Review Article

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Black soldier fly liquid biofertilizer in Bunga Mayang sugarcane plantation: From experiment to policy implications

Abstract

Sugarcane is one of the most important cultivated plants for more than a millennial. In Indonesia, especially in Java, sugarcane is also a part of symbolic local culture. In fact, during the Dutch colonialism sugarcane had given substantial wealth to the Dutch and in the early 1930s the export revenue of sugar from Indonesia was the second largest in the world. The status of sugarcane now is still important for Indonesia even though Indonesian status now is one of the largest sugar importing countries in the world. One of major problems for such contradicting path of history is that the continuously lowering Indonesian productivity of sugarcane since the last 45 years. The main conventional choice for sugarcane productivity improvement is, among others, maintaining high dosage of chemical fertilizer. The choice of using high dosage chemical fertilizer such as urea, for example, is not only costly in term of monetary spending but also is costly in term of environmental costs such as water, air, and soil pollutions. In fact agriculture is classified as one of the most polluted sector. This article shares the results of the case study that has been conducted one year (2017-2018) in sugarcane plantation in Bunga Mayang, Lampung Province, Indonesia. The experiment took full recommended dosage application of inorganic N, P, K, fertilizer as experimental control. The results showed that there were no significantly difference in the productivity of sugarcane between the application of full dosage of inorganic N, P, K fertilizer and the half-dosage of inorganic N, P, K fertilizer in combination with 60 l per ha of Black Soldier Fly (BSF)'s liquid biofertilizer. The results implied very important implications for future research, new agricultural practices and new development policy agenda. One of the most important policy implications is how to build a circular economic structure between rural-urban regions where now food and other agricultural products flow from rural to urban regions and create food and other organic wastes in cities. In the next system the circular structure will create no-organic waste that will pollute cities and other areas but cities will become agriculture regional source of biofertilizer produced by BSF's biofertilizer industry which will fertilize the country sides environments.

Keywords: black soldier fly, bio fertilzer, sugarcane, productivity, agriculture, pollution

Volume 5 Issue 2 - 2020

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Received: April 23, 2020 | **Published:** April 30, 2020

Abbreviations: BSF, black soldier fly; SOEs, State owned enterprises; RBD, randomized block design; Cd, Cadmium

Introduction

In 2018 sugarcane plantations covered about 26.2 million hectares of the earth surface. Brazil contributed 38.27 percent or about 10 million hectare of the world's sugarcane plantations. Brazil is the top country by sugarcane area harvested in the world. Next to Brazil sugarcane plantation in 2018 was India, China, Thailand and Pakistan with the sugarcane plantations areas were 4.73 million hectares, 1.41 million hectares, 1.37 million hectares, 1.10 million hectares, respectively. Those 5 countries contributed about 18.61 million hectares or about 71 percent of the world sugarcane plantation. Indonesia was in the 11th rank of the world sugarcane countries measured by the land size were 416,671 hectares or only about 1.59 percent out of the world's sugarcane areas.[1]

By using a long term data perspective of world sugarcane, Indonesia's experience can be used as a source of lesson learned. In the era of earlier than the year of 1975 the sugarcane yield in Indonesia was the highest case of the sugarcane productivity in the world. It was around 130 ton per hectare up to almost 160 ton per hectares. The maximum attainable yield is about 155 ton per hectare (Figure 1). The recent average sugarcane productivity of Indonesia is around 60 to 70 ton per hectare.[2]

The declining productivity has caused the declining income from sugarcane farming and sugarcane based industry; and consequently causes the next problem to come namely farmers or planters were exit from sugarcane business; and sugar mills were closed down. Sugarcane production of PTPN VII (Bungamayang Sugar Factory) in the last three years showed that productivity of sugarcane have declined from 72.9ton/hectare in 2017 to 59.1ton/hectare in 2018 and finally reached the lowest one in 2019 namely only reached 49.8ton per hectare.[3] There will be no opportunity to continue sugarcane business without improvement in productivity. On the other hand, there will also be opportunity to reduce cost if productivity is increased. The big question, as usually applied in all industries, is how we can develop an innovation to create a new mode of production.

