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EFFECT OF BIO FERTILIZER ON MATURE OIL PALM IN NORTH SUMATRA AND RIAU

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ABSTRACT

Chemical fertilizers have routinely been applied at oil palm plantations to maintain soil fertility. Due to the increase of chemical fertilizer prices, some efforts have been done at such as to reduce cost and increase efficiency in chemical fertilizer application at oil palm plantations include the use of bio fertilizer (BF). The objective of experiment was to evaluate the effect of reducing oil palm standard dosage of chemical fertilizers combined with BF on mature oil palm yield. The experiment was carried out in 2002-2003 covering an area of 4367 ha at PTPN IV in North Sumatra and of 515.58 ha at PTPN V in Riau. The planting material was Dura x Pasifera variety and planted in 1980-1995. A randomized block design was used having three fertilizer treatments: (A) 100% chemical fertilizer (normal dosage), (B) 75% chemical fertilizer + BF, and (C) 50% chemical fertilizer + BF. The replications at PTPN IV and V were 11 and 7, respectively. The BF was applied firstly in May 2002. Dosage of BF was 250 g tree^{-1} yr^{-1}. The BF was given in pockets with four pockets per palm tree. The parameters observed were fresh fruit bunch (FFB) weight, average of bunch weight, and average of bunch number. Results of the experiments showed that palm yield treated with 75% chemical fertilizer + BF and 50% chemical fertilizer + BF were both not significantly different with palm yield treated with 100% chemical fertilizer. The application of 75% chemical fertilizer + BF and 50% chemical fertilizer + BF gave benefit of Rp509,093 and Rp1,231,535 ha^{-1} yr^{-1}, respectively. Technically, nutrients given as chemical fertilizers using combination of 75% chemical fertilizer + BF are still higher than the nutrients transported into 26 tons palm FFB ha^{-1} yr^{-1}. Fertilizer treatment combination of 50% chemical fertilizer + BF will technically be safe only for palm yield of <16 tons palm FFB ha^{-1} yr^{-1}, since nutrients given as fertilizer are still higher than those transported into the palm yield.

[*Keywords:* Oil palm, bio fertilizer, yield, economic analysis]

INTRODUCTION

Any effort to reduce oil palm chemical fertilizers is necessary, for example by using bio fertilizers (BF). One of the Indonesian bio fertilizer (BF) products produced commercially during 2002 contains three kinds of bacteria, i.e. *Azospirillum*, *Azotobacter*, and *Aeromonas*, and one fungus i.e. *Aspergillus*. The use of BF combined with 50-75% chemical fertilizer produced crop yield similar to that of normal application dosage (100%) of standard chemical fertilizers (Goenadi 1998; Goenadi *et al.* 1999; Taryo-Adiwiganda and Goenadi 2002). On oil palm, BF has not been commercially used until 2004. Further elaboration on the use of BF at oil palm plantation at larger scale experiment is still necessary either technically or economically.

The benefit of using BF as chemical fertilizer substitution is due to the activities of *Azospirillum* and *Azotobacter* to fix N_2 gas from soil atmosphere (non-symbiotic N fixer) to become ammonium N, and due to the effect of phosphorylase as an enzyme produced by *Aeromonas* to dissolve fixed-P in the soil, and also due to the increase in particle soil aggregation and soil aeration done by *Aspergillus*. It has been reported that non-symbiotic N fixer may be able to fix N atmosphere as much as 2-200 kg N ha^{-1} yr^{-1} (Goenadi *et al.* 1999). *Azospirillum* is one of the non-symbiotic N fixer which increases root number 15-20% (Okon *et al*. 1989), crop root surface area (Dobereiner and Pedrose 1987), enzyme activities at root zone, concentrations of IAA, and soil aeration (Fallik *et al*. 1988). *Azotobacter*, a non-symbiotic N fixer increased crop yield up to 30%, and produced plant growth promoting substances such as IAA, giberrelin, and cytokinin (Goenadi *et al.* 1999). P-solubilizing bacteria such as *Aeromonas* increased solubility of soil nutrients such as S, Mn, Fe, and Si as much as 1.5 times on pine without P-application, and up to 8 times on pine fertilized with P (Roberts and Beryrelin 1986). The presence of many bacteria and fungi in soil at high population, in general, increased stability of the soil aggregation (Lynch 1983; Goenadi *et al.* 1999). The objective of this experiment was to evaluate the effect of bio fertilizer on oil palm yield, either technically or economically.

