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NUTRIENTS LOSS BY SURFACE RUNOFF IN AN IMMATURE OIL PALM FIELD UNDER CONTROLLED-RELEASE AND SOLUBLE CONVENTIONAL MIXED FERTILIZATION

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Abstract

Implementation of sound fertilizer management program in the tropics is essential in optimizing production and profitability. Controlled release fertilizers are expected to minimize nutrients loss from crop fields due to their potential to supply plant-available nutrients in synchrony with crop requirement. One-year field trial was established to investigate the impact of fertilization with water soluble conventional mixed and controlled release fertilizers on runoff loss of nutrients under immature oil palm cropping. Soluble mixed fertilizer posed the greatest risk of nutrients loss following fertilization due to elevated nitrogen (6.97%), potassium (13.37%), magnesium (14.76%) and Boron (5.65%) concentrations in runoff and eroded sediments. On the contrary, this risk decreased with the application of controlled release fertilizers, representing 0.75-2.44% N, 3.55-5.09% K, 4.35-5.43% Mg and 0.61-1.01% B loss. Meanwhile, nutrients loss via eroded sediments was minimal compared with loss through runoff. The findings demonstrate that the addition of controlled release fertilizers reduced the runoff risks of nutrients loss possibly due their slow release properties.

Keywords: Soluble conventional mixed fertilizers, controlled-release fertilizers, oil palm, nutrients loss, runoff

Introduction

Our quest to meet the world's escalating food needs cannot be achieved without fertilizers, with commercial fertilizers responsible for nearly 40-60% of the world's food production (Roberts, 2009). The oil palm (*Elaeis guineensis Jacq*.) requires quite large quantities of fertilizers to achieve good yields (Comte et al., 2012), accounting for 50-70% of field operational costs and about 25% of the total cost of production (Caliman et al., 2007; Goh and Härdter, 2003). Recent report by Murphy (2014) revealed that current oil palm yields are typically about 4-6 t ha^{-1} for the best commercial plantations and 3-4 t ha^{-1} for the small holders, which are far below the expected potential yield of over 10 t of oil per hectare. This yield disparity can be partially attributed to low efficiency of fertilizers in oil palm plantations. The cultivation of oil palm on highly weathered soils (Ultisols and Oxisols) that are typically acidic and infertile (Shamshuddin and Anda, 2012) poses a colossal challenge to oil palm growers. Low fertilizers use efficiency remained significantly low in most crop fields in the tropics, mainly due to the impact of runoff and leaching related nutrients loss processes, which may ultimately result in poor crop performance, and increased risk of environmental contamination on both surface and ground water aquifers. It has been suggested that implementation of appropriate best management practices (BMPs), particularly in relation to improvement in palm nutrition (Oberthür et al., 2012), fresh fruit bunch (FFB) yields of 25-30 t ha^{-1} could be obtained even on infertile soils. Controlled release fertilizers (CRFs) are expected to minimize nutrients loss from crop fields due to their potential to supply plant-available nutrients in synchrony with crop requirements. Information regarding the fate of these fertilizers in tropical oil palm agro-ecological conditions is limited. Therefore, this research was undertaken to compare the impact of fertilization of controlled-release (AJIB® CRF) and soluble conventional mixed fertilizers on surface runoff losses of nutrients in an immature oil palm field.

Materials and methods

The study was carried out in 2012/2013 on a newly established oil palm field at the experimental station of Universiti Putra Malaysia Agriculture Park in Puchong, Selangor (02°N 59.035', 101°E 38.913'). Experimental plots measuring 4 m × 4 m were delineated along uniform land slope of 10%. The plots were demarcated with transparent plastic sheets inserted 5cm deep into the soil and 15cm above soil surface to prevent lateral flow and control the risk of nutrient contamination. Daily precipitation records were taken throughout the experimental period using a rain gauge installed at the experimental site. Twelve months old oil palm clones (AA Hybrida IS) obtained from Applied Agricultural Resources Sdn. Bhd were planted using the 9 m x 9 m x 9 m triangular system. The treatments evaluated in this study were: (i) control; (ii) soluble mixed fertilizers (Mixture); (iii) full dosage of granular CRF (CRFG-100%); (iv) 60% dosage of granular CRF (CRFG-60%); (v) full dosage of briquette CRF (CRFB-100%) and (vi) 60% dosage of briquette CRF (CRFB-60%). Mixture treatment is composed of a blend of water soluble straight fertilizers, viz. ammonium sulfate (21% N), Christmas Island Rock Phosphate (30% P_2O_5), Muriate of Potash (60% K_2O), and Kieserite (27% MgO). The grade of the coated CRFs (AJIB® CRF) is 10-6-20-2. The amount of N, P, K, Mg and B applied for standard fertilizer rates (full dosage CRFs and Mixture treatments) were 48.96, 13.07, 81.60, 5.86 and 1.24 kg ha^{-1} yr^{-1}, respectively. The treatments were arranged in randomized complete block design (RCBD) with three replications. The fertilizers were surface placed under the plant canopy in two splits per year at six months intervals. Runoff water samples were routed via a V-shaped stainless steel aluminum spout attached to a funnel-fitted tank. The

runoff samples were collected after each rainfall event that generated measurable runoff for duration of one year. For each rainfall event, the total water volume per each tank was recorded and 1L sub-samples were collected in clean polypropylene bottles, after which they were transported to the laboratory, filtered and analyzed for N, P, K, Mg and B content following standard analytical procedures.