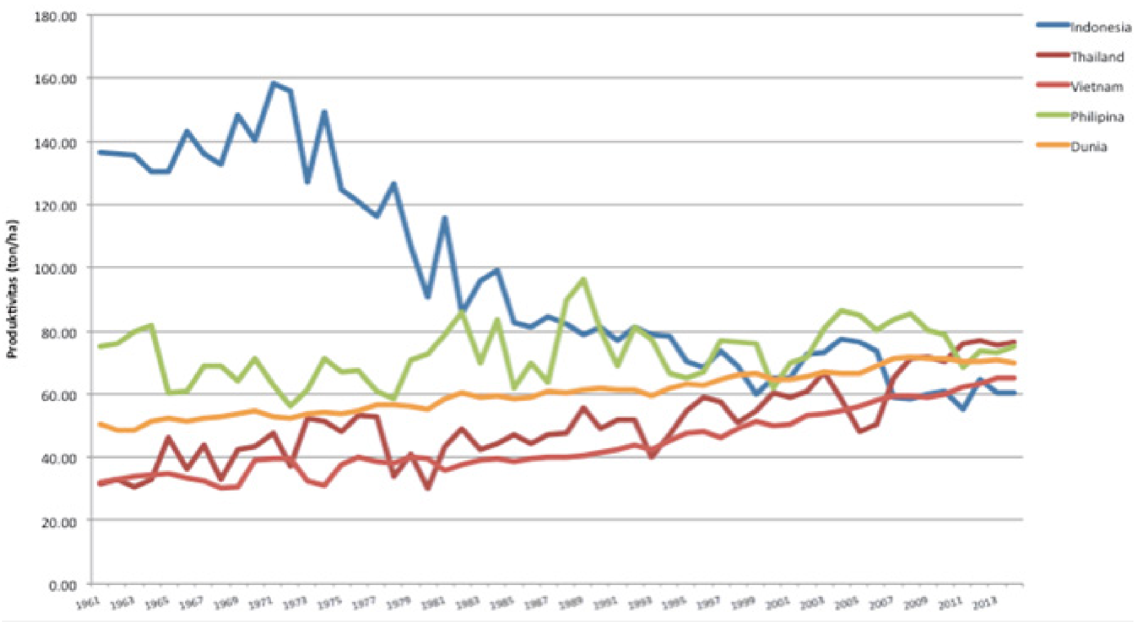

Figure 1 Long term trend of sugarcane yield by selected countries (AGI, 2016).

There are many areas which give possible opportunities to make an innovation. This article is only dealing with one aspect of innovation areas, namely the area of how reducing costs of production of sugarcane which is simultaneously reducing pollutions generated by chemical fertilizer. One of the most feasible opportunities that have been developed since decades is the use of biofertilizer.[4]

Even though there are variations in definition of biofertilizer among scientists, the essence is relatively the same, namely how microorganisms such as bacteria or fungi are used in agriculture for benefits of people, soil, plants and the environments as a whole. The practice of circular systems in agriculture had been actually as a practice of our ancestors in their closed systems of traditional agriculture. However, because of dynamics of economic and demographical factors in associations with the development of science and technology through industrial revolution in the 19th century the cycles of plants and animals raised by people were discontinued. The old systems have been replaced by the new ones.

The one which has produced the unimaginable impact was the innovation of urea by Haber and Bosch.[4,5] They invented a process of tapping Nitrogen from the atmosphere and converted to urea and other chemical elements which used to fertilize agriculture. The production of reactive Nitrogen (Nr) has been responsible for increasing food production that spur the world population from less than 2 billion people in 1900 to more than 7 billion people now. In order to feed more or less 9 billion people globally experts estimated that the food production must be increased by 70percent of present production.[5] It means the world should produce almost twice of food production given the land resources availability relatively constant.

When one uses price as an indicator of scarcity then by using 100 years or more time series data since 1900, one will reach conclusion that there has been no scarcity of resources. It means that the trend of agricultural prices has been declining over time. The rate of declining of agricultural real price was about -1.0percent per annum (Figure 1).[6] If one also uses a price forecast from 2020 to 2030 made by the World Bank such as published in Pink Data,[7] the conclusion would also be relatively the same since the trend of the real price of agricultural products will be relatively constant.

A closer look to fertilizer price data forecasted by the World Bank, the World Bank found that at the constant price of urea, the price will slightly decline from US $239per ton in 2020 to US $238 per ton in 2030. Within that time period the real price of TSP was forecasted slightly increasing from US $287 per ton to US $302 per ton (increasing by 0.5percent per annum); Potassium Chloride will increase from US $246 per ton to US $254 per ton (increasing by 0.3percent per annum); Phosphate Rock will increase from US $87 per ton to US $99 per ton (increasing by 1.4percent per annum); and DAP price will increase from US $307 per ton to US $358 (increasing by 1.6 percent per annum).[8]

The World Bank forecasted sugar price by 2030 will be about US $0.38 per kg, increase from US $0.29 per kg in 2020, increasing about 2.4percent per annum. Compared to declining price of urea which was predicted will be declining at the rate of -0.4percent per annum. By assuming the other factors remain constant (*ceteris paribus*) then the demand for urea will be increasing because the price of urea is declining but sugar price is still increasing. The increasing trend of demand for fertilizer, especially urea will be predictably increasing because the real price of agricultural commodity will be increasing relative to the price of urea.

The future problem that will be faced is not the problem directly with food and agricultural products market prices but largely with the environmental problems associated with heavier of air, water, and soil pollutions and biodiversity extinction in relation with chemical fertilizer especially with the over-supply of reactive Nitrogen (Nr). Of course, even though urea or ammonia has been called as "Detonator of the population explosion: Without ammonia, there would be no inorganic fertilizers, and nearly half the world would go hungry,"[9] the development of environmental sciences suggested that there are also significant environmental costs created by over-supply of Nr from agriculture. Both increasing food supply and declining or deteriorating environments have been coming simultaneously as Nr legacy.[10]

There are voluminous research publications in the area of environmental policies in relation how to solve the impact of applications of chemical fertilizer in pursuing better food security globally. The recommendations range from how to increase fertilizer efficiency at farm level up to how to turn agriculture from conventional one to organic agriculture. This article deals with not only how to reduce chemical fertilizer by using biofertilizer while maintaining the level of productivity such as the chemical fertilizer is fully used but also how to solve the world problems in association with organic wastes from various sources. In this case, Black Soldier Fly (BSF) (*Hermetia illucens*) is seen as "Haber-Bosch ammonia factory" which converts organic matters from a complex form into minerals, water, and beneficial microorganisms such as nitrogen fixer or phosphate and potash solubilizer. By using the BSF bioconversion technology the negative externalities created by Haber-Bosch technology will be overcome. In fact the BSF bioconversion technology will produce multiple positive impacts on almost all aspects of critical issues the world presently face such as protein for feed or food which will directly reduce the stress of ocean from fisheries overexploitation, biofertilizer for agriculture, antimicrobial peptides for mitigating antibiotic resistance, and other products that can be supported by insects products. This article will focus on the benefits of BSF's biofertilizer on cost reduction of fertilizer expenditure in sugarcane plantation and improvement of soil fertility indicators.

