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INCREASING PRODUCTION OF RICE FIELDS THROUGH THE APPLICATION OF N-TETHERING BIOFERTILIZER AND STRAW COMPOST IN TWO WATER MANAGEMENT FACILITIES

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ABSTRACT
Improving the fertility of rice fields can be carried out by utilizing straw compost and biofertilizer that are adaptive towards the rice fields' ecosystem. A study to determine the effect of N-Tethering biofertilizer and straw compost application on the content of C-organic, soil's available-N, and plants' N concentration and the rice field production in two conditions of water has been conducted at the rice fields of the farmers in Sukakarya Bekasi. Three treatments being investigated are application of biofertilizer + straw compost +2/3 measure of N-fertilizer, controlled aerob water management, IPAT plant system; application of biofertilizer + straw compost + 2/3 measure of N-fertilizer, water management as commonly used by local farmers, plant system of type 2 legowo 4:1; and fertilizing as recommended by local practice, water management and plant system as commonly practiced by local farmers. The investigation implements field research method on a square of rice field of ± 500 m^2 in area, analyzed using univariate analysis followed by LSD test. The results show that the application of 400 g $ha^{-1}$of N-tethering and 2 tons ha^{-1} of straw compost in the IPAT plant system with water management of spate irrigation and on type 2 legowo 4:1 plant system with inundation water management improves the soil's N and K content, the plant's N and K content, productive tillers and dried unhulled-rice harvest.

Keywords: biofertilizer, straw compost, rice field harvest, N-tethering bacteria

INTRODUCTION
The soil's content of organic materials is the primary indicator of soil sustainability. Organic materials are closely related with the physical and chemical nature of the soil as well as all functions of the soil. However, soil's organic materials are highly prone to changes that they need to be maintained regularly through soil management. The changes in soil's organic materials are indicated by the changes of carbon organic material (King et al., 2005; Liul et al., 2006). Soil organic carbon not only affects fertility, but also determines several functions of the environment (Juraj Balkovič*et al*., 2011). Organic materials of soil are important sources of soil carbon and play great roles in carbon sequestration (decreasing carbon in the atmosphere) (Liul et al., 2006).
The level of soil's C-organic will decrease with the intensive application of N-fertilizer through the process of organic materials mineralization in the soil. Agricultural intensification in irrigated

field experience decrease in production as the N-materials in the soil decreases, while C-organic of the soil increases (Olk et al., 1996). The application of bio-fertilizer significantly affects soil's C-organic content (Ramesh and Chandrasekaran, 2004).

According to Adiningsih and Rochyati (1988), there is positive correlation between the level of organic materials and the productivity of rice fields. The lower the level of organic material is, the lower the productivity will be. The findings of Kasno et al. (2003) on the 1548 samples of rice field soils from eight provinces in Indonesia show that 17% contains <1% C-organic, 28% contains 1 – 1.5% C-organic, 20% contains 1.5 – 2% C-organic, and only 34% contains >2% C-organic. This data implies that the content of C-organic in rice fields in Indonesia is relatively low; less than 2%. Based on the indicator of soil health, rice fields with less than 2% C-organic content belong to the category of unhealthy (Simarmata, 2007; Liul et al., 2006). On unhealthy soil, increasing the dosage of fertilizer will not result real improvements. To restore the health of the soil, it needs the increased use of bio-fertilizer, administered *in situ*. One of the potential sources of organic material is rice straws; which has been proven more effective than straw burning (Eagle et al., 2000). Regression model indicates that allowing grass/weed to grow and administering organic materials in soil will increase the level of soil's organic materials content; which significantly improves the production (Pulleman et al., 2000).

Attempts to remediate the health and fertility of rice fields can be carried out by utilizing straw compost and biofertilizers that are adaptive to the rice field ecosystem. The application of microbe-containing biofertilizer has shown to be effective in increasing plant's growth and improving soil's fertility (Wu et al., 2005).

The application of N-tethering biofertilizer such as *Azotobacter* sp. and *Azospirillum* sp. is able to decrease the application of Urea, to prevent the decrease in soil's organic materials, and to decrease the level of pollution. These reasons make the application of N-tethering biofertilizer worthy to be considered for rice fields environment.