MATERIALS AND METHODS

Experiment on Mature Oil Palm at PTPN IV in North Sumatra

The experiment was carried out in 2002-2003 on mature oil palm trees with different planting year at four estates of PTPN IV North Sumatra, i.e. Pulu Raja, Sosa, Sawit Langkat, and Balimbingan (Table 1). The planting material was Dura x Pasifera variety.

The experiment was arranged in a randomized block design with ll replications. The fertilizer treatments were: (A) 100% chemical fertilizer (normal dosage), (B) 75% chemical fertilizer + bio fertilizer (BF), and (C) 50% chemical fertilizer + BF.

The physical and chemical properties of BF used in the experiment was given in Table 2. The name of microbes and population of the BF were as follows (Goenadi 1998):

Azospirillum lipoverum BCC 2369 : 2.5×10^6 cells g^{-1}
Azotobacter beijerinckii BCC 2368 : 0.6×10^6 cells g^{-1}
Aeromonas punctata BCC 2367 : 10^8 cells g^{-1}
Aspergillus niger BCC F 194 : 10^4 cells g^{-1}

The plot sizes of this experiment followed commercial blocks; varied from 16 to 56 ha. Dosage of BF was 250 g^{-1} $tree^{-1}$ yr^{-1}. The BF was placed in four pockets per tree at the palm weeded circle at depth of 15-20 cm. The application times of BF were May 2002, October 2002, March 2003, and October 2003. Each application was 125 g BF per tree. The dosage of chemical fertilizers followed the estate practice recommended by the Indonesian Oil Palm Research Institute (IOPRI) at Medan. The chemical fertilizers were applied as broadcast at the palm weeded circle.

Table 1. Planting year, afdeling, number of blocks, and area of experiment at each estate of PTPN IV, North Sumatra.

Estates	Planting year	Afdeling	No. of blocks	Area (ha)
Pulu Raja	1988	I, II, 111, IV, V	36	1200
Sosa	1985	IV, V	81	1295
Sawit Langkat	1980	I	36	634
Balimbingan	1995	I, III, IV	65	1238
Total			218	4367

Table 2. Physical and chemical properties of bio fertilizer[1].

Item	Notes and result of analyses
Form	Granule of 2-3 mm diameter
Color	White grey
Moisture content (%)	14
pH	7.15
N (%)	0.89
P (ppm)	43 (0.0043%)
K (%)	0.63
Mg (%)	0.2
SiO_2 (%)	43

[1]According to PT Sucofindo, BF sample No. 2949945 (13 September 2001). The patent of the BF analysed was given by the Ministry of Justice and Human Rights in 1998 (No. ID 000 0206 S) and registered at the Ministry of Agriculture, the Government of Indonesia in 2001 (No. G 798/BSP/IX/2001).

The parameters observed were fresh fruit bunch (FFB) weight, average of bunch weight, and average of bunch number in 2003. Parameters observed in 2002 were considered as pretreatment yield since the BF application was done in May 2002. The effect of fertilizers including BF on yield was assumed that it can be seen at the second year after application (2003). Bunch weight and bunch number were noted weekly by estate labors for each treatment, block, and afdeling in each estate. The weekly data were tabulated into monthly data based on each treatment and afdeling in each estate. The monthly data were tabulated during a year. The average of palm yield, bunch weight, and bunch number were then calculated. In this large scale experiment, afdelings in four estates were considered as replications for statistical analyses.

Data were further analyzed statistically. Least significant difference (LSD) test was only applied when significant difference between treatments was found in the analyses of variance at $P < 5\%$. For technical analyses, the estimate amounts of N. P, K, and Mg transported into 16 and 26 tons FFB ha^{-1} yr^{-1} for B and C treatments were compared with 100% dosage of chemical fertilizer treatment and the amount of nutrients transported into palm FFB based on the data given by Hartley (1988). Economic analyses for the three treatments applied were done using fertilizer price assumption at the beginning of 2006.