Conceptual framework

The thinking framework applied in this article is based upon the framework of how an innovation can be activated and be institutionalized in daily practices of sugarcane plantation. This argument is reinforced by the implied fact in Figure 1, namely the sugarcane based industry in Indonesia has been trapped or locked in for a long term trend declining productivity. On the other hand, Thailand, Vietnam and the world in an aggregate show the long term trend increasing sugarcane productivity. The lines in Figure 1 send a very strong message which is louder than words. The main message is without innovation that can solve sugarcane productivity, Indonesian sugar industry will continue in very difficult situation.

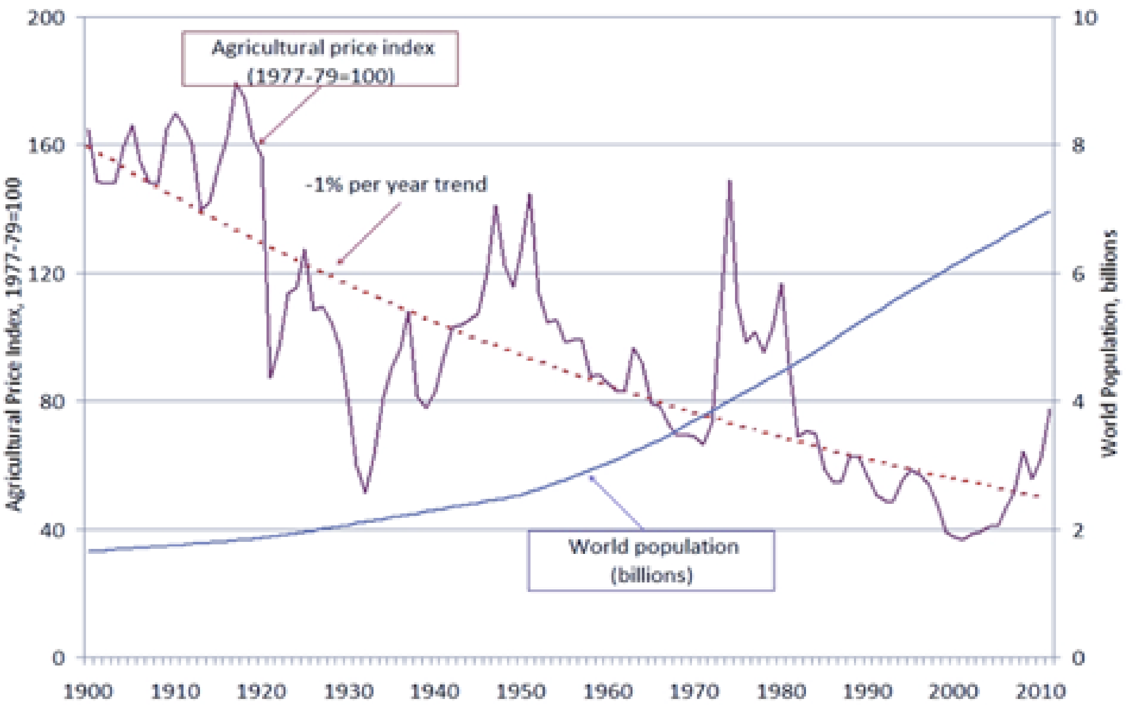

Figure 2 Trend of population vis. trend of agricultural price index(Fuglie and Wang, 2012).

Nature provides the source of energy and nutrition's for all livings. The source of idea underlining the experiment reported in this article is that the strongest energy of change is inherently embodied in nature (Figure 3). This assertion is used as foundation for innovation in increasing productivity of sugarcane plantation in Indonesia.

The process of nutrient cycles taught that matters are moving naturally through the nutrients cycle (Figure 3). In such a biological process, decomposition is a key to convert matters from a complex organic matter e.g., vegetables, to a simple one such as nitrogen; and, then the such outputs will be used to recreate or to rebuild a new living thing such as sugarcane. The process of recreation or rebuilding is a matter of sustainability in its owned process. Therefore, the main question in the area of increasing productivity of sugarcane is that what kinds of decomposition process which can be imitated in the process of increasing productivity of sugarcane. In the terms of increasing productivity there is also embodied the purpose of achieving the situation that characterize the process which is fast, cheap, easy and has no or only minimum negative impact on the quality of the environments within the context of recreation such as mentioned above.