Azotobacter sp. and *Azospirillum*sp. are heterotroph bacteria that live freely and need organic materials as their sources of energy. These bacteria perform nitrogen tethering activity so that it requires organic materials administration in this study. Gholami et al. (2009) reported that innoculation of *Pseudomonas, Azospirillum* and*Azotobacter*strains affects the height and width of the leaves in the innoculated plants. In addition, *Azotobacter* sp. and *Azospirillum* sp. are aerob bacteria; which means that oxygen supply needs to be regulated through water management. Organic fertilizer that is easy to access and appropriate to apply in rice fields is rice straws.

The study of Danapriatna *et al*. (2010) has succeded to isolate the prominent strain of *Azotobacter chroococcum* and *Azospirillum irakense* from the rhizosphere of rice plants in rice fields. The findings of the series of their study indicate that the application of *Azospirillum* and *Azotobacter* innoculant, both individually and in compound, increases the population of the two bacteria, total N in the soil and N-absorption of plants, total tillers, biomass, and N-absorption of rice planted in spate irrigation system. The application of innoculants promotes the increase in productivity (harvest) of rice in spate irrigation and flooded (inundation) irrigation systems. This indicates that both bacteria can be developed for rice plants.

Gholami et al (2009) reported that the improvement or remediation of plant's growth with innoculation of bacteria is due to the tethering of N_2, phosphate solution capacity. Burd et al. (2000) reported that rhizobacteria contributes to the increase in plant's height and productivity because it affects the growth hormone development and the increase of minerals availability. It also facilitates mineral absorption and decreases heavy metal toxicity in plants.

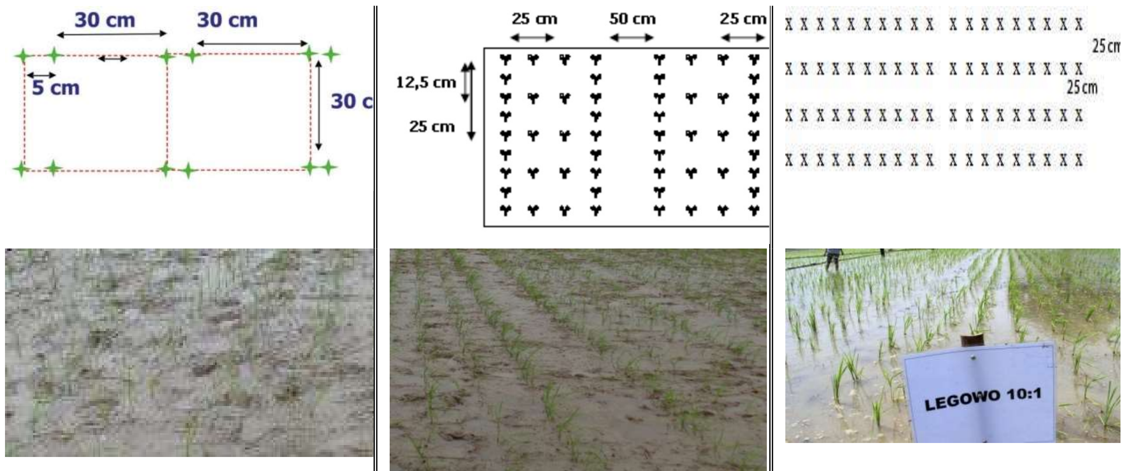
The ecosystem of rice fields is unique because there are two different ecosystems; the aerob and the anaerob (Yu et al., 2007). Inundated (flooded) rice fields have aerob layer around the top of the root, near the surface of the soil, and anaerob layer underneath (Kyuma, 1995). The oxidative layer is usually between 2 and 20 mm thick, depending on the amount of O_2 dissolved in the inundation water, the soil's reduction capacity (the level of C-organic in the soil), and water. According to Hardjowigeno and Rayes (2005), inundation water is a photic aerobic environment with positive redox potentials when Fe^{3+}, SO^2 and CO_2 are stable and the aerobic bacteria become dominant. *Azotobacter* and *Azospirillum* bacteria depend on oxygen and organic materials in performing their activities. It means that in the condition of flooded rice field, both bacteria can still grow and actively tether N from the air.

