Efficacy Of Control Release Fertilizer On Nutrient Uptake And Fresh Fruit Bunch Production In North Sumatra- Indonesia.

Muhammad Mahadani Lubis, Hanifah Mutia Z. N. Amrul

Abstract

Controlled Release Fertilizer/CRF was an alternative solution to increase the fertilizer efficiency by reducing rate of application, depressing fertilizer round application and losses through leaching and volatilization. The trial aimed to compare CRF with three different dosage with conventional (straight) fertilizer and to distinguish it's effect to vegetative growth, nutrient uptake and yield of the oil palm. Randomized block design was used with eight treatments and three replications. The result showed that there was no significant difference statistically at P 0,05 between CRF and straight fertilizer in term of vegetative growth, nutrient uptake and yield of oil palm, however there were an indication that the CRF at rate of 4 kg/palm//year tend to increase frond weight and leaf area by 3%, improved the nutrient uptake especially on Potasium in the leaf by 9% and consequently improved the bunch weight and number of bunch per palm by 7% and 3% respectively and eventually increased the fresh fruit bunch per ha by 7% compared to straight fertilizer with average dosage of 5,2 kg/palm/year over periode three years of maturity phase. The lower dosage of CRF require the enhancement after the sixth month of CRF application. To sum up CRF could substitute the straight fertilizer on the newly mature phase and CRF at 4kg/palm/year increased fresh fruit bunch production up to 7% compared to straight fertilizer and consequently depressed the man power requirement and minimized the negative impact of fertilizer to the environmental.

***Keywords**: fetiliser efficiency , Control Release Fertiliser, vegetative growth, nutrient uptake, yield, oil palm.*

Muhammad Mahadani Lubis
[1] Master of Agricultural Science, Panca Budi University, Indonesia
Email: mahadani.lubis@gmail.com

Hanifah Mutia Z. N. Amrul
[2]Master of Agricultural Science, Panca Budi University, Indonesia
Email: hanifahmutia@dosen.pancabudi.ac.id,

Introduction

Oil palm was a crutial agribisnis pillar in the North Sumatra Indonesia, however confronted on the challenge of the production cost efficiency and demands of environmental sustainability. Fertilizer as the highest component of production cost, still deal with the fundamental problem namely the low nutrient efficiency of conventional (straight) fertilizers, Prabowo et all found that the nutrient recovery efficiency for 1 kg of fertilizer was generally around 50% for K, 20-25% for N and 10-30% for P [6]. Nutrients were lossed throught leaching, fixation, and volatilization, which was not only economically detriminal but also burdens the ecosystem.

In this context, Control Release Fertilizer (CRF) has emerged as an innovative technology that promises precision in nutrient supply. According to Lewu et all, CRF was encapsulated in a shell that degradated at specific rate. The common used of encapsulated material was sulfur. Thermoplastic and some times ethylene-vinyl acetate and surfactants can be used as a coating material to produce diffusion-controlled release of Urea or other fertilizers [3], according to Chen and Wei, the use of CRF is an effective method to reduce N loss due to infiltration and run off as well as evaporation of NH3 and N2O [4], thus potentially synchronizing nutrient availability with the physiological needs of oil palm. However, the efficacy of CRF need to be scientifically proven in the field, particularly in increasing nutrient absorption and crop yields.

This study aimed to quantitatively the efficacy of CRF on nutritional status and oil palm productivity. The results are expected to provide scientific evidence and practical considerations for the plantation industry in adopting more advanced and sustainable fertilizer technologies.

Literature Review

Oil palm (*Elaeis guineensis* Jacq.) is one of the main plantation commodities in Indonesia which makes an important contribution to foreign exchange, employment and economic development. The productivity of this plant is determined by the interaction of many factors, including variety, soil fertility and properties, climate, cultivation techniques, fertilizer management, and plant age [3]. Agronomically, the yield of fresh fruit bunches (FFB) is a function of two main components, namely the number of bunches per tree and the average bunch weight. Because these two components can act in opposite ways, plant performance evaluation should consider both simultaneously to obtain a comprehensive picture of productivity [9].