The practice of the above framework of thinking has been applied in a traditional way by our ancestors. In terms of scientific concepts, the concept of recreation is actually applied by the practice of using biofertilizer. In fact, the first biofertilizer, namely Nitragin, was launched in 1895 by Nobbe and Hilther.[12]

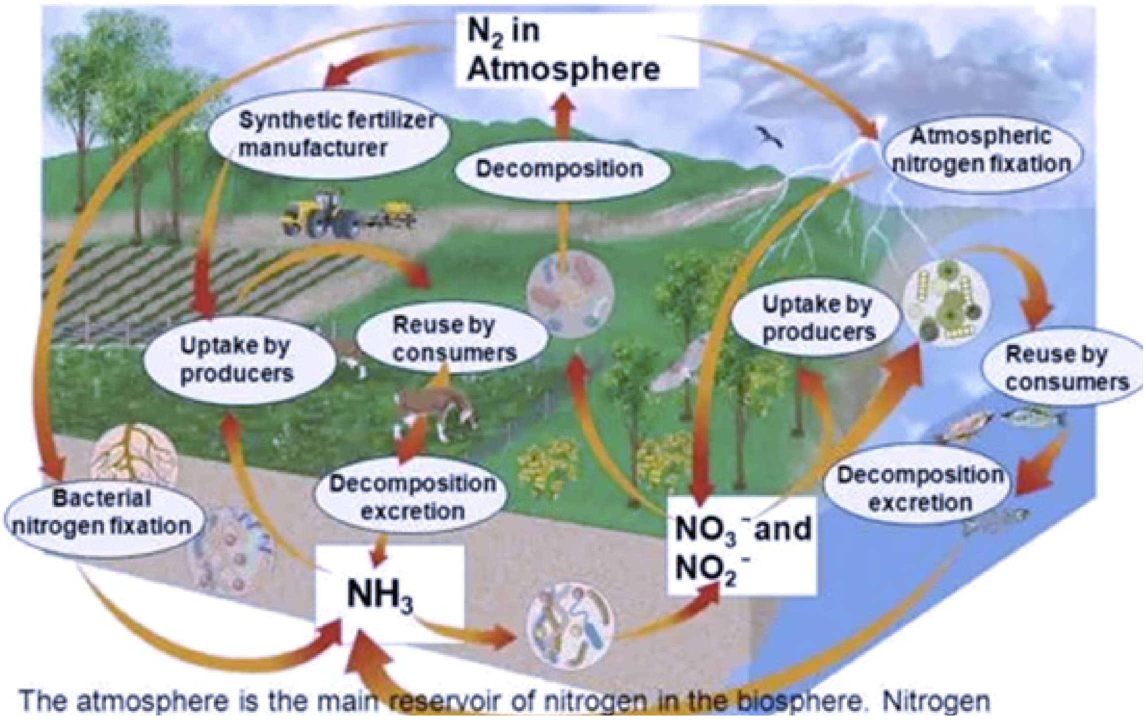

Figure 3 Nutrients cycles.[11]

Most of the works in the area of biofertilizer have been focusing directly on the microbes such as bacteria, fungi, yeasts, or cyanobacteria. However, in recent years the attention to the roles of insects as detritivore of organic wastes have been growing as alternatives for solving environmental problems, food security[13] and availability especially for animal protein production,[14–16] and biofertilizers to take care of soil fertility and health;[17,18] and to take care also the problem associated with antibiotic resistance.[19,20]

Even though the introduction of biofertilizer has been 125 years around, in the real practice it is still limited relative to the conventional agriculture using chemical fertilizer. The main reason is that the majority of farmers and corporations do business in agriculture have been the result of a global movement which has been named Green Revolution. In Indonesia the movement was started in late 1960s and Indonesia reached rice selfsufficiency in 1984. The Green Revolution can be seen as a global movement which has been orchestrated by global powerful institutions that has been focused into one target, namely changing the traditional practices of local farmers from traditional technologies which were based mostly on local wisdoms and ingenuity which had been passed through histories from older generations to the nexts. The changes have been packaged through a packaged of technology namely hybrid seeds, chemical fertilizer, pesticides, irrigation and extension services. The end results are production increase such as mentioned above that have made the significant growth of food production globally hand in hand with the increasing world population, rural to urban migration and deterioration of environmental resources.[21–25] Governments have created incentives for wide and intensive applications of chemical fertilizer across farmers or sectors. Subsidy for chemical fertilizer has been a huge amount of subsidy relative to other kinds of government spending.[26] Biofertilizer even though has almost or even older that chemical fertilizer has not been paid attention by global power relative to that of chemical fertilizer. This is the main reason why the application of biofertilizer still lagged behind the global needs.

In addition to the limiting factors associated with the natural resources in supplying chemical fertilizer, one of the most important limit now and will be heavier in the future is that the limitation of assimilative capacity of the environments. In fact, the assimilative capacity of the environments to assimilate heavy metals, in addition to Nr for example, is not only limited but the flow in of heavy metals to the environments from fertilizer industries will unavoidably create soil or water pollution. For example, when phosphate industry takes the roles in supplying of phosphate fertilizer, then it will be a part of supplying heavy metal such as Cadmium (Cd).[27] Heavy metals are dangerous for both human and other living things. Major agriculture like rice in Asia and Indonesia are threatened by heavy metals.[28–30] The rock phosphate that is used to produce phosphate fertilizer is composed of about 60 percent to 80 percent of Cd. In final product of phosphate fertilizer the content of Cd is about 3-110mg of Cd. The dosage of 50kg P_2O_5/ha/year will make Cd remains in the soil for about 0.15-5.5g Cd/ha/year. Cd causes kidney, pneumonia, coronary, and muscle disease.[31]