In line with organic farming development, the high prices of chemical fertilizers, and the increased awareness of farmers on the dangers of chemical substances, the use of organic fertilizers and biofertilizers has greater opportunities (Sentana, 2010; Simarmata et al., 2012). The application of biofertilizers, which generally contains microbes, often requires aerob soil (high oxygen content). Therefore, the application of biofertilizers is more common among the farmers in SRI (System of Rice Intensification) rice fields and n the Organic-based Controlled Aerob Rice Intensification (IPAT-BO). In the SRI system, according to Anugrah et. al. (2008), water level is maintained in moist state (using spate irrigation). It is the same with IPAT-BO system which, according to Simarmata (2008), depends on the ecology change of soil from inundated (anaerob) into non-inundated (aerob). However, most of the farmers in Bekasi still implement the conventional irrigation method (inundated/flooded irrigation) for their rice fields, with rice production of 4.91 tons ha^{-1} in average in 2012 (BPS Kabupaten Bekasi, 2013). This condition warrants a study concerning the effect of biofertilizer and straws compost application in flooded irrigation (as commonly used by farmers) and in spate irrigation on the increase of rice production. The study aims to discover the effect of N-tethering biofertilizer (*Azotobacter* and *Azospirillum*) and straws compost applications on the content of C-organic, the available N, P, and K of the soil, the concentration of N, P, and K of the plant and the rice production in two systems of water management; flooded (local tradition) and controlled aerob (spate irrigation) systems.

RESEARCH METHODOLOGY

The biofertilizer used in this study is N-tethering biofertilizer containing *Azotobacter chroococcum* ND 9.3 and *Azospirillum irakense* ND14 (Danapriatna, 2012). The formulation of biofertilizer in powdered form is in line with the findings of Danapriatna and Simarmata (2011).

The study was carried out for five months, May to September 2015. The experiment was performed in rice fields of farmers in Sukakarya, Bekasi, using field research design. Each rice field is ± 500 m^2in area. The treatments are (a) application of biofertilizer + straw compost +2/3 measure of N-fertilizer, controlled aerob water management, IPAT plant system; (b) application of biofertilizer + straw compost + 2/3 measure of N-fertilizer, water management as commonly used by local farmers, plant system of type 2 legowo 4:1; and (c) fertilizing as recommended by local practice, water management and plant system as commonly practiced by local farmers (legowo 10:1)



IPAT Plant System	Type 2 Legowo 4:1 Plant System	Legowo 10 : 1 Plant System

Figure 1. Plant systems and planting distances in the study

When the plant achieved the active vegetative growth phase (60 HST), soil sample and plant sample were taken from five sample points in each field for soil and plant analysis. The unhulled rice harvest in five plots of 2.5m^2 for each field was measured at the physiological maturity phase by weighing the harvest.

The response variables examined in each unit of experiment are:

(1) mineral (nutrients) content and chemical and biological nature of the soil at the final vegetative phase, consists of available N, P, and K; (2) N content of plant in final vegetative phase, based on the analysis of N, P, and K in plant's tissue; (3) products (harvested dried unhulled rice) and components of rice products (total seeds per clump and weight of 1000 seeds) per field during harvest.

To support the discussion of response, visual observations on plant's vigor were performed during the growth period. The univariate variance analysis was conducted to discover the effect of each treatment on all response variables. To test the difference of treatment effect on each response variable, LSD test on 5% level was carried out (Gomez and Gomez, 1995). Statistical analysis was performed using statistic processing software SPSS 20.

To measure the effectiveness of biofertilizer and straws compost application, relative agronomic effectiveness (RAE) measurement is performed. The standard value of RAE equals 100% and alternative fertilizer is considered more effective than the standard if its RAE is >100% (Directorate of Fertilizer and Pesticides, 2011).

