

Managing of Organic-Biofertilizers Nutrient Based and Water Saving Technology for Restoring the Soil Health and Enhancing the Sustainability of Rice Production in Indonesia

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Abstract. The effort to secure the sustainability of rice productivity is one of the main priority in providing enough food for rapidly growing population in Indonesia. Meanwhile, intensive use of agrochemicals fertilizers since the adoption of green revolution not only has boosted food production significantly but also accelerated to the soil health degradation. The intensive research has been done to develop of biofertilizers as consortia of inoculants (*Azotobacter sp.*, *Azospirillum sp.*, *Pseudomonas sp.*, *Bacillus sp.*, and *Acinetobacter sp.*). The formulated biotrilizers combined with water saving technology were implemented as an integrated organic-biofertilizers based of nutrients management and water saving technology, known as "IPATBO". Two young single rice seedling were planted at 30x35 cm, fertilized with 2-5 ton ha⁻¹ of organic ameliorant, and 500-1000 g of biofertilizers inoculant. The summarized field results from 2007-2018 at different locations in revealed that (1) the efficiency of water irrigation uses was increased by 35 %, (2) twin seedling planting technique of IPATBO increased the rice grain yield by 20-30 % compare to conventional methods, (3) application of 2-5 tons ha⁻¹ of organic ameliorant reduced the application inorganic fertilizers by 25-50 %, improved the soils health and increased the rice productivity significantly. The obtained rice grain yield ranged from 6-11 t ha⁻¹ was increased by 50-200 %. Briefly, IPATBO has a great prospect to increase the productivity from 5-6 to 6-8 tons ha⁻¹ of rice grain yield and to improve the sustainability of food security in Indonesia.

Keywords: nutrient management, soil health, biofertilizer, IPATBO, water saving

1. Introduction

The nutrient and soil health management of paddy soils play an important role in securing the sustainability of rice production as the main staple foods in Indonesia. The agricultural practices are force to increase the production to meet the food requirement of rapidly growing population. The Indonesian population in 2018 is about 265 million and expected to reach 480 million by the year of 2050 (Simarmata *et al.*, 2017; BPS, 2018). Consequently, the agriculture and the use of agrochemical are to become more intensive to boost the food production and productivity (Simarmata *et al.*, 2012). The need and application on inorganic fertilizers are increasing continually. The adoption of a technology package comprising improved high-yielding varieties of rice, irrigation or controlled water supply, improved moisture utilization, fertilizers and pesticides, and associated management skills has been increased sharply from



2.5 tons/ha in the 1960-1970s to 5-6 ton ha⁻¹2015 (Panujuet *et al.*, 2013, Simarmata *et al.*, 2017). Meanwhile, the intensive and heavy use of inorganic fertilizers has effected the environmental pollution and accelerated degradation of soil quality and soil (Simarmata *et al.*, 2012).

Recent study indicated that mostly of paddy soils (lowland rice irrigation) and dry ecosystems in Indonesia has been degraded and exhausted due to intensive agricultural practices and over mining of essential nutrient. About 70% of paddy soils has a low organic carbon (less than 1.5%) and about 90% of dry land has belong to sick soils (low organic carbon and high acidity) (Simarmata *et al.*, 2011; Simarmata *et al.*, 2017). Consequently, the need of organic fertilizers and other organic ameliorants are highly important to improve the soils health and quality (Simarmata *et al.*, 2017; Sudjana *et al.*, 2017). The locally available organic ameliorant (straw compost, biochar) as low external input of sustainable agriculture (LEISA) can be applied to remediate the soil health, increase the efficiency of fertilizers, and crop rice productivity. Straw compost not only is rich in energy (carbon) but also has the relative nutrient contents, especially potassium and silicon. The key success of rice cultivation depends on soil organic matter management for maintaining the carbon level in the soil. The rice straw is composted by using consortia of decomposer (*Streptomyces sp.*, *Trichoderma sp.*, *Cytophaga sp.*, *Pseudomonas sp.*, and *Bacillus sp.*) to accelerate the composting process to control the potential pathogen in straw and to produced bioaugmented compost, known as bioameliorant (Simarmata *et al.*, 2017). In addition, biofertilizers as bioresources is low cost eco-friendly and renewable sources of plant nutrients which supplement chemical fertilizers. Biofertilizers provide not only the main nutrient but also (a) produce a certain growth promoting substances like hormones, vitamins, amino acids, etc., (b) it has a residual effect on subsequent crops, (c) it improve the soil quality and plant health and (d) has nearly negative impact on environment (environmentally friendly fertilizers) (Singh and Purohit, 2011; Simarmata, 2013; Simarmata *et al.*, 2017; Ghany, *et al.*, 2013; Bhattacharjee and Dey, 2014). Application of biofertilizers can increase the yield by about 25–50 % and reduce the application inorganic fertilizers until 25–50 % for nitrogen and about 25 % for phosphor nutrient (Hayat *et al.*, 2014; Simarmata, 2013; Board, 2012; Ghany *et al.*, 2013; Purwanto *et al.*, 2017).