Using biological perspectives that seeing organisms as "evolutionary biological machine" that have been evolving for millennials then microorganisms that are able to solubilise phosphate for instance, can be chosen as biofertilizer.[32,33] Kalayu[34] elaborated the prospects of microorganisms that are able to solubilise phosphate and in consequent agriculture will not be as Cd polluter. According to Kalayu the groups of bacteria that are potentially used as biofertilizer are: *Bacillus circulans, Bacillus megaterium, Bacillus polymyxa; B. subtilis, Bacillus pulvifaciens, Bacillus coagulans; B. fusiformis; B. pumilus; B. chitinolyticus, Bacillus sircalmous, Thiobacillus* *ferrooxidans, Pseudomonas canescens, Pseudomonas putida, Pseudomonas calcis, Pseudomonas fluorescens, Pseudomonas striata, Pantoea agglomerans, Rhizobium meliloti, Rhizobium leguminosarum and Mesorhizobium mediterraneum;* the group of fungi are: *Aspergillus Niger, Aspergillus clavatus, Aspergillus awamori, Aspergillus candidus; A. parasiticus; Aspergillus fumigatues; A. rugulosus, Aspergillus flavus, Aspergillus foetidus; A. nidulans; A. wentii, Aspergillus terreus, Aspergillus tubingensis, Aspergillus sydawi; A. ochraceus; A. versicolor, Penicillium bilaii, Penicillium citrinum, Penicillium digitatum; P. lilacinium; P. balaji; P. funicolosum, Penicillium oxalicum, Penicillium simplicissimum; P. rubrum, Arthrobotrys oligospora, and Trichoderma viride;Acinetobacter rhizosphaerae;* and the group of Actinomycetes are:, *Streptomyces albus; S. cyaneus; Streptoverticillium album*; dan Cyanobacteria group is *Calothrix braunii.*

Comparing Table 1 and the above Kalayu's list above there are four microbes in the BSF's biofertilizer that are able to solubilise phosphate namely *Pseudomonas sp., Bacillus sp., Trichoderma harzianum,* and *Streptomyces sp.* In addition, there are also microbes that are able to fix atmospheric nitrogen, and to produce phytohormone. The BSF's biofertilizer is also fulfil the criteria of no pathogenity such indicated by negative indicators of *E. Coli* and *Salmonella sp*. which are below the standard. The pH value was 6.64 which are closed to neutral. In complement with Table 1, the laboratory test for heavy metal in BSF' solid biofertilizer indicates that as <0.01ppm, Hg<0.01ppm, Pb=3.7ppm, and Cd=0.17ppm.

Table 1 Microbes in BSF's biofertilizer according to laboratory analysis

S. no	Parameters	Methods	Unit	Results
1	*Azotobactor sp*	ICBB/MU/12.001.9	CFU/ml	2.91×10^4
2	*Nitrogen fixing microbe (Azospirillum sp)*	ICBB/MU/12.001.10	APM/ml	110000
3	*Rhizobium sp*	ICBB/MU/12.001.12	CFU/ml	3.34×10^7
4	*Pseudomonas sp**	Plate Count	CFU/ml	1.14×10^8
5	*Bacillus sp**	ICBB/MU/12.001.8	CFU/ml	3.59×10^7
6	*Phosphor (P) soluble microbes*	ICBB/MU/12.001.13	CFU/ml	2.56×10^6
7	*Trichoderma sp**	ICBB/MU/12.001.6	CFU/ml	$<1\times10^1$
8	*Saccharomyces sp*	ICBB/MU/12.001.7	CFU/ml	2.84×10^5
9	*Streptomyces sp**	ICBB/MU/12.001.14	CFU/ml	$<1\times10^1$
10	*Cellulolityc microbes*	Plate Count	CFU/ml	2.87×10^5
11	Auksin (IAA)*	HPLC	mg/L	113.95
12	*Test of pathogenicity*	Infeksi pada duan tembakau	-	Negatif
13	*Escherichia Coli*	ICBB/MU/12.001.2	APM/ml	<3
14	*Salmonella sp*	ICBB/MU/12.001.3	APM/ml	<3
15	pH*	Potensiometri	-	6.64

Notes: Heavy metals contents such as As, Hg, Pb, and Cd according the other test of BSF' biofertilizer were <0.01, <0,01, 3.07 and 0.17ppm, respectively
(Source: Atuthors)

The comparison between Table 1 and the list of microbes provided by Kalayu[34] can be seen as a methodology to find clarity, consistency and correspondency between a theory and a laboratory test of the subject matter,[35] i.e., BSF's biofertilizer is considered as the subject of this paper. The rest test is the test in the field of sugarcane plantation that will be described below.

From field experiment to policy implications

A. Purpose of the experiment

The main purpose of this experiment is to gain knowledge that is important for activating and institutionalizing innovation in the area of sugarcane production. Of course, there will be a long process between field experiments and its actualisation in the common practices. But, whatever how long the distance between common field practices and experiments, there always be a starting point.

This experiment simplified the production process into two major category, *ceteris paribus*, namely, first is a field of sugarcane which is fully fertilized by using full dosage such as recommended by an authoritative institution namely Indonesian Center for Sugar Research Institute in East Java, and, secondly, the experimental treatments which will be elaborated below. The full dosage of Urea, TSP, and KCl are 350kg/ha, 300kg/ha and 300kg/ha. By assuming equal weight among that fertilizer, the total amount of chemical fertilizer input per hectare in a year period of sugarcane plantation is 950 kg.

Besides the problems which are associated with chemical fertilizer such as explained above, in terms of business, corporate expenditure for chemical fertilizer is the second largest one. The total expenditure for chemical fertilizer per hectare in full dosage above in 2017 reached Rp 3,91 million.[36] By assuming selling price of sugar in 2017/18 was Rp 9700/kg and yield of sugar was 4.8 ton/ha, then the ratio of sugar revenue to inorganic fertilizer per hectare was 11.93. If the expenditure for fertilizer is reduced to a half, *ceteris paribus*, and add by new expenditure namely expenditure for BSF's biofertilizer by Rp 600,000 per hectare, then the ratio between income per hectare from sugar to new fertilizer expenditure changed to 18.26; or increase by 1.53 fold. Better situation will also occur if the cost reduction is also accompanied by production increase.