Experiment on Mature Oil Palm at PTPN V in Riau

The experiment was carried out in 2002-2003 on mature oil palm trees with different planting year at Sei Rokan II and Tanjung Medan estates of PTPN V, Riau (Table 3). The planting material or variety was Dura x Pasifera. The reason why this experiment was repeated at PTPN V was to get the experience in using BF on oil palm at a rather drier condition than at PTPN IV, North Sumatra.

Design of the experiment was a randomized block with seven replications. The fertilizer treatments were:

Table 3. Planting year, afdeling, number of blocks, and area of experiment at each estate of PTPN V, Riau.

Estates	Planting year	Afdeling	No. of blocks	Area (ha)
Sei Rokan II	1981-1984	VIII, X, XII	9	224.60
Tanjung Medan	1983-1985	I, II, III, IV	12	290.98
Total			21	515.58

(A) 100% chemical fertilizer (normal dosage), (B) 75% chemical fertilizer + BF, and (C) 50% chemical fertilizer + BF. The plot size of this experiment was 25 ha. Parameters observed and data analysis followed the method described previously.

RESULTS

Result of Experiment at PTPN IV in North Sumatra

Effects of fertilizer treatments on palm yield, average bunch weight, and average bunch number during observation period of 2002-2003 are presented in Tables 4, 5, and 6. Table 4 shows the decrease of palm yield in 2003. This was due to the palm age of more than 14 years. The important point from Table 4 is that the yield decrease of the 75% chemical fertilizer + BF and the 50% chemical fertilizer + BF treatments were both less than yield decrease of 100% chemical fertilizer. Table 5 shows the increment of palm bunch weight from 2002 to 2003; this was due to the increase in palm age.

Table 6 shows the decrease of palm bunch number in 2003 due to the increment of palm age, but the decrease of bunch number of 75% (N + P + K + Mg) + BF and 50% (N + P + K + Mg) + BF were both less than 100% (N + P + K + Mg). The significantly higher in bunch number of the 50% (N + P + K + Mg) + BF was probably due to the reduction of chemical fertilizer which promotes bunch number. According to field experience, the palm bunch number can be suppressed at high level of chemical fertilizers used.

Result of Experiment at PTPN V in Riau

Effects of fertilizer treatments on palm FFB, average bunch weight, and average bunch number during observation period of 2002-2003 are presented in Tables 7, 8, and 9. Table 7 denotes yield increment in 2003. According to the yield standar of palm, the yield usually decreases at older than 14 years of age.

Table 4. Effect of chemical fertilizers + bio fertilizer (BF) on the average palm fresh fruit bunch (FFB) at four estates of PTPN IV in North Sumatra, 2002-2003.

Treatments	2002[1]		2003	
	ton FFB ha^{-1} 9 $month^{-1}$	%	ton FFB ha^{-1} yr^{-1}	%
100% chemical fertilizer	19.3	100	16.1	83
75% chemical fertilizer + BF	18.6	100	16.3	88
50% chemical fertilizer + BF	19.2	100	16.8	88
F-calc	ns		ns	
SE	0.8		0.76	
CV (%)	9.8		12.5	

[1]Average of 9 months (April-December)
ns = not significant, SE = standard error, CV = coefficient of variation

Table 5. Effect of chemical fertilizers + bio fertilizer (BF) on the average of palm bunch weight at four estates of PTPN IV in North Sumatra, 2002-2003.

Treatments	2002[1]		2003	
	kg per bunch	%	kg per bunch	%
100% chemical fertilizer	19.9	100	20.7	104
75% chemical fertilizer + BF	20.3	100	20.9	103
50% chemical fertilizer + BF	20.0	100	20.8	104
F-calc.	ns		ns	
SE	0.25		0.26	
CV (%)	3.0		12.9	

[1]Average of 9 months (April-December)
ns = not significant, SE = standard error, CV = coefficient of variation

The low yield in 2002 was probably due to the low rainfall during 2000-2001. The difference between the three treatments in 2003 was not significant statistically, although the yield increase of both fertilizer treatments combined with BF (B and C treatments) were higher than the 100% chemical fertilizer.

Average bunch weight of the three chemical fertilizer treatments increased in 2003 (Table 8).