Application ameliorant and consortia of beneficial rhizobacteria (biofertilizers) combined system of organic based aerobic rice intensification (SOBARI), well known as IPATBO in Indonesia and categorized as water saving technology. The main focus of IPATBO are (1) the use of locally available organic material and other bioresources to restore or to remediate the soil health and soil quality, (2) efficient use of water by adopting the intermittent irrigation system, (3) efficient use of nutrient by adopting the integrated organic-biofertilizers nutrient management to enhance the fertilizers efficiency and to reduce the application of inorganic fertilizers, and (4) to improve and increase the rice productivity in sustainable ways (Simarmata *et al.*, 2012). The summarized of IPATBO results revealed that the application of 2-5 ton of ameliorant (straw compost and biochar) and 500-1000 g of microbial fertilizers (biofertilizers inoculant) has increased of water irrigation by 30-40 %, fertilizer efficiency and the soils health and the rice productivity significantly (Turmuktini *et al.*, 2012; Simarmata *et al.*, 2011; Simarmata *et al.*, 2018). Briefly, adoption and dissemination of integrated organic-biofertilizers nutrient management combined with water saving technology are expected to be one of solution for improving or restoring the soil health, the fertilizers efficiency and enhancing the rice productivity to secure the food availability in sustainable ways.

2. Material and methods

The technology of IPATBO has been adopted and disseminated since 2007 at different area and provinces in Indonesia. The size of rice fields as demo plot were mostly about one ha. The best practises that widely adopted are as follows; after land cultivation and preparation, the drainage canal (20 cm wide and 10 cm depth) were provided each 4 m distance within the plots to manage the water height or depth. Moreover, the drainage canals were also provided surrounding the plots to allow the controlling the water excess (Simarmata *et al.*, 2011). The composted rice straw or fermented organic compost as bioameliorant were applied during land preparation. Young seedlings (12 – 15 days) is planted with plant spacing about 30 x 30 cm or 30 x 35 cm. A single seedling is planted in twin methods (two single seedlings is planted in line about 5 cm distance from each other at point of planting cross section (Figure 1). The seedling is planted by slipping in sideways rather than plunging it into the soil vertically 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 (Simarmata *et al.*, 2011). The water saving technology was adopted to allow rice roots growing properly and to stimulate the growing of soil organisms and as well as its biodiversity. In general, the rice field are maintain in muddy condition and rice field were irrigated up to 1-2 cm high if the water gauge indicated the yellow color as shown in Figure 2 (Turmuktini *et al.*, 2012; Antralina *et al.*, 2015).