Therefore, the purpose of this experiment is to find out whether the application of BSF's biofertilizer will be able to reduce the sugarcane production costs, given the constant level of production such as achieved by control. The definition of production cost here was reduced to the cost of chemical fertilizer spending and the additional cost of BSF's biofertilizer procurement, *ceteris paribus*. So, when the experimental result was showing that the treatment was not significantly different from the control the purpose was achieved.

B. Description of experiments

The experiment was structured such as depicted in Table 2. There were 7 blocks with the size of the block ranges from 0.51 to 0.57hectare, and the total experimental land size was 3.77 hectares.

Table 2 Structure of experiment: treatment, replication and blocks

NO.	Block	Size of the block (Ha)	Treatment	Replication	NPK fertilizer
1	A.A.	0.53	Dosage of BSF's Fert. 30 l/ha	1	50percent dosage
2	A.B	0.52	Dosage of BSF's Fert. 60 l/ha	1	50percent dosage
3	A.C	0.51	Dosage of BSF's Fert. 30 l/ha	2	50percent dosage
4	A.D	0.54	Dosage of BSF's Fert. 60 l/ha	2	50percent dosage
5	A.E	0.56	Dosage of BSF's Fert. 30 l/ha	3	50percent dosage
6	A.F	0.57	Dosage of BSF's Fert. 60 l/ha	3	50percent dosage
7	C	0.54	Control 100percent of chemical fertilizer dosage		100percent dosage
	Total (ha)	3.77	-	-	-

Notes:

1. Control was an application of 100 percent dosage provided by Indonesian Sugar Research Institute, namely: UREA 350, TSP 300, KCL 300 per ha
2. All BSF's fertilizers were diluted in 400 l water/ha

The experimental control was the application of 100percent recommended dosage of chemical fertilizer namely 350kg/ha of Urea, 300kg/ha of TSP and 300kg/ha of KCl. The treatments were the application of BSF's liquid organic fertilizer namely: 1) the application of 30 lper ha of BSF's liquid organic fertilizer, and 2) the application of 60 l per ha of BSF's liquid organic fertilizer. Both treatments were combined with the application of 50percent dosage of chemical NKP fertilizer. The experimental design use in this experiment was Randomized Block Design (RBD) (Table 2).

There was standard agronomical research in the area of sugarcane production. Among others, the selected variables which were considered as important determinant for sugarcane productivity are population density of sugarcane per m^2, the height of sugarcane stalk (cm), the diameter of sugarcane stalk, the sugarcane productivity per hectare and the sugar recovery (percent). The main hypotheses were there will be no statistically difference between the reductions by 50percent dosage of chemical fertilizer in combination with BSF's liquid organic fertilizer.

Experimental results

More on statistics: According to statistical analysis there are no significantly different between treatments and control with respects to sugarcane productivity, sugar recovery, and diameter of sugarcane stalks at significant level P=0.05. This means that the treatment of BSF's liquid biofertilizer and reduction of 50percent of NPK fertilizer produced the same result as given by the full dosage of NPK chemical fertilizer. The same case also took place with sugar recovery and sugarcane stalks diameter (Tables 3–5).

Table 3 Effect of treatments on sugarcane productivity

Treatment	Code	Productivity
BSF's Fert 30 l/Ha+NPK 50percent	1	93.053a
BSF's Fert 60 l/Ha+NPK 50percent	2	98.623a
Control (NPK 100percent)	3	94.900a
P (percent)		0.3589

Table 4 Effect of treatments on sugarcane recovery (percent)

Treatment	Code	Recovery
BSF's Fert 30 l/Ha+NPK 50percent	1	7.66a
BSF's Fert 60 l/Ha+NPK 50percent	2	7.85a
Control (NPK 100percent)	3	7.88a
P (percent)		0.2736

Table 5 Effect of treatments on sugarcane stalk diameter (Cm)

Treatment	Code	stalk diameter
BSF's Fert 30 l/Ha+NPK 50percent	1	26.232a
BSF's Fert 60 l/Ha+NPK 50percent	2	25.963a
Control (NPK 100percent)	3	27.312a
P (percent)		0.1105

On the other hand, the experiment provided significantly different parameters between the treatments and sugarcane population density per meter square and the height of sugarcane stalks. In means that there is no significant different between treatments and control but for both cases the results of applying BSF's liquid fertilizer with the rate of 60 l per ha in combination with 50percent dosage of NPK chemical fertilizer created higher performance relative to that of the rate of 30 l per ha + 50percent of NPK chemical fertilizer (Table 6) (Table 7).

Table 6 Effect of treatments on sugarcane stalk density (number of stalks/m^2)

Treatment	Code	number of stalks/m^2
BSF's Fert 30 l/Ha+NPK 50percent	1	7.3498b
BSF's Fert 60 l/Ha+NPK 50percent	2	7.7010a
Control (NPK 100percent)	3	7.3960ab
P (percent)		0.0498

Table 7 Effect of treatments on sugarcane stalk height (cm)

Treatment	Code	height
BSF's Fert 30 l/Ha+NPK 50percent	1	293.93b
BSF's Fert 60 l/Ha+NPK 50percent	2	302.33a
Control (NPK 100percent)	3	299.63ab
P (percent)		0.0236

Up-taking the results for management and policies

a. The Cost reduction impact

In PTPN VII, where P.G. Bunga Mayang is a part of PTPN VII, the sugarcane productivity in three latest consecutive years were declining from 72.9ton per hectare (2017), 59.1ton per hectare (2018) and 49.8ton per hectare (2019) (Table 8). The pattern of long term trend declining sugarcane productivity such as depicted in Figure 2 and the case of PTPN VII must reinforce the high demand for innovation in this problem area.