FINDINGS AND DISCUSSION

Rice fields provide direct and indirect benefits to the society. The direct benefit is the rice as source of food. The indirect benefit includes straws which can be used to improve soil organic materials, particularly C-organic material. C-organic as the result of straws immersing is acceptable as reliable alternative to strengthen food security and mitigate greenhouse gas in the farming area (Pan et al, 2009).

Long term study indicates that continuous agricultural planting may cause the decrease in soil's C-organic, although the rate and level of the decrease depend on climate and the soil. It can be improved or remediated through the practice of smart soil cultivation (Reeves, 1977). Straws as agricultural waste are highly useful for farmers. According to Bird et al. (2001), straws as agricultural waste can be highly useful if incorporated to the soil along with N-fertilizers on the surface (0 – 15 cm depth). However, this resource has not been utilized correctly by local farmers. Therefore, utilizing straws is very important in soil management (cultivation) to improve soil quality (Reeves, 1977).

High quality soil is a necessary foundation of sustainable agricultural development. Doran et al. (1994) stressed that sustainable agricultural practice should focus on holistic management approach to optimize the functions of soil, soil conservation, and soil quality and health improvement. Furthermore, Doran (2002) defined sustainable agricultural as agricultural practices that can sustain farmers and land conservation.

N, P, K, and C-organic Content of Soil

Application of 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} of straws compost, and plant system significantly improve N, K, and C-organic content of soil. This is in line with the findings of Liul et al. (2006) that fertilizer application, combined with green fertilizer (bio-fertilizer), can improve soil's mineral content and C-organic. Meanwhile, the applications of 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} straws compost, and plant system do not have significant effect on P content variable (Table 1).

Table 1. Effects of biofertilizer applications and plant systems on soil's N, P, K, and C-organic content

Treatment	N (%)	P (ppm)	K (ppm)	C-org (%)
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, controlled aerob water management, IPAT plant system	0.188 b	36.02 a	142.06 b	2.324 b
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, local farmers' traditional water	0.188 b	30.52 a	134.88 ab	2.256 ab

management (flooded irrigation), type 2 legowo 4:1 plant system				
Fertilizer application as recommended by local farmers, water management as commonly used by local farmers (flooded irrigation), 10:1 legowo plant system	0.134 a	29.66 a	123.92 a	2.096 a
LSD 0.05	0.045	8.684	12.960	0.169

Note: numbers followed by the same small letters in a column indicates no significant differences based on LSD test with significant level of 5%.

Application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost improves N content of the soil in IPAT plant system and type 2 legowo 4:1 plant system to 40% compared to the fields using local farmers' recommendation of fertilizing, flooded water management, and legowo 10:1 plant system (local farmers' conventional system). The same thing also occurs on soil's K content variable that increases 61% and 37%, respectively, on application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost in IPAT plant system and type 2 legowo 4:1 plant system; compared to the fields using local farmers' recommendation of fertilizing, flooded water management, and legowo 10:1 plant system (local farmers' conventional system). Soil's C-organic content increases 11% and 8%, respectively, on application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost in IPAT plant system and type 2 legowo 4:1 plant system; compared to the fields using local farmers' recommendation of fertilizing, flooded water management, and legowo 10:1 plant system (local farmers' conventional system).

The increase of N, K, and C-organic content of soil in the application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost, both in IPAT plant system and type 2 legowo 4:1 plant system, is due to the increase of nitrogen from the activities of N-tethering bacteria contained in biofertilizer and the increase of N from straws decomposition process. In addition, straws compost also contributes to the increase of potassium (K) and C-organic. This is in line with the findings of Adiningsih (1988) and Nursyamsi et al (1997) that reported that straws immersion to the soil can improve C-Organic, K, CEC, K-absorption, and rice field production. Indriyati et al (2007) found that straws immersion in rice field can increase the activity of nitrogenase enzyme to tether N_2, which will be the source of N to be used by paddy (rice plant) in the generative growth phase. *Azotobacter* and *Azospirillum* bacteria from biofertilizer will actively tether N with energy source from the straws compost incorporated in the rice field. The increase of available N in the soil will increase the population of *Azotobacter* and *Azospirillum*; which in turn will increase the activity of N-tethering. This is in line with the findings of Danapriatna et al (2010) that the application of *Azospirillum* and *Azotobacter* inoculants, both individually and in compound, can increase the population of both bacteria. Hussain et al (1993) reported that the application of N-fertilizer and organic fertilizer improves *Azotobacter* effectiveness in tethering.

