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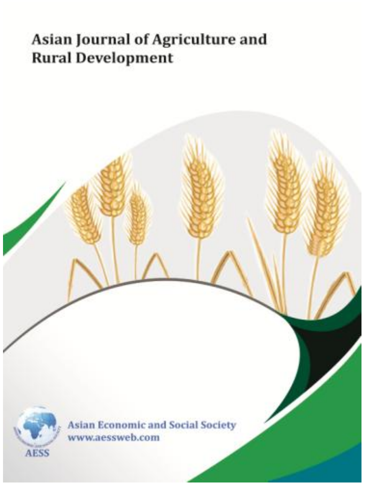

Restoring the Health of Paddy Soil by Using Straw Compost and Biofertilizers to Increase Fertilizer Efficiency and Rice Production with Sobari (System of Organic Based Aerobic Rice Intensification) Technology

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Abstract

Current conditions indicate that about 70% of paddy fields in Indonesia has been experiencing severe degradation of land and can be categorized as an illness (sick soils), therefore, efforts to restore health and increase the productivity of paddy soil in a sustainable manner can be done by integrating fertilizer-based integrated management organic and biological fertilizers (biofertilizers) with SOBARI (system of organic based aerobic rice intensification)technology. The experiment was conducted from March to August 2011 in the fields eksperiment Faculty of Agriculture Padjadjaran University, Bandung with the aim of testing the use of straw compost + biofertilizer for efficientcy inorganic fertilizer (N, P, K) and increase rice production by SOBARI technology. Experiments was using a split plot design. The main plot consists of 8 standard combination of organic fertilizer (compost straw 0: 2.5: 5.0 and 7.5 t ha^{-1}, with no biological fertilizers and biological fertilizers 400 g ha $^{-1}$. Sub plots consisted of 5 standard: organic fertilizer N, P and K (100%, 90%, 80%, 70% and 60% of recommended dosage). The results are: interaction occur between the provision of straw compost + biofertilizer, to the yield per plot. Dosage of 5.0 t ha $^{-1}$ of compost straw + 400 g ha^{-1} biological fertilizer by accompanied N, P, K 80% of the recommended, may show the highest yields and increase the yield of 13.3% compared to controls is 7.29 kg plot $^{-1}$(6.654 t ha $^{-1}$) and gained efficienciy fertilizer N, P, K 20%, of the recommendation.

Keywords: Wetland restoration, fertilizer efficiency, straw compost, biofertilizer, SOBARI technology

Introduction

Sustainability of food security (rice) is highly dependent on the quality of wetland health and water availability. Current conditions indicate that about 70% of paddy fields in Indonesia has been degraded can be categorized as an illness (Sick Soils). These problems can lead to food crises and humanitarian issues, and therefore efforts to increase rice production will not be successful without being accompanied by restoring wetland health, because the land has been levelling off. In wetland restructure the efficient use of inputs necessary for farming can compete with other commodities. A technology of rice cultivation with integrated organic wetland management, water-saving technology, power biological crop management, organic based fertilizers and bio fertilizers (biofertilizers) is breakthrough technology that can increase rice production and a sustainable agriculture.

Rice cultivation techniques IPAT-BO (Intensifikasi Padi Aerob Terkendali Berbasis Organik In Indonesian language) or SOBARI

(System of Organic Based Aerobic Rice Intensification) is one of the new technology of rice cultivation in Indonesia that can be used to overcome the degraded irrigated lands, marginal paddy soils, reduced irrigation water, high prices of chemical fertilizers and mitigation for the solution of green house effect that cause global warming which is already happening in the present. This technique was conceived and researched by Prof. Dr. Ir. Tualar Simarmata MS, a professor of Faculty of Agriculture, University Padjadajaran since 2006 and is constantly being researched and developed to get the best method as an alternative solution, especially for irrigated rice crops in Indonesia. SOBARI is a controlled aerobic intensification technology-based organic material which focuses on the strength of soil biological power, restore the function of the food web and soil as natural fertilizer factory (Simarmata 2007 and Simarmata et al. 2008).