Palm Oil Mill Effluent (POME) is a byproduct of the FFB processing process. Physically, POME is a thick, brown liquid with a solids content of around 4–5%, mostly organic, and the remainder is dominated by water; this waste reacts acidically and has high COD and BOD values [6]. On the other hand, POME is rich in nutrients, especially nitrogen (N), phosphorus (P), and potassium (K), and contains calcium (Ca), magnesium (Mg), and a number of microelements. This nutrient and organic content makes POME potentially useful as a liquid organic fertilizer if managed properly [5][6].

Land Application (LA) is a method of utilizing POME by flowing treated waste into ditches or rorak on plantation land so that nutrients are absorbed into the soil. Before being applied, POME must go through a Wastewater Treatment Plant and meet quality standards, including a BOD value not exceeding 5,000 mg/L, a pH in the range of 6–9, and not be applied to peatlands, according to applicable regulations [8]. The LA practice through this rorak system is also applied to oil palm plantations in the Bengkulu region [7].

Various studies have shown that POME application through LA improves the chemical, physical, and biological properties of soil. A study in Karang Tinggi District, Central Bengkulu, reported that LA POME increased pH, K, Ca, and Mg content, cation exchange capacity (CEC), base saturation, and phosphorus and oil/fat content in the topsoil, with the effect tending to decrease with increasing soil depth [7]. Consistently, another study found that POME application significantly increased total microbial content, organic matter content, and soil pH [8]. Observations of plant rhizospheres also showed that land with POME application had higher total microbial content, organic carbon, soil respiration, and CEC than land without application [9]. Overall, these findings confirm the role of POME in enriching organic matter and increasing nutrient availability in the soil.

Improvement of soil properties by POME in turn supports plant growth and production. A study in Lampung reported that the use of POME tends to increase plant productivity in the range of 7.57–63.23% while potentially reducing the need for inorganic fertilizers [10]. From a physiological perspective, the supplied nutrients play specific roles: potassium (K) is important in the fruit filling process, nitrogen (N) supports vegetative growth and leaf formation, while phosphorus (P) plays a role in root formation and flower development. However, the magnitude of plant response to POME application is not uniform, but is influenced by variety, plant age, soil conditions, rainfall, application dose, and garden management [5][8].

Plant responses to environmental conditions, including POME application, are thought to differ between varieties due to differences in genetic traits. Classical research on oil palm found significant differences between hybrids in bunch number, average bunch weight, and FFB yield, as well as significant genotype-by-environment (year) interactions [9]. Evaluation of various dura × pisifera progenies also revealed significant variation in almost all yield and vegetative traits [10].

Importantly for this study, there is a tendency for a trade-off between yield components, namely a negative correlation between bunch number and average bunch weight [11]. This means that varieties that produce a high number of bunches tend to have lighter bunches, and vice versa. This phenomenon explains why two varieties can exhibit different production characteristics even when managed under similar conditions. In addition to genetic factors, plant age also determines bunch weight and yield; production generally increases until maturity and then plateaus, so comparisons between varieties with different planting years should be interpreted with caution [3].

Based on the above analysis, POME application through Land Application has been proven to improve soil properties and increase nutrient availability, thus supporting oil palm productivity. However, the magnitude of these benefits depends on the variety due to differences in genetic characteristics in nutrient utilization, and is influenced by environmental factors and plant age. Studies that specifically compare the performance of several varieties in a single Land Application area especially those that include a comparison without LA and standardize plant age are still limited. This research aims to fill this gap by evaluating the performance of several oil palm varieties in the Land Application area at the Torgamba Plantation, so that the results can provide a basis for selecting more appropriate varieties for production objectives.