The amount of straws biomass made into compost is 2 tons ha^{-1}, which significantly improve the soil's C-organic. If the treatment of compost incorporation is carried out in every planting season, it has great opportunities to accumulatively improve soil's C-organic and achieve soil's health level up to 3%.

The findings of this study show the importance of changing the farmers' behaviors in utilizing straws. The farmers usually burn the straws, which brings the risk of greenhouse gas emission increase, particularly CO_2. With little additional funding to produce the compost, they can utilize straws waste to improve soil's health. In addition, it will also save some money for fertilizer. Meanwhile, increasing C-organic of soil can only be done by administering biomass compost.

N, P, and K contents of plants

Application of 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} of straws compost, and plant system significantly improve N and K contents of plants. The application does not have significant effect on plant's P contents variable (Table 2).

Table 2. Effects of biofertilizer applications and plant systems on plant's N, P, and K content

Treatment	N (%)	P (%)	K (%)
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, controlled aerob water management, IPAT plant system	1.696 b	0.27 a	2.002 b
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, local farmers' traditional water management (flooded irrigation), type 2 legowo 4:1 plant system	1.614 ab	0.258 a	1.948 ab
Fertilizer application as recommended by local farmers, water management as commonly used by local farmers (flooded irrigation), 10:1 legowo plant system	1.42 a	0.248 a	1.814 a
LSD 0.05	0.215	0.029	0.139

Note: numbers followed by the same small letters in a column indicates no significant differences based on LSD test with significant level of 5%.

N content of plants increased by 19.4% and 13.7% respectively on the application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost in IPAT plant system and type 2 legowo 4:1 plant system; compared to the fields using local farmers' recommendation of fertilizing, flooded water management, and legowo 10:1 plant system (local farmers' conventional system). The difference in water management affects oxygen content in the soil, while oxygen plays important role of oxidizing organic materials (Olk et al, 1996). IPAT plant system with spate irrigation contains more oxygen than the conventional water management system (flooded irrigation).

Similar thing occurs to K content, increasing 10.4% and 7.4% respectively on the application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost in IPAT plant system and type 2 legowo 4:1 plant system; compared to the fields using local farmers' recommendation of fertilizing, flooded water management, and legowo 10:1 plant system (local farmers' conventional system).

The increase in N content on the application of biofertilizer and straws compost is due to the contributed N from bacterial tethering of the biofertilizer and the process of straws decomposition. As Danapriatna (2012[a]) stated, *Azospirillum* and *Azotobacter* bacteria from biofertilizer can tether N from the air and made it available for the plants. The increase in N content of the plants occurs because the N content of the soil increases (Table 1). In addition, microbes from biofertilizer, i. e. *A. chroococcum* ND 9.3 and *A. irakense* ND 14, are able to produce cytokine, gibberellins, and IAA growth hormones (Danapriatna, 2012) which can stimulate the growth of roots to increase the ability to absorb nitrogen from the soil.

The increase of K content in plants on the application of biofertilizer and straws compost is due to the addition of available K from straws decomposition. As fertilizer, straws are not effective and not efficient as sources of N and P minerals; but they are effective as the source of K and C (Makarim et al, 2007). The more K is available in the soil, the easier for plants to obtain it. The lack of K will contribute to the low response of N and the low amount of harvest (Eagle et al. 2000).

Products and Products' Components

Application of 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} straws compost and plant system significantly increase the amount of productive tillers and the dried un-hulled rice production. It has no significant effect on the variable of 1000 seeds' weight (Table 3).