The investigation conducted in 2002, showed that eight provisions in Indonesia already had low C -organic levels, example 17% of land contain <1%, 26% of land contain 1 - 1.5% and 20% of land contain 1.2 - 2%, especially in agricultural production center like Java island has already in a critical condition characterized by C-organic content of < 2% (Kasno et al. 2003). Water application for agriculture is large enough about 70%, but in developing countries it can reach 80% - 90%. (Koenhuan 2003). In reality, farmers are still wasteful using water. Estimated loss of water by 60%, which is lost while in the plot, 40% lost due to evaporation, seepage, leaks in the irrigation channel, and because of operational errors (Palioptro 1991). Global warming affecting the climate, planting periode, and soil water availability becomes the limiting factor of the sustainability of food availability. Similarly, efforts to mitigate greenhouse gas emissions, especially methane, in order to obtain rice cultivation techniques that are friendly environmental.

Simarmata et al. (2011), mentions techniques SOBARI is expected to be a solution to overcome agriculture issues in Indonesia, because it has four advantages, namely 1. Saving water; efficient using water, where water level is 1 cm above the soil surface to -5 cm below the surface of the soil / aerobic controlled; 2. Efficient fertilization because it adds organic matter (compost + biofertilizer), 3.Saving seed; using twin seedling system, it has 2 seed at one planting hole with 5 cm distance, and 14-day-old plants after the seedlings, 3.Efficient fertilizer because added organic matter as rice straw compost, biological fertilizers expected to reduce the use of inorganic fertilizers which is highly expensive ; and 4.Soil utilization as biological power which is sources of organic matter, biological fertilizers and biological agents, or as an bioreactor to functioning of natural fertilizer factory and increase the resistance of plants against soil-borne diseases. (Turmuktini and Simarmata, 2010, Simarmata and Benny Joy 2011).

Rice straw can easily found at paddy fields, when returned to the land is expected to be a cheap source of organic material, as controlling the natural balance of land, restoration of chemical, biological and physical soil quality which damaged due to land degradation . The occurrence of soil degradation can be caused by excessive use of inorganic fertilizers: affect the soil to be levelling off, using of herbicides and insecticides continuously.

Decreasing in soil quality will directly affect reduction in rice production, besides addition the use of immature rice straw compost can cause disease contamination, conttribute as source of greenhouse gas emissions and slow release agent; therefore it has to be composted. Rice straw compost contains 1.5 - 2% N, 15-24% C-organic, 1.5 - 2%. K, and 2-3% P.

The principle of composting is to lower C / N compost until near the C / N soil, which is 12-15. Compost is considered indispensable because of the need for organic materials for fertilizers have not been met despite the available manure or green manure. There are several factors driving the need compost include difficulty obtaining mature manure in large quantities, the constraints in the use of green manure because of time and soil for planting green manure crops. Whereas, rice straw compost prices are relatively inexpensive because it can be easily found.

Giving the compost has beneficial properties that include: 1) improve soil structure 2) increase the holding capacity of soil nutrients, 3) increase in soil water holding capacity, 4) improve the drainage and air circulation in the soil, and 5) contains a complete nutrient ,althought in small amounts (Diah Setyorini et al. 2006).

According Simanungkalit et al. (2006) *Azotobacter* and *Azospirillum* are non symbiotic bacteria as nitrogen fixing, while *Bacillus* sp., And *Pseudomonas* sp. identified capable of dissolving insoluble forms of P into P form available to plants. Thus the availability of soil microorganisms are able to increase the availability of plant nutrient elements, especially N and P. Bio fertilizers are used in this study contains a microbe fastening N non symbiotic (*Azotobacter* and *Azospirillum*) and phosphate solubilizing bacteria (*Pseudomonas sp*. and *Bacillus sp*.) Is able to provide nutrients in a non-symbiotic with plants, such as N and P nutrients so that soil fertility is increasing (Fitriatin et al. 2007).

The purpose of this study was to assess the effect of application of organic fertilizer (straw compost+bio fertilizer), on growth, crop yield rice varieties Ciherang and efficiency of synthetic fertilizer (N, P, K) with SOBARI-method

Materials and Methods

Experiments carried out in filed experiments of Faculty of Agriculture district Ciparai in Bandung from February 2011 until August 2011. Materials used biofertilizer *Bacillus sp, Azospirillum*, *Azotobacter*, *Pseudomonas sp* (Soil Microbiology lab collection Faculty of Agriculture UNPAD), bolotong bagasse, rice straw compost (the incubation period of 3 weeks), urea (45% N), SP-36 (36% P_2O_5), KCl (60% K_2O), insecticide Decis 25 EC.Experiment was using a split plot design which consists of two factors and three replications. main plot: Organic fertilizer dosage (J) (Straw Compost and bio fertilizer) with eight standard treatment, namely:

- j_0: straw compost 0 t ha-^{1} + bio fertilizer 0 g ha^{-1} (control)
- j_1: straw compost 0 t ha^{-1} + bio fertilizer 400 g ha^{-1}
- j_2: straw compost 2.5 t ha^{-1} + bio fertilizer 0 g ha^{-1}
- j_3: straw compost 2.5 t ha^{-1} + bio fertilizer 400 g ha^{-1}
- j_4: straw compost 5.0 t ha^{-1} + bio fertilizer 0 g ha^{-1}
- j_5: straw compost 5.0 t ha^{-1} + bio fertilizer 400 g ha^{-1}
- j_6: straw compost 7.5 t ha^{-1} + bio fertilizer 0 g ha^{-1}
- j_7: straw compost 7.5 t ha^{-1} + bio fertilizer 400 g ha^{-1}

Sub Plots: percentage of NPK dosage (of the standard dosage) (P):

- p_1 = 100% (of the standard dosage per hectare: 300 kg Urea, SP 36 100 kg, 100 kg KCl)
- p_2 = 90%, p_3 = 80%, p_4 = 70% and –p_5 = 60%

Implementation of cultivation techniques using SOBARI. method number of plots in this experiment is 120 each with an area of 3 m x 3.5 m. Spacing (30 cm x 35 cm), the population of 100 clumps of plants per plot and using *twin seedling planting*, where one planting hole consist of 2 seeds plant with 5 cm distance . Provision of compost made one week after planting (WAP) along with tillage, seeds used was 14 DAS (days after seedling), bio fertilizer is given a day before planting (with a ratio of 100 grams of bio fertilizers: 10 kg blotong), fertilizer N, P and K were given respectively individual: for Urea 3 times, 1/3 dosat planting, 1/3 dosage at the age of 15 DAP (days after planting) and 1/3 dosagee at the age of 30 DAP (days after planting). SP-36 one time, at the time of planting and KCl are given two times, at planting time and the age of 30 DAP (days after planting). After planting, water management conducted, using water-saving technology (SOBARI), the water is maintained in a condition where water level is 1 cm above the soil surface to -5 cm below the surface of the soil, except for 2 days just before weed control and at the end of vegetative age 50 to 60 DAP (days after planting) performed inundation 5 cm above the ground, that serves to suppress the growth of rice tillers and then performed the provision of water where water level is 1 cm above the soil surface to -5 cm below the surface of the soil back until 2 weeks before harvest. The data were statistically tested using ANOVA and the Duncan Mutiple Range Test at α 5% (Gomez and Gomez. 1995). For more details, provision of straw compost, planting systems twin (twin seedling) with a distance of 35 cm x 30 cm, and the appearance of vegetative and generative phase of the experiment the plants can be seen in figure below.

Figure 1: Incorporation of compost a week before planting and display the twin plant system (TS: Twin seedling)

Figure 2: Display water-saving techniques SOBARI (controlled aerobic) in the vegetative phase and display in generative of plants in field trials (documentation: Tien Turmuktini, 2010.)

Results and Discussion

The interaction occured between organic fertilizers (compost manure + bio) to rice production per plot in various doses. Table 1. Independent test on plant growth showed that administration of compost and bio fertilizer has no influence on plant height, number of tillers and number of productive tillers.

Table 1: Average of plant height, number of tillers and productive tillers

Treatment Dosage of straw compost + bio fertilizer	Plant height (cm)		The number of tillers (pcs)		The number of productive tillers (pcs)
	5 WAP	7 WAP	5 WAP	7 WAP	
0 t/ha + 0 g/ha	53.547a	67.040 a	30.333 a	39.173 a	22.867 a
0 t/ha + 400 g/ha	51.707 a	64.973 a	29.293 a	34.747 a	23.253 a
2,5 t/ha + 0 g/ha	51.853 a	66.080 a	28.587 a	33.733 a	24.347 a
2,5 t/ha + 400 g/ha	52.227 a	65.867 a	26.867 a	33.373 a	23.227 a
5,0 t/ha + 0 g/ha	52.307 a	66.427 a	27.813 a	33.627 a	24.320 a
5,0 t/ha + 400 g/ha	50.867 a	65.587 a	25.573 a	35.427 a	23.960 a