Table 6. Effect of chemical fertilizers + bio fertilizer (BF) on the average of palm bunch number at four estates of PTPN IV in North Sumatra, 2002-2003.

Treatments	2002[1]		2003	
	bunch tree^{-1} 9 months^{-1}	%	bunch tree^{-1} yr^{-1}	%
100% chemical fertilizer	7.9	100	6.0a	76
75% chemical fertilizer + BF	7.4	100	6.2a	84
50% chemical fertilizer + BF	7.8	100	7.2b	92
LSD 0.05	ns		0.54	
SE	0.4		0.26	
CV (%)	12.3		9.5	

[1]Average of 9 months (April-December)
ns = not significant, SE = standard error, CV = coefficient of variation
Number followed by the same letters was not significantly different at P<5% using LSD test.

Table 7. Effect of chemical fertilizers + bio fertilizer (BF) on the average palm fresh fruit bunch (FFB) at two estates of PTPN V in Riau, 2002-2003.

Treatments	2002		2003	
	t FFB ha^{-1} yr^{-1}	%	t FFB ha^{-1} yr^{-1}	%
100% chemical fertilizer	13.9	100	19.2	138
75% chemical fertilizer + BF	14.4	100	21.5	149
50% chemical fertilizer + BF	14.1	100	19.9	141
F-calc.	ns		ns	
SE	0.7		1.06	
CV (%)	9.5		9.8	

ns = not significant, SE = standard error, CV = coefficient of variation

Table 8. Effect of chemical fertilizers + bio fertilizer (BF) on the average palm bunch weight at two estates of PTPN V in Riau, 2002-2003.

Treatments	2002		2003	
	kg bunch^{-1}	%	kg bunch^{-1}	%
100% chemical fertilizer	20.1	100	22.4	111
75% chemical fertilizer + BF	20.3	100	21.8	107
50% chemical fertilizer + BF	20.4	100	21.8	107
F-calc.	ns		ns	
SE	0.4		1.2	
CV (%)	3.8		9.4	

ns = not significant, SE = standard error, CV = coefficient of variation

Table 9. Effect of chemical fertilizers + bio fertilizer (BF) on the average palm bunch number at two estates of PTPN V in Riau, 2002-2003.

Treatments	2002		2003	
	bunch tree^{-1} yr^{-1}	%	bunch tree^{-1} yr^{-1}	%
100% chemical fertilizer	4.7	100	7.0	149
75% chemical fertilizer + BF	4.8	100	7.5	156
50% chemical fertilizer + BF	4.8	100	7.5	156
F-calc.	ns		ns	
SE	0.2		0.3	
CV (%)	8.6		6.5	

ns = not significant, SE = standard error, CV = coefficient of variation

Although in 2003, the increase in bunch weight of 100% chemical fertilizer was higher than bunch weight of the two fertilizer treatments combined with BF, the difference was statistically not significant. The increase in bunch number for the two chemical fertilizers combined with BF were higher than 100% chemical fertilizer, but statistically the difference was also not significant (Table 9).

DISCUSSION

Combination Effect of Chemical Fertilizer and BF on Oil Palm Yield

Average palm yield on the experiment of BF at PTPN IV in North Sumatra for all treatments decreased up to 12-17% in 2003; this was probably due to the increase in palm age and climate factors. The decrease in palm FFB of the two treatments using BF shows the superiority of chemical fertilizer treatment combined with BF compared with the 100% chemical fertilizer treatment, although statistically the difference was not significant.

As seen at PTPN IV, the experiment at PTPN V also indicated that the palm yield of the three fertilizer treatments in 2003 was not significantly different. Since the difference in palm yield in 2003 of the three fertilizer treatments was not significant, either at PTPN IV or PTPN V, we may conclude that the benefit of using BF was on the lower of fertilizer cost of fertilizer treatments combined with BF as will be discused at later section.

Analyses of Plant Nutrients Transported into Palm Yield

Plant nutrients transported into 16-26 tons FFB ha^{-1} yr^{-1} are presented in Table 10. Percentage of average nutrients transported in the forms of urea, SP-36, KCl, and kieserite, compared with standard dosage of chemical fertilizers, are 43%, 25%, 65%, and 60%, respectively. When dosage of chemical fertilizer should be reduced, nutrients of the reduced ones should be still higher than those transported into palm FFB to keep the optimum nutrient balance in the soil.