Table 3. Effect of the application of biofertilizers and plant systems on the production and products' components

Treatment	Amount of productive tillers	Weight of 1000 seeds (g)	Production (ton/ha)
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, controlled aerob water management, IPAT plant system	32 b	28.2 a	10.84 b
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, local farmers' traditional water management (flooded irrigation), type 2 legowo 4:1 plant system	30 b	27.82 a	10.36 b
Fertilizer application as recommended by local farmers, water management as commonly used by local farmers (flooded irrigation), 10:1 legowo plant system	26 a	27.78 a	8.64 a
LSD 0.05	3	0.50	1.07

Note: numbers followed by the same small letters in a column indicates no significant differences based on LSD test with significant level of 5%.

The amount of productive tillers increases by 23.1% and 13.8% respectively on the plants that are applied 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} straws compost on the IPAT plant system and the type 2 legowo 4:1 plant system; compared with the fertilizer application as recommended by local farmers, flooded water management, and legowo 10:1 plant system (local farmers' conventional method).

The dried unhulled rice harvest increases by 25.5% and 19.9% respectively due to the application of 400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} straws compost on the IPAT plant system and the type 2 legowo 4:1 plant system; compared with the fertilizer application as recommended by local farmers, flooded water management, and legowo 10:1 plant system (local farmers' conventional method). The increase is because the plants' mineral needs are satisfied, mostly from the activity of biofertilizer and straws compost. Straws compost contains a lot of C-organic (around 30-40%), and complete minerals, including 1,5–2,0 % N, 15–24 % C, 1,5–2,0 % K, 2,0–3,0 % P, 1,5–2,0 % Ca, 0,5 % Mg and other nutrients lain (Simarmata and Yuwariah*,* 2008).

The findings of this study is in line with the findings of Danapriatna et al (2012[a,b]) that the application of 400 g ha^{-1} N-tethering biofertilizer (*Azotobacter* and *Azospirillum*) and 2 tons $^{ha-1}$ straws compost with IPAT-BO technology can revitalize soil's health, as indicated by the increase of C-organic to more than 2% and the increase in population and increase of bacteria, resulting in the increase in dried unhulled rice harvest by 4%.

Relative agronomic effectiveness (RAE) of the plants treated with biofertilizer and straws compost (400 g ha^{-1} N-tethering biofertilizer, 2 tons ha^{-1} straws compost) on the IPAT plant system and the type 2 legowo 4:1 plant system scored 152.1% and 140.7%, respectively (table 4). It means that the production of dried unhulled rice of the plants treated with the fertilizer is higher than that of the plants treated with fertilizers recommended by local farmers, flooded water management, and legowo 10:1 plant system (local farmers' conventional method).

Table 4. Effects of the application of biofertilizer and plant systems on the agronomic effectiveness and production increase

Treatment	Relative Agronomic Effectiveness (%)	Production increase (%)
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, controlled aerob water management, IPAT plant system	152.1	25.5
Application of 400 g ha^{-1} biofertilizer + 2 tons ha^{-1} straws compost + 2/3 measure of N, local farmers' traditional water management (flooded irrigation), type 2 legowo 4:1 plant system	140.7	19.9

Fertilizer application as recommended by local farmers, water management as commonly used by local farmers (flooded irrigation), 10:1 legowo plant system	100.0	0

This study can provide solution to various environmental problems, including the scarcity of water resource, the increase of greenhouse gas emission, and the increase of food needs. The innovation of technology and farmers' changes of behavior can contribute to solve these problems.

Controlled aerob water management applied in IPAT plant system is one of the solution in an area with limited water supply. The application of biofertilizer combined with straws compost is an innovation to improve soil's health and to decrease the dependency on anorganic fertilizer, as well as to reduce the emission of greenhouse gas (Liul et al, 2006).

On the other hand, another significant benefit of this treatment is the increase in agricultural output to solve the problems of food supply. The increase in agricultural output from this treatment is 19.9 – 25.5%.

CONCLUSION

The application of 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost on IPAT plant system with spate irrigation and on the type 2 legowo 4:1 system with flooded water management increases soil's N and K contents, plants' N and K contents, productive tillers and dried unhulled rice production, as well as the net income of farmers. Farmers that applied 400 g ha^{-1} N-tethering biofertilizer and 2 tons ha^{-1} straws compost on IPAT plant system and on the type 2 legowo 4:1 plant system achieved up to 10.84 and 10.36 tons ha^{-1}, respectively.

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