7,5 t/ha + 0 g/ha	52.813 a	66.133 a	26.987 a	35.160 a	24.693 a
7,5 t/ha + 400 g/ha	52.973 a	66.440 a	27.093 a	36.293 a	25.640 a
fertilizer NPK (P)					
100%	53.817 c	67.800 c	30.125 c	36.525 b	25.850 c
90%	52.800 bc	66.667 bc	29.117 bc	36.258 b	24.567 bc
80%	51.842 ab	65.742 b	26.833 ab	34.650 ab	23.492 ab
70%	52.167 b	65.617 ab	27.208 ab	34.550 ab	23.250 ab
60%	50.808 a	64.517 a	25.808 a	33.975 a	23.033 a

Description: The average number of the same letters in the column as indicated are not significantly different according to Duncans multiple range test at level 5%

Table 2. Average of rice production as a result of organic fertilizers (Straw compost+Bio fertilizers) and inorganic fertilizers (N, P and K) application

Dosage of fertilizer straw compost and bio fertilizers	Rice production (kg plot $^{-1}$)				
			NPK fertilizer (P)		
	100%	90%	80%	70%	60%
0 t/ha + 0 g/ha	6,59 b (e)	6,48 d (d)	6,35 c (c)	6,07 b (b)	5,99 b (a)
0 t/ha + 400 g/ha	6,77 d (e)	6,44 c (d)	5,87 a (b)	6,21 c (c)	5,59 a (a)
2,5 t/ha + 0 g/ha	6,82 e (e)	6,18 a (c)	6,40 d (d)	5,91 a (b)	5,57 a (a)
2,5 t/ha + 400 g/ha	6,66 c (d)	6,24 b (b)	6,17 b (a)	6,49 g (c)	6,17 d (a)
5,0 t/ha + 0 g/ha	6,29 a (c)	6,63 e (e)	6,48 e (d)	6,24 d (b)	6,12 c (a)
5,0 t/ha + 400 g/ha	6,83 e (c)	6,62 e (b)	7,20 g (d)	6,36 e (a)	6,63 f (b)
7,5 t/ha + 0 g/ha	6,88 f (e)	6,61 e (d)	6,32 c (a)	6,45 f (c)	6,41 e (b)
7,5 t/ha + 400 g/ha	6,88 f (c)	6,90 f (c)	6,99 f (d)	6,56 h (b)	5,99 b (a)

Description: The average number of letters indicated in the brackets on the same horizontal direction and the same letters without the brackets indicates the vertical direction are not significantly different according to Duncans multiple range test at the level of 5%

The utilization of fertilizer N, P, K gives significant effect on plant height, number of tillers and number of productive tillers, higher dosage of N, P, K, more than 60% showed the

improved results, but the same dosage 90% has the same results with 100%.
Fertilization is one aspect to consider in the rice crop intensification program. Utilization synthetic fertilizer is the most preferred action for this, because it has a nutrient's available for plants and immediately visible effect on plants. Compost contains micro and macro elements, each of them has a function to enhance growth and yield of crop needs (Maschner 1986), but the provision of intensive chemical fertilizers in rice cultivation has led to impaired fertility (Gunarto et al. 2002) and stimulate mineralization of soil organic matter resulting in decreased levels of C-organic in soils, soil health and quality of rice is low (Arafah and Sirappa 2003; Simarmata 2007).

Decreasing in the effectiveness of synthetic fertilizer has an impact on soil and plants can be balanced by the provision of organic fertilizer. The aplication of organic matter in addition to increase nutrients in the soil also can improve crop biophysical environment, among others, can improve soil productivity and efficiency of synthetic fertilizers (Arafat and Sirappa 2003). This is why that the organic fertilizer in the form of straw and manure compost has no influence, while provision of synthetic has significant on plant growth (plant height, number of tillers and number of productive tillers).

Fastening bio fertilizer free-living N_2, non-symbiotic, such as *Azospirillum* and *Azotobacter* and *Pseudomonas spp* are found in the rhizosphere and in plant tissues have been able to increase significantly mooring N_2 (James and Olivares, 1997). *Azotobacter* is an N_2 anchor bacteria capable of producing gibberellins, cytokinins and indole acetic acid, the substance of plant growth regulators that stimulate root development. Mooring of N_2 from the air into ammonia assisted by the enzyme nitrogenase which depends on the physical, chemical and biological soil. Availability of energy resources in the form of organic matter rhizosfer environment is a major factor that determines the amount of N_2 produced (Alexander, 1997), Phosphate solubilizing bacteria (*Pseudomonas sp.* and *Bacillus sp*.) is able to provide the nutrients that increase soil fertility. (Fitriatin, et al. 2008). Dissolution of phosphate occurs biologically because the microbes that produce enzymes phosphatase excreted by plant roots and by the dominant microorganism (Joner et al. 2003). In addition it also produced phytase enzyme (Alexander 1977). Phosphatase enzyme known to play a role in the mineralization process of organic phosphate compound that is described in the form of organic phosphate into inorganic phosphate in the form provided. Activity of microorganisms is influenced by soil pH and substrart (Alexander 1977).