Research Methodology

This experiment was conducted on the endemic ganoderma disease area (3rd oil palm generation) so the new seedling was planted in the big hole (6 x 3 x 1 meters long, width and depth respectively) to protect the new seedling from ganoderma attack. The results of soil analysis at the bottom of the hole (planting point) are presented in Table 1, the seed planted was DxP BLRS Varieties DP BL7 with population of 143 palm/ha and the planting progress was complete planted on December 24, 2019, namely 19113001 Manahul division - Bahlias plantation PT.PP.London Sumatra, tbk in Simalungun district-North Sumatra, Indonesia (30 11’25.4 N; 990 18’ 50’5’’E) with a location altitude of 46 m above sea level.

Tabel 1. Soil analysis result of 50 cm from the basal of the palm on the control plot.

Parameters	UoM	value	criteria	Reference
pH H_2O	-	5,00	Medium	Goh et at.,1997
Organic matter	%	2,30	High	Goh et at.,1997
Total_N	%	0,11	Low	Goh et at.,1997
K exchangeable	cmol kg^{-1}	0,30	High	Goh et at.,1997
Mg exchangeable	cmol kg^{-1}	0,75	Very high	Goh et at.,1997
Ca exchangeable	cmol kg^{-1}	1,65	Very low	Puslitan Bogor
P_Bray	mg kg^{-1}	3,79	Very low	Puslitan Bogor
Cu	ppm	5,68	enough	Puslitan Bogor
Zn	ppm	7,90	enough	Puslitan Bogor
Fe	ppm	5,65	enough	Puslitan Bogor
Mn	ppm	210,45	High	Puslitan Bogor
Texture		Sandy clay loam		

The first treatment application was carried out when the palms were twelve months old, started from December 2020 to December 2025. The general measurements (yield, growth and nutrient content) were taken over a three-year period (2023 until 2025) and averaged to obtain values on an annual basis with the following treatment:

Table 2. Treatments on mature phase (2022-2024)

Treatment	Mature (kg/palm/year)						
	Urea	RP	MOP	Dolomit	Borat	CRF	Total
Control	0	0	0	0	0	0	0
Straight	1,75	2	1,75	1	0,07	0,00	6,57
CRF 4 Kg/p/yr						4,00	4,00
CRF 2 Kg/p/yr						2,00	2,00
CRF 1 Kg/p/yr						1,00	1,00

Over period of immature phase the treatments as follow:

Table 3. Treatments on immature phase (2020-2021).

Treatment	Immature (kg /palm/year)						
	Urea	RP	MOP	Kieserit	Borat	CRF	Total
Control	0	0	0	0	0	0	0
Straight	1,20	2,00	0,75	1,00	0,05	0,00	5,00
CRF 4 Kg/p/yr						2,80	2,80
CRF 2 Kg/p/yr						1,40	1,40
CRF 1 Kg/p/yr						0,70	0,70

Unfortunately the actual application of straight fertiliser was dicounted due to the economic depression as follow : 3,00 kg/palm/2022 ;7,50 kg/palm/2023 ; 4,81 kg/palm/2024 so the average of straight fertiliser during three years was about 5,2 kg/palm/year. The CRF fertilizer grade 13.6.27.2 with trademarks of Emcote imported from Japan by PT.Mest Indonesia was used in this experiment. There were three levels of CRF fertilizer tested in this experiment, namely 0,7; 1,4 and 2,8 kg/palm/year for immature phase and 1; 2 and 4 kg/palm/year for mature phase. The experimental design used was a completely randomized block design (RCBD) with eight treatments and three replications, each experimental plot consisting of 7 x 9 trees. The parameters observed were vegetative growth including stem circumference, number of fronds, frond thickness, frond length, frond weight and leaf surface area which was carried out every June, the number of bunches and bunch weight were recorded at each harvesting round. The type of soil used was *oxic dystrudept*, with rainfall, rainy days and water deficit of 2,104 mm, 109 days and 236 mm respectively in the period 2021-2024.

Results

The effect of fertilizer on the vegetative growth of oil palm.

The vegetative growths of the palms over three years of observation was shown in Table 3.

Table 4. The vegetative growth of oil palm over period of three years of maturity.

