by microbial process (mineralization or decomposition and oxidation of organic substances). The released nutrients are highly to plant (plant-available form) and

the stable organic fraction (humus) adsorbs and holds nutrients in a plant-available form, (2) entry point of energy flow (supply) into soils ecosystem, (3) an agent to activate and regulate the biological system in soils .and (4). an agent to improve soil health and soil,quality (Simarmata et al. 2011). Consequently, organic fertilizers in form straw compost plays an important and has a vital role in soils and it may categorized as heart of paddy soil ecosystem.

In addition, straw compost which is rich organic carbon (30 – 40 %) contain about 1.5% N, 0,3 – 0,5 % P<sub>2</sub>O<sub>5</sub>, 2 – 4% K<sub>2</sub>O, 3 – 5 % SiO<sub>2</sub>) and micro nutrients, such as Cu, Zn, Mn, Fe, Cl, Mo. Actually, the main product rice cultivation is not grain yield itself but the organic fertilizers in form rice straw. In General the straw production is about 1.5 x rice grain yield. If productivity of rice is about 6 – 8 ton grain yield/ha, than the production of straw is about 9 – 12 ton/ha. The nutrients contain of ice straw and it potential to substitute the inorganic fertilizers is presented in Table 2.

**Table 2: Nutrients content of straw, economical value (IDR) and it potential to substitute the main inorganic fertilizers (Simarmata and Joy, 2011)**

| Nutrients | Contain (%) | kg/ton straw | Equivalent in 5 t straw |       |
|-----------|-------------|--------------|-------------------------|-------|
|           |             |              | kg/ha                   |       |
| C-Org     | 40          | 400          | 2000,0                  |       |
| N         | 0,65        | 6,5          | 72,2                    | Urea  |
| P         | 0,1         | 1            | 13,9                    | SP-36 |
| K         | 1,45        | 14,5         | 161,1                   | KCL   |
| Ca        | 0,6         | 6            | 30,0                    |       |
| Mg        | 0,2         | 2            | 10,0                    |       |
| Si        | 5,5         | 55           | 275,0                   |       |
| S         | 0,10        | 1            | 5,0                     |       |

| Rice production in 2010 = about 60 million ton or 90 million ton of straw |    |       |                   |
|---|----|-------|-------------------|
| Equiavlent :  |    |       | IDR               |
| 1.299,60  | MT | Urea  | 4.678.560.000.000 |
| 250,20  | MT | SP-36 | 900.720.000.000   |
| 2.174,40  | MT | KCL   | 7.827.840.000.000 |

The price **Urea Rp 3600 (Rp 1200, SP-36 Rp 4000 (Rp 1850) dan KCL Rp 6000**

As shown in Table 2, the reuse of straw as an organic fertilizers can substitute the inorganic fertilizers up to 50% of major nutrients, such N,

P and K., while other nutrients (Ca, Mg, Si, S) and micro nutrients (Cu, B, Zn, Fe) could be fully substitute. The application of straw is also

act refilling or recharging of the fuel or energy into soil ecosystem, every 5 ton straw will supply about 2000 kg organic carbon into soils. Thus, the activity of soil organisms is highly correlated with the supply of straw which act as energy source (fuel).

The composting of straw with appropriate technology will increase not only nutrient contents, beneficial organisms and but also important to control the pathogen microbes which has been existed in the straw. The

increasing population of organisms in straw compost (bacteria, fungi, animal and others) will improve the quality of straw compost significantly (Figure 2.4). In general, the straw compost content about 30 – 40 % of total carbon (rich in humus and organic acids), 1 – 1,5 %, 0,5 %  $P_2O_5$ , N, 2 – 3 %  $K_2O$ , 3 – 5% of  $SiO_2$  and other essential nutrients. In situ composting of straw has been developed (Simarmata and Joy 2010) for the remediation of paddy soils in Indonesia (Figure 2.4).



**Figure 2.2: In situ direct composting of straw (A = preparation of decomposer inoculant, B = compost box, piling of straw and inoculation, C= Straw pile, D= covering straw pile G & H = mycelium of fungi is growing well on straw compost and I = mature straw compost (Simarmata & Joy, 2011).**

### Application Methods

Briefly, the application of composted straw can be applied or incorporated (1) before land preparation and (2) after transplanting for remediating or restoring the soil health of paddy soils.

**Before Land Preparation:** Shortly before land cultivation with tractor, the composted straw (normally 2 – 3 weeks has a C/N ration to 30 - 40 after 2 – 3 weeks composting process) and it can be applied on the surface of paddy field homogenously. Subsequently, the land is cultivated using tractor or others equipment to

incorporate the straw compost into the soils (Figure 2.3). In general one week after incorporation, the C/N ratio of soil will be

decreased to below  $< 20$  and the rice seedling or rice seed can be planted.