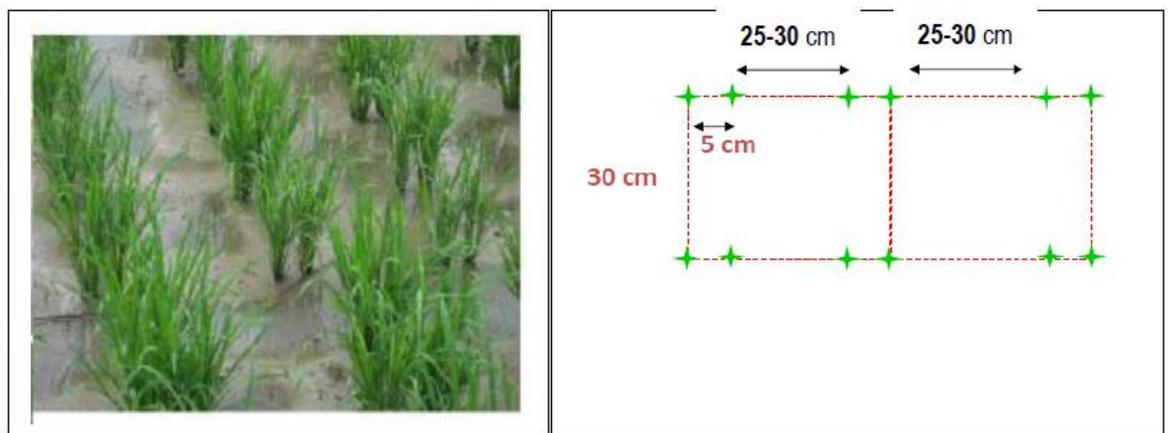


Figure 1. The twin seedling methods of IPABO (two single seedlings with 5 cm distance are planted on the cross section of planting space (30 x 30 cm or 30 x 35 cm) (Simarmata *et al.*, 2011)

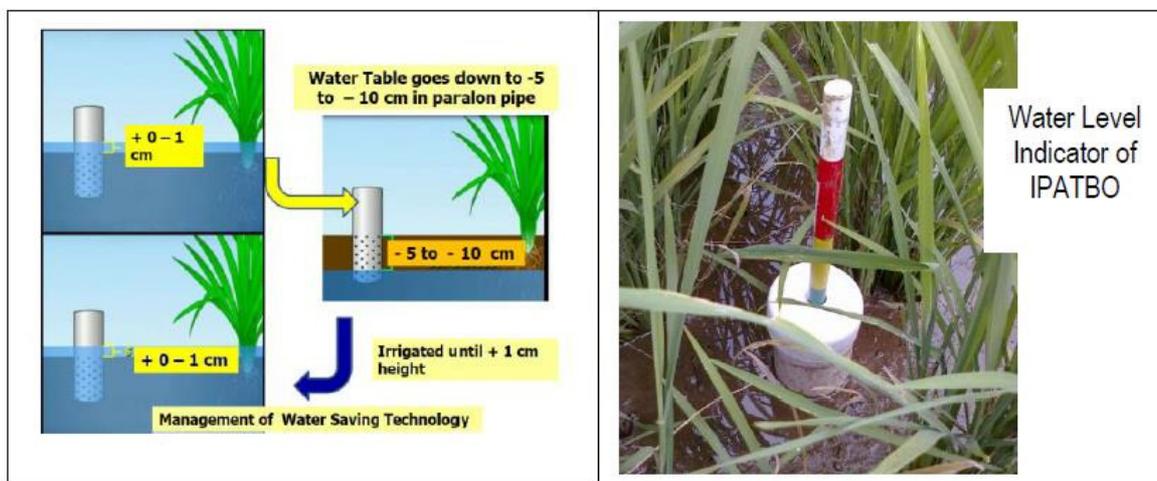


Figure 2. Water saving technology using water level indicator for irrigating the rice fields (Anthralina *et al.*, 2015; Simarmata *et al.*, 2011)