Treatment	Trunk circumference (cm)	Number of fronds	Frond length (cm)	Frond weight (kg)	Leaf surface area (m^2)
Control	266,3	47,7	439,1	1,7	5,8
Straight	275,4	47,6	462,8	1,9	6,6
CRF 4 Kg/p/yr	261,9	48,0	460,2	2,0	6,8
CRF 2 Kg/p/yr	274,6	47,5	445,1	1,9	6,3
CRF 1 Kg/p/yr	260,8	48,4	463,9	2,0	6,5
Mean	267,8	47,8	454,2	1,9	6,4
Sig	0,262	0,977	0,268	0,268	0,276
LSD 5%	17,7	3,6	29,4	0,2	1,0
CV (%)	3,5	4	3,4	6,7	8,6

Table 4 showed that CRF gave no significant effect in term of vegetative growth compare to straight fertilizer, however there was an indicating that CRF 4 Kg/p/yr gave more higher frond weight by 3%, and leaf surface area by 2% compare to Straight fertilizer,
Table 4. also showed that the control treatment tend to depressed the frond weight by 9% and leaf surface area by 13% growth compared to straight fertilizer treatment however did not showed a significant difference statistically, this was indicated that the soil was quite fertile, as shown in Table 1. This soil has a fairly good pH, high organic matter, and very high exchangeable K and Mg cations, thus the nutrient needs of oil palm was quite fullfilled.

The effect of fertilizer on nutrient concentrations in leaves and rachis of oil palm over the three years was presented in Tables 5.

Table 5. the average of leaf and rachis nutrient content over period of three years of maturity.

Treatments	Leaf (% dry matter)					Rachis (% dry matter)			
	N	P	K	Mg		P	K		Mg
Control	2,45	0,168	1,04	0,27	b	0,08	1,15	a	0,10
Straight	2,47	0,167	0,97	0,28	c	0,09	1,27	ab	0,11
CRF 4 Kg/p/yr	2,49	0,173	1,06	0,26	a	0,09	1,40	bc	0,10
CRF 2 Kg/p/yr	2,49	0,173	1,03	0,27	ab	0,09	1,39	bc	0,10
CRF 1 Kg/p/yr	2,45	0,160	1,03	0,27	b	0,08	1,22	a	0,10
Mean	2,48	0,169	1,05	0,27		0,08	1,29		0,10
Sig	0,82	0,06	0,15	***0,00***		0,16	***0,00***		0,27
LSD 5%	0,12	0,01	0,10	0,01		0,01	0,14		0,01
CV (%)	2,70	3,20	5,40	2,40		8,50	6,10		4,10

Tabel 5 demonstrated that both CRF gave no significant effect to Nitrogen, Phosphor and Potassium uptake in the leaf statistically ,this was indicate that the supplied of Nitrogen from CRF and Straight fertiliser was equal and CRF rate 2 and 4 kg/palm/year tend to slightly increase Nitrogen uptake by 1% compare to Single fertiliser. Further more the adequate Nitrogen uptake of CRF also would stimulated Phosphorus and Potassium nutrient uptake in accordance with the Prabowo et all findings that the application of certain fertilizers has a positive impact on other nutrients, for example N and P fertilizers showed a positive synergistic relationship, where increasing N stimulated P uptake and vice versa in all experiments conducted [7]. Table 5 also showed that CRF 2 and 4 kg/palm tend to increased Phosphor uptake by 4% compare to Single fertiliser, unfortunetely CRF 1 kg/palm depressed the Phosphor uptake by 4%, this was indicate CRF 1 kg was un able to supply adequate Phosphor for the palm. Interestingly, there was a clear indication that the CRF 4, 2 and 1 kg/palm /year could increased the Potassium uptake by 9%, 6% and 5% in the leaf respectively compared to Single fertilizer. Hence it would support the increament of the fresh fruit bunches as found by Prabowo that bunch yield was significantly increased by application of K in five of the seven sites (by 4.8–11.9 t ha−$_{1}$) [8]. According to Lubis the order of the most important nutrients needed by oil palm was Potassium, Nitrogen, phosphorus and Magnesium respectively because it will impact production [5], while according to Sudrajat the nutrient most needed by oil palm plants is Potassium, the next nutrient order is Nitrogen, magnesium and Phosphorus [10].