Table 8 Average productivity of sugarcane in PTPN VII, 2017-2019

Items	2017	2018	2019
Harvested area (ha)	17460	17654	15697
Milled Sugarcane (ton)	1273366	1043025	782136
Productivity (ton/ha)	72.9	59.1	49.8

Source: PTPN VII

The experiment provided knowledge that there was no different in the yield of sugarcane harvested per hectare between sugarcane fully fertilized by NPK and by a half of it plus 60 l of BSF's liquid organic fertilizer. It means that there is a highly potential of reduction of the chemical NPK fertilizer without jeopardising the harvested yield. The chemical fertilizer cost reduction reached Rp 1.9 million per hectare (Table 9). In addition, the area will gain the non-financial benefits such as reduction of environmental pollution costs, health hazard effects to human and animals, increasing soil organic matters and at the same time improving soil fertility and soil health.

Table 9 Cost reduction due to treatments (Rp/ha)

Fertilizer	Recommended dosage/Ha (Control)			50percent dosage reduction			Difference in fertilizer cost
	Dosage/ha (Kg)	Price (Rp/Kg)	Cost /Ha	Application/ha (Kg)	Price (Rp/Kg)	Cost /Ha	Rp/ha
Urea	350	3596	1258600	175	3596	629300	629300
TSP	300	4582	1374600	150	4582	687300	687300
KCL	300	4271	1281300	150	4271	640650	640650
Total	950	-	3914500	475	-	1957250	1957250

Source: PTPN VII, analysed by authors

If the above technology is applied in all area of Bunga Mayang and Cinta Manis plantation, i.e. about 18.000 hectare, the reduction of chemical fertilizer cost will reach about Rp 35.28 billion. It is much more than the additional cost to procure BSF's liquid organic fertilizer, which was bought from PTPN VII worker cooperative, namely Rp 10,000/l or only about Rp 10.8 billion. Therefore, the net cost reduction of fertilizer spending was Rp 24.48 billion.[37] This implies that the experimental results showed that the biological treatment will expand significantly socioeconomic environmental benefits to the corporation and create positive externalities to the surrounding communities.

b. Change in income

Beside reduction of cost, there is also potential increase in income. The treatment of 60 l of BSF's liquid organic fertilizer per hectare in combination with 50percent dosage of NPK was much higher than that of the average actual productivity achieved by PTPN VII in 2017. This implies that the significant changes such as depicted in Table 10 will possibly be achieved. There was a gap of productivity of the selected treatment and the actual performance of productivity in 2017 by 25.8ton/ha. This gap was equivalent with the increasing income by Rp 414 billion. Therefore, the total income of PTPN VII using the above line of thought would be about Rp 1.03 trillion plus Rp 414 billion that would add up to Rp 1.44 trillion (Table 10).

Policy implications

As has been mentioned above that the basic idea behind this experiment was the question of how to trigger the innovation process that enable increasing sugarcane productivity on the one hand and giving the environmental solutions on the other hand. The route was started with the motivation how to find natural mechanisms that can be replicated in the industrial complex process. The key point here is that the common practices in agriculture now is indicated by highly dependent on Haber-Bosch process,[38,39] which is underlining the systems of production using chemical fertilizer like ammonium and pesticides. Of course, such mechanisms have been successfully contributing to substantial increase in food production up to present. However, such dependency is in contradiction by itself with the purpose of sustainable future. Therefore, by the support of scientifically proven evidence that agriculture can pollute the environments through varieties of ways and subjects, including food chains contaminations, then the new ways of agriculture should be innovated.

Table 10 Potential income increase due to treatment application

Items	Productivity (ton/ha)	Sugar Recovery (percent)	Sugar (Ton/ha)	Molases (ton)	Income of sugar (Rp)	Income of molasses(Rp)	Total (Rp) Income	Different from control/from actual 2017 (Rp)
BSF's Fert 30l/ha+NPK 50percent	93.1	7.67	7.16	4.65	69452000	5580000	75032000	-3406000
BSF's Fert 60l/ha+NPK 50percent	98.7	7.85	7.77	4.93	75369000	5916000	81285000	2847000
NPK 100percent (Kontrol)	94.9	7.88	7.5	4.74	72750000	5688000	78438000	-
PTPN Average in 2017	72.9	7.5*	5.46*	3.64**	52962000	4368000	57330000	23955000#

Notes:

1) Price of sugar Rp 9700/kg and price of molasses Rp 1200/l
2) * = calculation by the authors based on Table 8
3) ** = Rate of molasses was assumed 5percent and 1 kg of molasses was assumed equal to 1 l
4) # = the difference between the income generated by the treatment of 60 l of BSF's liquid organic fertilizer and 50percent dosage of NPK and the performance of PTPN VII in 2017

Within the context of how nature works, the stage of decomposition in natural cycles such as nutritional cycles, is the key for understanding of what kind of innovation should be pursued. The process of decomposition can be seen as a process of energy dissipation (*entropy*). But, such physical process is recreated into new energy for supporting new live by microorganism. It is a process of *antientropy*[40] or a process of *recreation,* as mentioned above. Within the context of biofertilizer, microorganism produces minerals, humus and other matters that are useful for plants such as sugarcane. The scientific idea of the important of microbes in agriculture production is not new.[41] What is relatively new now is of how to use insects, especially Black Soldier Fly (BSF) (*Hermetia illucens*) to take the roles in *recreating* sustainable agriculture.