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. The integrated fertilizers management as described are divide in 3 steps, as follows: (1) basic fertilizers is applied shortly before transplanting, consisted of 2–3 ton/ha straw compost, 400-1000 g of rhizobacteria inoculant with the population density ranged 10^8 - 10^9 cfu/g/bacteria (*Azotobacter sp.*, *Azospirillum sp.*, *Pseudomonas sp.*, *Bacillus sp.*, and *Acinetobacter sp.*) (Simarmata *et al.*, 2011; Simarmata *et al.*, 2018). In addition, the Rhizobacteria inoculant was applied about 200 g/ha as seed treatments shortly after seed soaking (10 g of inoculant were mixed carefully with a kg of rice seed) and nursery application about 400 g/ha¹ (combined with 50 kg urea, 50 kg SP-36 and 25 kg KCl or 50 kg urea and 100 kg NPK), (2) 100kg applies at 18 – 21 days after transplanting or after weeding, (3) finally, 50 – 100 kg urea and 25 – 50 kg KCl per hectare or 50 kg urea and 50 - 100 kg NPK are applied at 35 – 38 days after transplanting. Leaf Color Chart (LCC) can be used to monitor the nutrient conditions and to determine the N rate.

3. Results and discussion

The field results from 2007-2018 in several Provinces or districts revealed that the adoption of IPATBO with various rice variety under different planting season has resulted 40 – 60 tillers/clump plant, 150 – 250 grains per panicle and rice grain yield range 8-10 ton/ha (Simarmata *et al.*, 2011; Simarmata *et al.*, 2018). The rice growth (number of tiller and plant height) of IPATBO plots were significantly higher than conventional methods (Table 1).

Table 1. Plant growth (number of tillers and plant height) of IPATBO compared to conventional methods (Ministry of Research and Higher Education, 2017; Simarmata *et al.*, 2017)

Plant Growth	Parameters	IPATBO	Conventional	Increment (%)
< 30 Days	Tillers Number (Tiller/Seedling)	10	-	
	Tillers Number (Tiller/Clump)	23	15	53.3
	Plant Height (cm)	65	30	216.7
30-45 Days	Tillers Number (Tiller/Seedling)	21	-	
	Tiller Number (Tiller/Clump)	41	25	64
	Plant Height (cm)	85	50	79
>45 Days	Tiller Number (Tiller/Seedling)	22	-	
	Tiller Number (Tiller/Clump)	43	30	43
	Plant Height (cm)	91	70	30

The obtained grain yield ranged from 4.4 to 10.9 ton ha⁻¹ (average yield about 8.24 ton ha⁻¹) of 22 demo plots in South Sulawesi (planting season April-August 2017) confirmed the obtained yield as mentioned above. These results are in line with the obtained rice grain yield (ranged 6.5-9.6 ton ha⁻¹) in 2018 in different area in Sumatera, Java and Bali island (Table 2). The summarized of obtained grain rice yield were increased 25–200% compared to traditionally flooded of rice cultivation. Briefly, the rice productivity was increased by at least 25% compare to the conventional methods.

Table 2. The field result of IPATBO in different location in Indonesia (Simarmata *et al.*, 2011; Ministry of Research and Higher Education, 2017; Simarmata *et al.*, 2018).

Year	Different Districts of Several Provinces	Grain Yield (ton/ha)	Increment compare to Conventional Methods
2007-2015	West Java, East Java, Central Java, South Sulawesi, North Sulawesi, North Sumatera, Banten, Bali, NTT etc	7.0-11.0	50-200 %
2016-2017-	South Sulawesi (22 District), West Java (Cianjur, Ciamis, Karawang, Garut), North Sumatera (Samosir, Binjai, Deli Serdang), etc.	6.0 -10.4	25-100 %
2018	North Sumatera (District of Binjai, Langkat, and Deli serdang), East Java	6.5-9.6	25-50 %

	(Jejara, Nganjuk), Bali (Buleleng)		
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In addition, application of 2-5 ton of compost straw combined with the application of 400-1000 g of biofertilizers has increased the soil health, the rice yield and reduced the inorganic fertilizers by at least 25% (Simarmata *et al.*, 2011, Simarmata *et al.*, 2012; Simarmata *et al.*, 2018). The chemical properties (total carbon, CEC and others nutrient status) and biodiversity of soil microbes (total bacterial population, nitrogen fixer and phosphate solubilize bacteria) were significantly increased by the application of organic ameliorant (straw compost and biochar). More over the water irrigation was reduced about 30-40% compared to conventionally methods or permanently flooding technique (Turmuktini *et al.*, 2012; Simarmata *et al.*, 2012).

