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BIO-SUPERPHOSPHATE (BIO-SP) APPLICATION ON SUGAR CANE (*Saccharum officinarum* L.)

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ABSTRACT

The highest expense on sugarcane management is fertilization in which one of them is phosphate fertilizer produced by imported raw materials. An innovation was made by using the local phosphate deposits with low reactivity processed further to improve their effectiveness for sugarcane. The objective of this study was to investigate the growth, yield and quality of sugarcane as affected by bio-superphosphate (Bio-SP) application on a highly weathered tropical soil. A nine-month field experiment was conducted at Jatitujuh Sugar Mill area, West Java, Indonesia, comparing between sugarcane fertilized with Bio-SP to replace conventional single superphosphate (SP-36) and that fertilized with SP-36. Urea and MOP (Muriate of Potash) were applied at similar dosages as recommended by division of Jatitujuh Sugar Mill Agronomy Research. Bio-SP was formulated by reacting a Central Java Rock Phosphate with liquid culture supernatant (LCS) and phosphoric acid characterized by 33% total soluble P_2O_5, 23.1, and 10.7 % citric acid and water-soluble P_2O_5, respectively. The results indicated that Bio-SP at 50% dosage of SP-36 was as effective as the SP-36 in supporting sugarcane growth and improved yield up to 8% as crystal sugar. Further consequence of this finding is that the application of Bio-SP reduced 9.2% of fertilizer cost for sugarcane.

Keywords: microbial enrichment, highly weathered soils, fertilizer efficiency

INTRODUCTION

Natural phosphate rocks (PRs) have been recognized as a valuable alternative and the only economical source of P for production phosphate fertilizer. Reactive phosphate rock and partially acidulated PRs are satisfactory source of P for crops, especially for acid tropical soils. Based on Indonesia's geography and geology characteristic, phosphate resources are mined from igneous and weathered, marine phosphate, and biogenic (van-Straaten, 2002). Research and exploration of PRs still focuses on Java and Madura (Goenadi *et al.*, 2002). The Department of Energy and Mineral Resource reported that PRs in Indonesia was distributed in West, Central, and East Java, South and East Kalimantan. Unfortunately, most rock phosphate deposits found in Indonesia is classified as low reactive PRs and has low quality for plant fertilization. The composition of these rock phosphates varies from one deposit to another. The availability of the raw material with good quality for production of soluble phosphate fertilizer is limited, and therefore, it cannot be used successfully as phosphorus (P) sources for crop production.

The conventional method for enhancing the PRs availability is to increase its solubility by treating with inorganic acids, mainly sulphuric acid and phosphoric acid (Jasinski, 2011**),** however, this approach is not applicable because of high capital production. A very attractive approach for rock phosphate dissolution is the application of microbes capable of excreting organic acids (Alam *et al*., 2002; Nenwani *et al.*, 2010). In vitro studies with microbial isolates from soil indicated that fungi were more efficient in the dissolution of organic phosphate as compared to bacteria (Pandya and Saraf, 2010). Filamentous fungi are widely used as producers of organic acids, particularly *Aspergillus niger* and some *Penicillium* sp., which have been tested in fermentation systems or inoculated directly into soil in order to dissolve rock phosphate (Saber *et al*., 2009).

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Previous studies indicate that activation of relatively low P-soluble content phosphate rock by using a so-called Liquid Culture Supernatant (LCS) improved P solubility in citric acid and water (Santi *et al.*, 2000; Goenadi *et al.*, 2000). A series of greenhouse experiments was also indicative in which the 50%-reduced rate of LCS-treated phosphate rocks can replace the standard P fertilizer, i.e. Single-Superphosphate (SP-36) for selected plantation crop species (Goenadi *et al.*, 2002). This study was carried out to investigate the growth, yield and quality of sugarcane as affected by bio-superphosphate application at Kerticala area, Jatitujuh Sugar Mill, West Java, Indonesia.

MATERIALS AND METHODS

Production Technology of Bio SP

Many common soil microbes that can dissolve insoluble and inorganic phosphate have been extensively studied at Laboratory of Indonesian Biotechnology Research Institute for Estate Crops, PT Riset Perkebunan Nusantara. Fifty phosphate-solubilizing fungi (PSF) were isolated from soil adjacent to and in PR deposits at Cileungsi (West Java) and Madura Island (East Java). There were two genera, *i.e*. *Aspergillus* sp. and *Penicillium* sp., found to be dominant in the sample investigated. Further characterization showed that the *Aspergillus* sp. Korbe 0909 isolate had the highest ability in solubilizing various sources of P, *i.e*. Cileungsi PR (CPR), Madura PR (MPR), $Ca_3(PO_4)_2$, and $AlPO_4$.The result showed that the LCS produced by *Aspergillus* sp. Korbe 0909 cultivation significantly improved the P-PR_S dissolution (Santi *et al.*, 2000; Goenadi *et al.*, 2002).