The addition of straw compost as a source of carbon to the soil accelerate the development of nitrogen solubulizing bacteria and phosphate solubulizing bacteria. This indicate why the number N_2 is moored or dissolved P in bacteria varies in each place, it is dependent on energy availability and the ability of bacteria to compete with another bacteria which is given from outside or exogenous (in the form of bio fertilizers or bacteria found in compost) or the local bacteria (indogenous) living and breeding depends on the same energy source. Microbial activity depends on their ability to compete with abiotic factors such as environment, temperature, pH, substrate and biotic factors, namely competition with similar microbes and various other types of microbes. The success of microbial tolerance will generate the necessary nutrient such as N, P, K are as many and quickly so as to substitute the need for inorganic fertilizers.

Application of straw compost and bio fertilazer affect each other. The highest result is obtained with treatment compost 5 t ha^{-1} + 400 g ha^{-1} bio fertilizer with 80% standard dosage of inorganic fertilizer N, P and K, with rice production 7.20 kg plot $^{-1}$ is equivalent to 6.65 t ha^{-1} , this treatment led to occur 13.3% yield increase compared to controls. Provision of compost 2.5 t ha^{-1} and 5 t ha^{-1} + 400 g ha^{-1} of bio fertilizers with organic fertilizers 70% and 60% of the standard dosage can produce grain each 6.49 kg plot $^{-1}$ and 6.63 g plot $^{-1}$ equivalent to each of 6.18 t ha^{-1} and 6.31 t ha^{-1} , this treatment led to an increase in the 6.18% respectively and 10, 8% compared with respective controls. Improved results show that with the contribution of organic fertilizer bio fertilizer and straw compost could substitute inorganic fertilizer 20% to 40%. This is supported by plant nutrient uptake of nutrients and the chemical state of the land has increased to fit the needs of plants.

According to the description of Ciherang varieties showed that the number of productive tillers rod is 14 -17, 1000 grain weight was 28 g, the average result is 6 t ha^{-1} and 8.5 t ha^{-1} rice production. Compared to the rice experimental results, it turns out the number of tillers increased to 33 up to 36.293 pieces, the average increase of 125% and the number of productive tillers increased to 23 to 25.64 pieces per cluster, an increase of 54% compared to the number of tillers description. An increasing number of tillers and number of productive tillers is the success of the technique in which SOBARI- cropping systems using TS (Twin Seedling) planting method.

The main focus in savings synthetic fertilizers is to use N,P, K fertilizer more efficiently by giving N bacteria and phosphate solubilizing bacteria. Utilization of these bacteria are applied directly or with the addition of compost, to increase the efficiency of fertilizer N, P and K around 20%. According to the description Ciherang rice varieties showed that the number of productive tillers rod is 14 -17, 1000 grain weight was 28 g, the average result is 6 t ha^{-1}yield potential and 8.5 t ha^{-1} rice production. Compered to the rice experimental results, it turns out the number of tillers increased to 33 up to 36.293 pieces, the average increase of 125% and the number of productive tillers increased to 23 to 25.64 pieces per cluster, an increase of 54% compared to the number of tillers description. An increasing number of tillers and number of productive tillers is the success of the technique in which SOBARI - using TS (Twin Seedling) planting system.

Improvement in crop production is closely related to the ability of plants to tolerate environmental and genetic nature itself (Salisbury and Ross 1995). Availability of nutrients in the soil will improve crop production, but the utilization of nutrients is limited to the adequacy of the needs and capabilities of the plant itself is carried genetically. (Gardner et al. 1991). In achieving the ultimate goal of long-term strategy, the use of rice straw compost and bio fertilizers is to increase production and improve the efficiency of fertilizer N, P, K is expected to be positively correlated to the increasing productivity land and farm income.

Conclusion

The results are: interaction occurs between the provision of straw compost + biofertilizer, to yield per plot. Dosage of 5.0 t ha^{-1} of compost straw and 400 g ha^{-1} dosage biological fertilizer by accompanied N, P, K 80% of the recommended, indicate the increase of yield about 13.3% compared to controls is 7.29 kg $plot^{-1}$(6.654 t ha^{-1}) and gained efficienciy fertilizer N, P, K 20%, of the recommendation.

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