The improving of soil health, nutrients status and the biodiversity combined with the proper water and fertilizers management will contribute to growth and development of crops (Sharma,*et al.*, 2004; Hayat *et al.*, 10; Simarmata *et al.*, 2017). The application of composted straw increased the nutrient status, particularly the Si and K were increased significantly (Turmuktini *et al.*, 2012; Simarmata, *et al.*, 2017). The availability of soil organic carbon is highly correlated with the activity of rhizobacteria in rhizosphere (Kloepper, 1993, Vessey, 2003, Singh and Purohit, 2011, Nirajan *et al.*, 2005; Simarmata *et al.*, 2017).

4. Conclusion

Biofertilizers is a low cost, renewable sources of plant nutrients and environmentally friendly fertilizers that can be used to facilitate nutrients availability, improve and remediate the soil health to increase productivity of agricultural crops and to reduce the application inorganic fertilizers in sustainable ways. Application of 500-1000 g of biofertilizers and 2–5 ton ha⁻¹ of ameliorant (composted straw, biochar) as low input and ecofriendly fertilizers combined with water saving technology (IPATBO) could improve the soil organic carbon, reduce inorganic NPK fertilizer by at least 25% and increase the rice productivity significantly (obtained yield range 6-11 t ha⁻¹ or increment: 50-200 %). The adoption and dissemination of IPATBO technology are need to accelerate for increasing the rice productivity from 5-6 ton ha⁻¹ to 6-8 ton ha⁻¹ in sustainable ways

References

- Antralina, M., Yuyun Yuwariah, Y, dan T Simarmata. 2015. Effect of Difference Weed Control Methods to Yield of Lowland Rice in The SOBARI. *Procedia Food Science* 3 (2015) 323 – 329
- Bhattacharjee, R and U. Dey. 2014. Biofertilizers a way towards organic agriculture: A Review. *African Jour. Micro. Res.* Vol 8 (24): 2232-2342

- BPS, 2018. Bureau of Indonesian Statistic. <https://www.bps.go.id/>.
- Hayat. R., S. Ali, U.Amara, R. Khalid and I. Ahmed.2010. Soil beneficial bacteria and their role in plant growth promotion: a review. *Ann. Microbiol.* DOI 10.1007/s1321-010-0117-1.
- Kloepper, J.W., 1993, Plant growth-promoting rhizobacteria as biological control agents in *Soil microbial ecology-applications in agricultural and environmental management*. Metting, F.B. Jr. (ed.). Mercel Dekker, New York,pp 255-274
- Ministry of Research and Higher Education. 2017. Short Report and Evaluation of Demo Plots 22 District/City In South Sulawesi. (Laporan Singkat Pelaksanaan Monitoring dan Evaluasi ke 1 Bakti Teknologi Untuk Negeri Tanam padi Unggul di 24 Kab/Kota Provinsi Sulawesi Selatan Dalam Rangka Peringatan HAKTEKNAS ke 22 di Makasar. Dirjen Penguatan Inovasi Kemenristekdikti.2017
- Niranjan R.S., Shetty, H.S. and M.S. Reddy. 2005. Plant Growth-Promoting Rhizobacteria: Potential Green Alternative For Plant Productivity. In Z.A. Siddiqui (ed.), *PGPR: Biocontrol and Biofertilization*, 197-216. Springer, Dordrecht, The Netherlands. <http://www.ag.auburn.edu/enpl/faculty/Reddy/PDFs/39.pdf>
- Panuju, D.R., Nizuno, K and B.H. Trisasonoko. 2013. [The dynamics of rice production in Indonesia 1961–2009](#). *Journal of The Saudi Soc. of Agric. Sci.* vol 12 (1): 27-37
- Purwanto, Yuwariah Y, Sumadi and T. Simarmata. 2016. Nitrogenase activity and IAA production of indigenous diazotroph and its effect on rice seedling growth. *Journal of Agricultural Science*. 2017. 39(1): 31-37
- Sharma, R.A., Totawat, K.L. , Maloo S.R and L.L. Somani. 2004. *Biofertilizer technology*. Udaipur, Agrotech Publishing Academy. ISBN 81-85680-90-6.
- Simarmata, T, Benny Joy and Tien Turmuktini 2011. Water Saving and Organic Fertilizers Based Technology to Remediate the Health of Paddy Soils and to Increase Rice Productivity in Indonesia. Tropentag 2011, University of Bonn, October 5 - 7, 2011. Proceeding (Online) available at <http://www.tropentag.de/2011/abstracts/full/694.pdf>
- Simarmata, T.,Setiawati, M.R., Herdiantoro, D., Fitriatin, B.N., Turmuktini, T., Citraesmi, A. and B. Sudjana.2017.Dissemination of Beneficial Rhizobacteria and Bioameliorant Combined with Water Saving Technology (IPATBO) as Low Input of Integrated Bioertilizers Management to Enhance the Soils Health and Increase the Rice Productivity. Presented paper on the 9thInternational Seminar of Indonesian Society for Microbiology (ISISM 9), November 14th-15th 2017 in Palembang. https://drive.google.com/drive/folders/1afHfDggtt1Nr1l6Q1AyLb2xj2gKm_2uqz
- Simarmata, T. 2013. Tropical Bioresources to Support Biofertilizer Industry and Sustainable Agriculture In Indonesia. Invited and presented Paper for International Seminar on Tropical Bio-resources for Sustainable Bioindustry 2013; from Basic Research to Industry, 30 – 31st October 2013 in West and East Hall – ITB-Bandung-Indonesia. https://www.researchgate.net/profile/Tualar_Simarmata/publications/?linkType=fulltextFile&ev=prf_pubs_file
- Simarmata, T., Hersanti, Turmuktini, T, Fitriatin, B.N, Setiawati, M.R, and Purwanto. 2017. Application of Bioameliorant and Biofertilizers to Increase the Soil Health and Rice Productivity. *HAYATI Journal of Biosciences* 23 (2016): 181-184