Figure 1 shows that the N, P, K, and Mg for the 75% (N + P + K + Mg) + 250 g BF $tree^{-1}$ yr^{-1} treatment are also still higher than the four nutrients transported into 26 tons FFB ha^{-1} yr^{-1}. Figure 2 shows that N, P, K, and Mg for 50% (N + P + K + Mg) + 250 g BF per tree yr^{-1} treatment are also still higher than the four nutrients transported into 16 tons FFB ha^{-1} yr^{-1}. Therefore the combination of 50% (N + P + K + Mg) + 250 g BF $tree^{-1}$ yr^{-1} is recommended only for palm yield of <16 tons FFB ha^{-1} yr^{-1}.

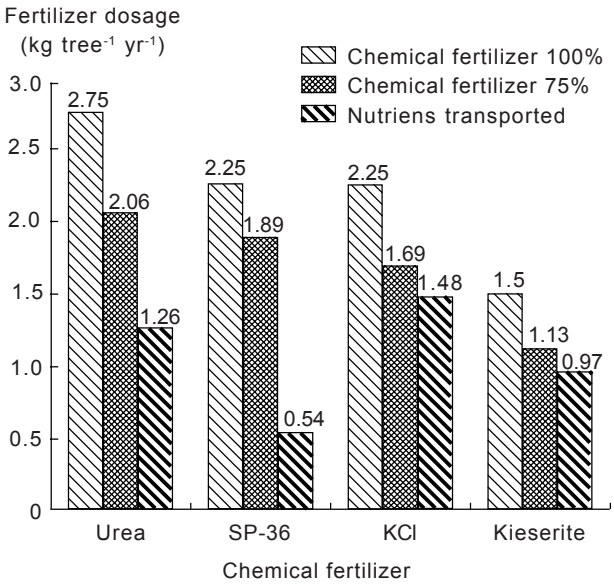

Fig. 1. Comparison of nutriens given at 100% chemical fertilizer dosage, 75% chemical fertilizer dosage, and nutrients transported in fertilizer form into 26 tons palm FFB ha^{-1} yr^{-1} of 9-13 years palm age.

Table 10. The percentage of plant nutrients in the form of fertilizers transported into palm fresh fruit bunch (FFB).

Group of palm age (yr)	Productivity (t FFB ha^{-1} yr^{-1})	Fertilizer dosage (kg $tree^{-1}$ yr^{-1})				Nutrients transported into palm FFB							
						kg $tree^{-1}$ yr^{-1}*				% of the standard dosage			
		Urea	SP-36	KCl	Kis.	Urea	SP-36	KCl	Kis.	Urea	SP-36	KCl	Kis.
3-8	16	2.00	1.50	1.50	1.0	0.77	0.33	0.91	0.59	39	22	60	59
9-13	26	2.75	2.25	2.25	1.5	1.26	0.54	1.48	0.97	46	24	66	65
14-20	22.1	2.50	1.75	2.00	1.5	1.07	0.46	1.25	0.82	43	26	63	55
21-25	16	1.75	1.25	1.25	1.0	0.77	0.33	0.91	0.59	44	27	73	59
Average										43	25	65	60

*Nutrients transported into each ton palm FFB: 2.89 kg N, 0.43 kg P, 3.65 kg K, and 0.76 kg Mg (Hartley 1988).
Source: Taryo-Adiwigwida *et al.* (1997).