**Figure 2.4: Spreading and incorporation of straw compost and following with land cultivation or preparation (Simarmata and Joy, 2011)**

**After Transplanting:** The application of mature straw compost (C/N ratio about 20 or less) is applied about 2-3 weeks after transplanting. The incorporation or placement of compost straw within plant row is done after the first weeding (Figure 2.5). During this

activity, the weeds that still exist and growth closely to the rice clumps can be eliminated manually. Subsequently, it is recommended applying of inorganic fertilizers to boost the plant growth.



**Figure 2.5: Application of straw compost within plant row after the first weeding (about 2 – 3 weeks after transplanting). The straw is placed or incorporated into soils by stepping (Simarmata and Joy 2011)**

### Field Results and Close Remarks

The application of compost straw or straw has shown a great impact on the improving the soil

quality and soil health. The content of organic carbon, availability of nutrients and on biodiversity of organisms in soils was increased significantly. The application of 2 – 6 ton/ha of compost straw increase the rice yield and



reduce the rate of inorganic fertilizers significantly (Table 3).

**Table 2: Effect of straw compost the rice grain yield under different rate of potassium fertilizers (Nazarudin *et al.*, 2010).**

| Straw Compost<br>(ton ha <sup>-1</sup> ) | Rate of KCl (kg ha <sup>-1</sup> ) |             |             |             |
|--|------------------------------------|-------------|-------------|-------------|
|  | 0                                  | 50          | 100         | 150         |
| 0  | 2,90 a<br>A                        | 3,80 b<br>A | 6,20 c<br>A | 6,44 c<br>A |
| 2  | 4,20 a<br>B                        | 5,48 b<br>B | 8,49 c<br>B | 8,54 c<br>B |
| 4  | 7,21 a<br>C                        | 9,28 c<br>C | 9,49 c<br>D | 8,76 b<br>C |
| 6  | 8,84 a<br>D                        | 9,20 b<br>C | 9,20 b<br>C | 9,10 b<br>D |

**Note:** Value number within row or column followed by the same letter (capital for vertical in column) is not different significantly according to the LSD 0.95 test

It is estimated that application of 2 – 4 ton straw compost within 3 years (about 6 planting season) will be able to restore and improving the health of paddy soils. As indicator of the soil health recovery can be seen on the main indicator such as the biological, chemical and physical indicator. Briefly, the content of organic carbon must be much more than 2% and availability of major nutrients is at least belonging to medium category. Subsequently, it is need the management of soil organic matter by using the straw as` main source of organic fertilizers. The habit to burn of straw must avoid or forbidden strictly. The straw burning not only polluted the environment but also led to the loss of major nutrients significantly. About 91% C, 91% N, 45 % P, 70 % K, 50 % Ca, 20 % Mg and others nutrients were loss due to the straw burning (Husnain *et al.* 2008).

The success key of restoring and maintaining of soils health for sustainable rice cultivation to ensure the food security in Indonesia is highly depend on management of soil organic matter. The use of straw as the main source of organic fertilizers is absolutely correct. It has been ready available on site. Therefore it belong the low cost and effective agent that can be used as agent for re-healing and to maintain the health of the soils ecosystem. Thus, the SOBARI combined with management of rice straw can be implemented to speed the paddy soil remediation and to increase the rice productivity in Indonesia in sustainable ways.

## Conclusions and Suggestions

The conclusions and suggestions can be summarized as follows:

1. System of organic based aerobic rice intensification (SOBARI) is a holistic of water saving and inorganic fertilizers reducing technology focusing on soil biological and rice power management and as well as integrated fertilizers management to increase rice production and to improve the soil quality significantly. It can reduce the water irrigation by at least 30 - 50%, seed rate about 75%, and inorganic fertilizers by at least 25%, and increase the rice yield about 50% - 100% compared with traditionally flooding rice cultivation.
2. The main goals of SOBARI as water saving and organic based fertilizers technology are (1) to remediate, improve and maintain the health and quality of paddy soils and (2) to increase the productivity of paddy rice in sustainable ways, (3) to promote efficient and eco-friendly paddy soil cultivation and (4) to reduce the inorganic fertilizers application significantly.
3. Adopting the SOBARI as water saving and environmentally friendly cost reducing technology combined with

straw and integrated nutrients managements will promote and speed the remediation or restoring and improving of paddy soils health and increase the sustainability of rice production

4. Furtherer research are need, especially on; (1) a comprehensive water requirements, (2) soil biological activity (macro- and microorganisms) and roots system under different water conditions, (3) The application organic and Biofertilizers to substitute or reduce the inorganic fertilizers (5) the performance of roots system, growth and yield various rice variety under different planting season

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