- Simarmata, T., Setiawati, M.R, Herdiyantoro, D, Fitriatin, B.N dan D.H. Arief. 2018. Pengelolaan Lahan Sawah Berkelanjutan Berbasis Teknologi IPAT-BO dan Bioamelioran untuk Pemulihan Kesehatan Tanah dan Peningkatan Produksi Padi Dalam Mewujudkan Kedaulatan Pangan di Indonesia; In Eds: Sutyasti Sumitro Remi, Tarkus Suganda, Nurpilihan Baldan dan Warid Qosim. 2018. **Agrokompleks Menjawab Tantangan SDG^s**. Hal 150-165: Unpad Press. ISBN 975-702-438-376-2
- Simarmata, T., Tien Turmuktini, Anya Citraesmi and Benny Joy. **2012**. Biofertilizer and Straw Compost Management for Restoring the Paddy Soils Health and to Increase Rice Production In Indonesia. Proceeding of International Seminar Rice Innovation for Increasing Production and Conserving Environment under Global Climate Change July 11 – 12th, 2012 at Indonesian Center for Rice Research (ICRR), Sukamandi, Subang. West Java- Indonesia
- Singh, T and S.S. Purohit. 2011. Biofertilizers Technology. Agrobios (India).
- Sudjana, B, Jingga, A. and T. Simarmata. 2017. Enriched Rice Husk Biochar Ameliorant to Increase Crop Productivity on Typic Hapludults. Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 6(5), May, 2017 Issue.
- Turmuktini, T, Kantikowati, E., Fitriatin, B.N., Setiawati, M. Yuwariah, Y. Joy, B and dan T. Simarmata. 2012. 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”, Asian Journal of Agriculture and Rural Development, Vol. 2, No. 4, pp. 519 – 52
- Turmuktini, T, Kantikowati, E., Fitriatin, B.N., Setiawati, M. Yuwariah, Y. Joy, B and dan T. Simarmata. 2012 “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”, Asian Journal of Agriculture and Rural Development, Vol. 2, No. 4, pp. 519 - 526
- Vessey, J.K. 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil, 255:571-586