Development of pilot scale bio-activation production technology of low solubility of phosphate rock was based on an efficient principle of bioprocess technology that means a simple technology, cheap and abundance of materials, and an effective product output. Detailed process of Bio-SP is kept in secrecy as it is in the process for patent application. Bio-SP from Central Java origin rock phosphate is semi-slow release, containing 33% P_2O_5-soluble in perchlorate, 23.1% P_2O_5 -soluble in citric acid 2%, 10.7% P_2O_5-soluble in water respectively, and has granular size of 2-4 mm with crushing strength of 4.9 kgf values (Figure 1).

Figure 1. Bio-superphosphate in granular size of 2-4 mm in diameter.

Effect of Bio-SP Fertilizer on Sugarcane Yield and Quality

The field experiment was conducted at Block 345 Kerticala area, Jatitujuh Sugar Mill, West Java, Indonesia. The areas of experiment of Bio-SP and SP-36 treatments were 2.1 ha, respectively. Bio-SP fertilizer was compared with conventional SP-36 (36% total of P_2O_5) and the dosage applied for this treatment was equal to 50%, the dosage of which was recommended for SP-36. Nutrient application rates were determined based on soil testing and subsequent crop responses. The treatments were (in Ku/ha): [A]. 3 (Urea), 1 (ZA), 0.75 (Bio-SP), and 2.5 (ZK plus), and [B]. 3 (Urea), 1 (ZA), 1.5 (SP-36), and 2.5 (ZK Plus). The ZK Plus was locally made of K_2SO_4 enriched with micronutrient.

The cleaned sugarcane seed of PA 198 variety was planted at field experiment. Fertilizer application was conducted by mixing urea, Bio-SP or SP-36, and ZK Plus in fertilizer applicator equipment (Figure 2 and 3). Sugarcane seedlings of PA 198 variety were planted after fertilizer application. The parameters of sugarcane growth were: (i) germination, (ii) number of stalk/meter, (iii) stalk diameter, (iv) plant height, and (v) yield after 9-month planting. The crop was harvested manually at maturity and the yield and yield attributes were recorded.

Figure 2. Applicator fertilizer at field experiment of Kerticala, PG Jatitujuh unit.

Figure 3. Row applications of Bio-SP or SP-36 treatments at Kerticala area,Jatitujuh Sugar Mill.

RESULTS AND DISCUSSION

Data regarding vegetative growth of sugarcane, i.e. germinating seeds (percent of seed), number of stalk/meter, stalk number, height, and stalk diameter were not significantly different among the treatments although Bio-SP was applied at 50% dosage of SP-36. This evidence proves that Bio-SP has slow-release character protecting excessive losses of P due to soil fixation before plant uptake takes place. Table 1 indicates that Bio-SP tended to promote during 1.5 months period resulting in higher number of stalk per meter three months after planting.

Sugarcane performance depends on availability of major nutrients in the soil among other factors. One such major nutrient is phosphorus (P) which is the third most commonly limiting nutrient after water and nitrogen (Sundara *et al*., 2002). Phosphorus plays an important role in sugarcane germination and early stages of growth generally referred to as sugarcane establishment. P role in sugarcane is for root and primary shoot development, tillering and stalk elongation. It also promotes sucrose synthesis and accumulation (Bokhtiar and Sakurai, 2003). Phosphorus deficiency results in reduced metabolic rate and photosynthesis leading to reduced yield and quality. This is undesirable as it could lead to a fall in sugarcane productivity. The main effect of P deficiency is retarded growth. Older leaves may turn yellow and eventually die back from the tips and along the margins. Phosphorus occurs in soil in both inorganic and organic forms. The concentration of the inorganic forms in the soil solution is the most important factor governing the availability of this element to plants. Phosphate equilibrium in the soil system is non-labile P ----- labile P ------ solution P ------ plant root uptake (Vadas *et al*., 2006; Yang and Post, 2011). While most soils contain substantial reserves of total P, they remain relatively inert and less than 10% of the soil P enters the plant animal lifecycle. Another characteristic of P which influences P management for crop use is referred to as P fixation. This fixed P in the soil exchange site is consequently released in soil solution for plant uptake. However the release depends upon several factors such as the soil condition and soil types. Soil condition with regard to soil pH affects the dynamics of P. Acid soils below pH of 6.0 and alkaline soils above pH of 8.0 increase P fixation and hence unavailability to the soil solution for plant uptake (Gahoonia and Nielsen, 2004). Soil types rich in 1:1 clay minerals are rich in sesquioxides and high Al oxides which increases P fixation unlike clay rich in 2:1 clay minerals.