In this article the word of *recreation* is used to replace the technical terms used in solid waste management: *reduce, reuse, and recycle*. The main reason is that in the bioconversion process, the processes themselves are the processes of new life creation rather than new things creation. Biofertilizer is by itself a concept of living organisms that is useful for plants like sugarcane. Of course there is water, minerals or organic matters but it cannot be called biofertilizer if there are no microorganisms such as *Azospirillum* in it. The roles of microorganisms such as listed by Kalayu[42] have the more roles which are played by chemical fertilizer manufactures. However, the impacts generated by microorganisms and by chemical fertilizer manufactures are very different. One of the most debated aspects is the negative impact of chemical fertilizer on environmental sustainability.

This article harvested the benefits of BSF. BSF was seen as biological agent that not only equipped by numerous of microorganism that help BSF to decompose organic matters but also the time process of decomposition were completed at very short time relative to the other techniques of decomposition available now. In fact, the process of producing liquid biofertilizer from vegetables and fruit sources can be harvested for every 24 hours. In addition, the bioconversion by using BSF created opportunity to harvest the animal sourced products such as animal protein, lipids and chitin.

BSF's liquid biofertilizer can be made available in a large scale with a simple technology. Vegetable and fruits have varieties of moisture content ranging from 60percent up to 90percent which depends of what kind of vegetables and fruits being discussed.[43] The rate of BSF's biofertlizer harvest is about 30percent of the inputed vegetables and fruits. For example, from one tone of "vegetable and fruits waste" per day it will be harvested by about 300 l per day of BSF's liquid biofertilizer.

The above experiment suggested that in order to be able to apply 60 l per hectare of BSF's liquid biofertilizer in 18,000hectare of sugarcane plantation there will be required 1,080,000 l. To fulfil such need there is required 3,240,000 kg of vegetables and fruits left over. In one day a city like Jakarta supplies organic wastes about 3.5 thousand ton or 3,500,000kg[44] which is more than sufficient to fulfil the needs of whole PTPN VII sugarcane. In fact, from Jakarta City alone will be able to produce BSF's liquid biofertilizer about 425,833,333 l/year. By using the rate of application in this experiment the Jakarta City production will be able to fertilise about 7.1 million hectare. The size of sugarcane area in Indonesia is abut 400 thousands hectare and the size of rice land in Indonesia is about 7 million hectare. If all food wastes in Indonesia, where Indonesia is classified as the second largest food waste emitter,[45] were bio-converted by BSF, Indonesia will have more than enough BSF's biofertilizer in both liquid and solid forms, to fertilize Indonesian agriculture which will simultaneously solve environmental, health, food, feed, and other problems which are associated with organic wastes.

The main problem now is how to scale up into industrial scale. Just like other cases in innovation area there are must be heroes. The term of heroes used here is following Platt's social traps[46] concept which is saying that heroes are required to break social traps. The case of lack of innovation in the areas of sugarcane increasing productivity and sustainability is the case of how to break such a social trap.

The roles of State Owned Enterprises (SOEs), like PTPN VII are very critical. It is because the problem of scaling up of BSF's biofertilizer is looking simple. In practice, it is very complex. The most complex problem comes from the side of organic left over or what usually called organic wastes which is unmanaged yet even though the law and regulations underlining solid waste management have been made available since 2008.[47] However, the obligation to separate wastes according to its characteristics since its sources have not been practiced. In fact the city wastes management is still practicing the old ways of wastes management, especially sending them to landfills.

SOEs has higher corporate social responsibility to take advantage of waste management in the one hand and using the products like biofertilizer in SOEs owned plantation, on the other hand.

Conclusion

This article shows that the subject of sugarcane can be seen as a case study that can be taken as an important lesson for solving other similar cases. Bioconversion of leftover of vegetables and fruits by BSF can produced BSF's biofertilizer. In this experiment, the BSF's liquid biofertilizer was used as treatments. The rate of 60 l per ha plus 50percent of NPK recommended dosage had no significantly different productivity level with the full NPK recommended dosage application. This implies that bioconversion of organic left over by BSF can be seen as a new window for alternative sources of biofertilizer in order to reduce chemical fertilizer. The crucial impact of applying the above technology is preparing the better future through integrating food and environmental policy within the context of rural-urban integration linkages. It will be important for Indonesia especially when about 80 percent of Indonesian population will reside in urban regions in 2050. SOEs are institutions that seen to have strategic roles to materialized the ideas expressed in this article. Of course, there still researches are needed ranging from disciplinary research, subject matter research and problem solving research where the last two types of research are called for multidiscipline's or even trans-disciplines fields of sciences and technology.

Acknowledgments

Thanks to the Board of Directors (BOD) of P.T. BCN and to the BOD of P.T. Perkebunan Nusantara VII for cooperation and supports in this experiments and in using the results for this article.

Funding

All funding for research in Bunga Mayang was a part of annual P.T. BCN operational budget.

Conflicts of interest

The authors declare there are no conflicts of interest.

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37. It was calculated by deducting Rp 35.28 - Rp 10.8=Rp 24.8 billion.

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