Table 5 also showed that Single fertilizer increased Magnesium uptake higher than Control and CRF, probably due to the good nutrient release and intensive rotation of the Single fertilizer application. Unfortunetely acording to Prabowo et al, high Mg uptake was not always positively correlated to fresh fruit bunch production ,where only two of the seven experimental locations gave a positive response by 7,2-12,3 t/ha^{-1} [8].

Table 5 depicted that CRF did not gave the signifcant effect to Phosphate uptake in the rachis compare to straight fertiliser, interestingly, both Straight and CRFfertliser increased the Potassium uptake significantly compare to control except CRF at rate 1 kg /palm/year. More over the CRF at rate 2-4 kg/palm/year to increase the Potassium uptake by 10-11% in the rachis compare to straight fertilizer,. This was indicated that CRF supplied the better Potassium compared to Straight fertilizer except for CRF 1 kg/palm/year.

Thus the CRF 2-4 kg/palm/year demonstrated it’s superiority to supply Potassium by 10-11% in the rachis compare to straight fertilizer. Furthermore the findings from Foster and Prabowo, indicate that most of P and K were retained in reserve tissue ,with only a small fraction entering the leaves, therefore both P and K content in the rachis shoud be consider in making fertilizer recommendations [2].

Table 6. The fresh fruit bunches components of oil palm production over period of three years of maturity.

Treatments	The average of yield components over three years			
	Average bunch weight (kg)	Number of Bunch/palm	Fresh fruit bunch/palm (kg/palm)	Fresh fruit bunch/Ha (Ton/Ha)
Control	5,9	19,5	115,8	16,6
Straight	6,8	18,4	130,8	18,7
CRF 4 Kg/p/yr	7,3	19,0	139,4	19,9
CRF 2 Kg/p/yr	6,6	16,7	112,1	16,0
CRF 1 Kg/p/yr	6,9	17,7	125,8	18,0
Mean	6,7	18,3	124,8	17,8
Sig	0,157	0,399	0,153	0,153
LSD 5%	1,1	3,4	24,1	3,4
CV (%)	8,8	9,8	10,3	10,3

Table 6 showed that CRF gave no significant effect on the fresh fruit bunches yield components over the three years of maturity phase compare to straight fertilizer, however CRF at rate of 4 kg/palm/year tend to increase bunch weight by 7% and number of bunch per plam by 3% and consequently increased the fresh fruit bunches yield by 7% compare to straight fertilizer. The increment of bunch weight and number of bunches supportd by higher Potassium uptake both in the leaf and rachis by 11% and 9% than straight fertilizer. Prabowo found the that high Potassium uptake in the rachis will stimulate the formation of bunches, that high K absorption gave a high production response in five of the seven experimental locations of 4.8-11.9 tons/ha [8]. This was indicated that CRF at 4 kg/palm/year aacomplished to replace the straight fertilizer. Unfortunately CRF at rate of 1 and 2 kg/palm/year depressed the number of bunches per palm by 4 and 10 percent respectively compared to straight fertilizer and consequently depressed the fresh fruit bunches per hectar by 4-14% respectively compare to straight fertilizer, this fenomena probably due to the time release of nutrients of CRF was only a couple of months , thus there was some months the nutrients were not available when the palm requiring those nutrients to produce the bunches and increasing the bunch weight. According to Lubis and Hanifah , the time released of CRF was only a half year although there was another nutrient peak on the 12th month after application but those nutrients released was not adequate to fulfill the nutrient requirements. Therefore CRF at rate 1-2 kg/palm/year required the enhancement of CRF or staright fertilizer in another half year .