Table 1. Response of Bio-SP treatments on sugarcane seedlings (PA 198) growth

Treatments	1 month after planting (% seed)	1.5 months after planting (% seed)	3 months after planting (number of stalk/meter)
Bio-SP	47.44	53.15	8.07
SP-36	42.72	45.41	7.59
% Bio-SP to SP-36	111.00	117.00	106.00

Table 2. Response of Bio-SP treatments on sugarcane (PA 198) growth

Treatments	6 months after planting			9 months after planting		
	Stalk number	Height (cm)	Stalk diameter (cm)	Stalk number	Height (cm)	Stalk diameter (cm)
Bio-SP	6.73	215.00	2.72	6.75	287.10	2.90
SP-36	6.47	213.00	2.69	6.51	285.20	2.75
% Bio-SP to SP-36	104.00	101.00	101.00.	104.00	101.00	105.00

Table 3. Response of Bio-SP treatment on sugarcane production

Treatments	Brix (%)	Pol (%)	Crystal hablur	Crystal fraction	Sugar content (%)	Sugar cane/ha (ton)	Crystal/ha (ton)	Sugar/ha (ton)
Bio-SP	19.03	16.78	88.07	20.99	9.56	98.9	9.45	9.48
SP-36	8.84	16.90	89.64	6.50	9.68	90.2	8.73	8.75
% Bio-SP to SP-36	101.00	99.00	98.00	127.00	99.00	110.00	108.00	108.00

Table 4. The economic analysis of Bio-SP treatment on sugarcane at PG Jatitujuh field experiment

Expenses	Description	Cost (IDR)	Bio-SP Treatment		SP-36 Treatment	
			Materials	Cost/ha (IDR)	Materials	Cost/ha (IDR)
Material and process	Urea (kg)	246,000	3.00	738,000	3.0	738,000
	ZA (kg)	155,000	1.00	155,000	1.0	155,000
	SP-36 (kg)	274,500	-	-	1.5	411,750
	ZK Plus (kg)	165,000	2.50	412,500	2.5	412,500
	Bio-SP (kg)	350,000	0.75	262,500	-	-
			Crystal		Crystal	
	cane cut down (IDR)	2,000	989.00	1,977,800	902.00	1,801,000
	delivery expense (IDR)	2,000	989.00	1,977,800	902.00	1,801,000
	sugar processing (IDR)	84,350	94.54	7,974,449	87.27	7,361,225
Materials + Process				13,498,049		12,680,475
Production	Production/ha (ton)		98.90		90.20	
	Sugar content (%)		9.56		9.68	
	Crystal/ha (ton)		9.454		8.727	
	Sugar/ha (ton)		9.483		8.753	
	Sugar value/ton (IDR)		470,000		470,000	
	Value/ha (IDR)		44,570,100		41,139,100	
% Bio-SP to SP-36				109.2%		

The intention of producing alternative P fertilizer from locally available source of phosphate rock is generally to provide a cheaper cost in comparison to the standard P fertilizer (single superphosphate). Data presented in Table 4 show that the fertilizer cost in Bio-SP treatment was about 9% lower than that of SP-36 application. On the other hand, due to a higher sugarcane biomass the harvesting cost and sugar processing of the former was 6%

higher than the latter. However these cost differences were after all compensated with higher revenue obtained from Bio-SP treatment compared to the SP-36 (9.2%). Therefore it was confirmed that the formulation and the application of Bio-SP on sugarcane is highly prospective to increase fertilizer efficiency by cost reduction and, at the same time, increase yield.

CONCLUSIONS

The study exhibits that the reactivity of locally available phosphate rocks could be improved by using a bio-chemical approach producing a cheaper P fertilizer. By provision of rock phosphate bio-activation technology and acceptability of this product by user were expected to be able to reduce dependency P fertilizer from imported material. Furthermore, availability of P fertilizer could be guaranteed more to farmers and planters and the use of domestic resources could be improved in line with sustainable agriculture practices.

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