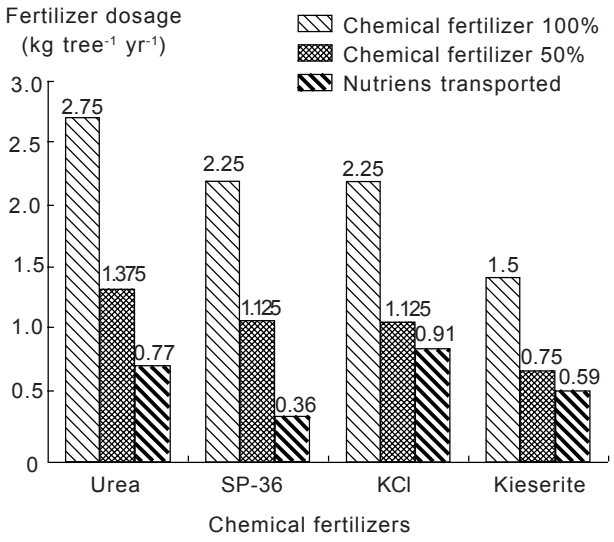

Fig. 2. Comparison of 100% chemical fertilizer dosage, 50% chemical fertilizer dosage, and nutrients transported in fertilizer form into 16 tons palm FFB ha^{-1} yr^{-1} of 9-13 years palm age.

Economic Analyses on the Use of BF

According to the nutrient balance in soil, the combination of 75% (N + P + K +- Mg) + 250 g BF tree^{-1} yr^{-1} is safe to be recommended for mature oil palm having yield of >26 tons FFB ha^{-1} yr^{-1}. Economically, the fertilizer treatment gives possible benefit of Rp509.09 ha^{-1} yr^{-1}. The combination of 50% (N + P + K + Mg) + 250 g BF tree^{-1} yr^{-1} for palm age of 9-13 years with yield of <16 tons ha^{-1} yr^{-1} may give possible benefit of Rp1,231,535 ha^{-1} yr^{-1} (Table 11).

CONCLUSION

Palm yields treated with 75% chemical fertilizer + BF and 50% chemical fertilizer + BF were both not significantly different with palm yield treated with 100% chemical fertilizer. The application of 75% chemical fertilizer + BF and 50% chemical fertilizer + BF

Table 11. Possible benefit on the use of bio fertilizer (BF) on oil palm.

Details	Treatment[1]		
	A	B	C
Palm density (tree ha^{-1})	130	130	130
Fertilizer dosage (kg tree^{-1} yr^{-1})			
Urea	2.75	2.06	1.375
SP-36	2.25	1.688	1.125
KCI	2.25	1.688	1.125
Kieserite	1.5	1.125	0.75
Fertilizer dosage (kg ha^{-1} yr^{-1})			
Urea	357.5	268.125	178.75
SP-36	292.5	219.375	146.25
KCI	292.5	219.375	146.25
Kieserite	195	146	98
Fertilizer price (Rp kg^{-1})			
Urea	2,287	2,287	2,287
SP-36	2,672	2,672	2,672
KCI	3,079	3,079	3,079
Kieserite	2,000	2,000	2,000
Fertilizer cost (Rp ha^{-1} yr^{-1})			
Urea	817,603	613,202	408,801
SP-36	781,560	586,170	390,780
KCI	900,608	675,456	450,304
Kieserite	390,000	292,500	195,000
Total cost of N, P, K, Mg (Rp ha^{-1} yr^{-1})	2,889,770	2,167,328	1,444,885
Dosage of BF (g tree^{-1} yr^{-1})	0	250	250
Dosage of BF (kg ha^{-1} yr^{-1})	0	33	33
Price of BF (Rp kg^{-1})	0	4,950	4,950
Cost of BF (Rp ha^{-1} yr^{-1})	0	163,350	163,350
Cost of BF placement (Rp ha^{-1} yr^{-1})	0	50,000	50,000
Cost of BF + cost of placement (Rp ha^{-1} yr^{-1})	0	213,350	213,350
Total cost of N, P, K, Mg + BF	2,889,770	2,380,678	1,658,235
Benefit of using BF (Rp ha^{-1} yr^{-1})	0	509,093	1,231,535

[1]A: 100% (N + P + K + Mg), B: 75% (N + P+ K + Mg) + BF, D: 50% (N + P + K + Mg) + BF

gave benefit of Rp509,093 and Rp1,231,535 ha^{-1} yr^{-1}, respectively. Technically, nutrients given as chemical fertilizers using combination of 75% chemical fertilizer + BF are still higher than the nutrients transported into 26 tons palm FFB, but fertilizer treatment of 50% chemical fertilizer + BF will technically be safe only for palm yield of <16 tons palm FFB ha^{-1} yr^{-1}.

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