BLRS report showed that N, P, K, and Mg fertilizers play an important role in increasing bunch weight[1], likewise Soon and Hoong stated that N and K fertilizers significantly increased bunch weight[9].

Table 6 also showed that CRF 4 kg/palm/year gave a significant higher bunch weight by 13% compare to control (with out fertilizer) and consequently increased fresh fruit bunch per hectar significantly by 11% compared to control, this was indicated that CRF demonstrated the positive effect to mature palm.

Further more the production of fresh fruit bunches per hectar were not optimal because the palms in the experiment experienced with etiolation due to big hole, and consequentlt depressed the fresh frut bunch production.

Conclusion

There was no significant difference statistically at P 0,05 between CRF and straight fertilizer in term of vegetative growth, nutrient uptake and the fresh fuit bunches yield of oil palm in mature stage, however there were an indication that the treatment of CRF 4 kg/palm//year tend to increase frond weight and leaf area surface by 3 ans 2 % respectively ,improved the nutrient uptake especially on Potasium in the leaf by 9 % and thus, improved the bunch weight (7%) and number of bunch per palm (3%) ,consequently increase the fruit fruit baunches per hectar by 7% compared to straight fertilizer over periode three years of maturity phase. Unfortunately, eventhought the lower dosage increased the Potasium uptake in the leaf by5-6%, however had not effect to increased the yield components, which indicate the requirement of enhancement another CRF in the second round of applicition. Further more CRF 4 kg/pal/year significantly increased bunch weight by 13% and consequently improved fresh fuit bunch per hectare significantly by 11% compared to Control. To sum up the CRF at rate of 4 kg/palm could substitude the straight fertilizer only once application but the lower rate requiring enhancement in the second round of application on mature stage because able to provide a better nutrient and yield.

References

[1] BLRS (2009). Annual Research Report 2009. Bah Lias Research Station, PT. PP. London Sumatra Indonesia.

[2] Foster HL, Prabowo NE (2006) Partition and transfer of nutrients in the reserve tissues and leaves of oil palm. Workshop on nutrient needs in oil palm–a dialogue among experts. Singapore, 17–18 October 2006.

[3] Lewu F.B, Tatiana Volova, Sabu Thomas and Rakhimol R.K, 2021 Controlled Released Fertiliszer for sustainable agriculture.

[4] Jiajun Chen and Xiangying Wei, 2018. Controlled-Release Fertilizers as a Means to Reduce Nitrogen Leaching and Runoff in Container-Grown Plant Production.

[5] Lubis, Muhamad Mahadani, Muhammad Abror dan Jajan Djuhjana, 2023. Effect of fertilizer discount on fresh fruit bunches production and nutrients in north Sumatra Indonesia. 7th International Oil Palm ConferenceIOP Conf. Series: Earth and Environmental Science 1308 (2024) 012004 IOP Publishing doi:10.1088/1755-1315/1308/1/012004

[6] Lubis, Muhamad Mahadani and Hanifah Mutia Zaida Ningrum Amrul, 2026. Evaluasi Control Release Fertiliser Pada Bibit Kelapa Sawit di Sumatra Utara Indonesia.Universitas Panca Budi Medan.

[7] Prabowo, N.E, Tohiruddin Lubis, Fairhurst, T.H, Foster,H.L. dan Evi Navisah N, 2002. Efficiency of fertiliser recovery by oil palm in sumatra. International Oil palm conference, Nusa Dua Bali, July 8-13 2002. AG-18

[8] Prabowo, N.E, Huge L. Foster, Paul L Nelson, 2023. Potassium and magnesium uptake and fertiliser use efficiency by oil palm at contrasting sites in Sumatra,Indonesia.

[9] Soon, B.B.F. and H.W. Hoong. 2001. Oil palm responses to N, P, K and Mg fertilizers on two major soil types. In: Proceedings PIPOC International Palm Oil Congress (Agriculture) Sabah

[10] Sudradjat. 2020. *Kelapa Sawit: Prospek Pengembangan dan Peningkatan Produktivitas*. Bogor. IPB Press