Results

In general, loss of nutrients from plots treated with soluble mixture fertilizer was rapid at the initial stage following fertilization and then declined rapidly afterwards. Cumulatively, annual loss of N through runoff in the plots treated with Mixture fertilizers was 4.78 kg ha^{-1}, whereas the N loss from applied CRF fertilizers ranged between 1.73-2.56 kg ha^{-1} (Table 1). The net losses of added K and Mg fertilizer were greatest for mixture fertilizer treatments, accounting for 13% and 15%, respectively. Average annual loss of P in the runoff due to fertilization was relatively low with full dosage of granular CRF accounting for 4% loss. The losses of nutrients from the reduced dosages of CRFs (CRFB-60% and CRFG-60%) were consistently lower than their full dosage counterparts, although the latter showed better plant response. By comparing the nutrients lost through surface runoff with those lost in the eroded sediments, it is clear that runoff losses of nutrients in all treatments were substantially greater than those lost in displaced sediments. Results from this study also clearly demonstrated that fertilization with reduced dosages of both granular and briquette CRFs (CRFB-60%) and CRFG-60%) reduced the nutrients loss much better than both soluble Mixture and full dosage CRFs.

In economics sense, the results demonstrated that net annual nitrogen loss was MYR 19.35 ha^{-1} as ammonium sulfate from mixture fertilizer and MYR 5.36-7.93 ha^{-1} as ammonium sulfate from the CRFs (Table 2). The economic loss of P was MYR 4.20 ha^{-1} yr^{-1} as phosphate rock from Mixture fertilizer and MYR 5.50-8.52 ha^{-1} yr^{-1} as diammonium phosphate (DAP) from applied CRFs. Loss of K and Mg from applied Mixture fertilizer translated into MYR 35.09 ha^{-1} yr^{-1} as muriate of potash and MYR 6.87 ha^{-1} yr^{-1} as kieserite, respectively. For the CRFs, the losses of these nutrients (K and Mg) ranged from MYR 15.84-18.86 ha^{-1} yr^{-1} as muriate of potash and MYR 4.04-4.31 ha^{-1} yr^{-1} as kieserite, respectively. The results further indicate the total annual monetary value from fertilizers loss for Mixture, CRFB-60%, CRFG-60%, CRFB-100% and CRFG-100% were MYR 68, MYR 33, MYR 34, MYR 39 and MYR 43 ha^{-1} yr^{-1}, respectively. The findings also indicated that application of reduced dosages of CRFs appears to be the most effective option in saving cost compared to other treatments. In essence, the results implied that savings of MYR 26-35 ha^{-1} yr^{-1} may be attainable by adopting CRF application program in immature oil palm fields, assuming that field agro-ecological conditions are similar to the present study.

Table 1: Summary of net nutrients losses in oil palm ecosystem through surface runoff and eroded sediments

Fertilizer treatments	Net loss in runoff (kg ha^{-1} yr^{-1})	Net loss in eroded sediments (kg ha^{-1} yr^{-1})	Net total loss (kg ha^{-1} yr^{-1})	Net loss as % of nutrient applied
		Nitrogen (N)		
Control	1.20c ± 0.04	0.17c ± 0.01	1.37c ± 0.04	-
Mixture	3.85a ± 0.22	0.93a ± 0.27	4.78a ± 0.09	6.97
CRFB-60%	1.33bc ± 0.02	0.40ab ± 0.24	1.73bc ± 0.07	0.75
CRFG-60%	1.39bc ± 0.24	0.39ab ± 0.20	1.78bc ± 0.20	0.84
CRFB-100%	1.81b ± 0.26	0.41ab ± 0.12	2.22b ± 0.09	1.74
CRFG-100%	1.98b ± 0.30	0.58ab ± 0.16	2.56b ± 0.05	2.44
		Phosphorus (P)		
Control	0.40cb ± 0.16	0.12b ± 0.01	0.52b ± 0.02	-
Mixture	0.70ab ± 0.09	0.30a ± 0.07	1.00a ± 0.08	3.74
CRFB-60%	0.45b ± 0.14	0.24ab ± 0.05	0.69ab ± 0.05	1.31
CRFG-60%	0.49b ± 0.01	0.29a ± 0.03	0.78ab ± 0.06	2.02
CRFB-100%	0.64ab ± 0.03	0.31a ± 0.02	0.95a ± 0.02	3.28
CRFG-100%	0.92a ± 0.19	0.15b ± 0.06	1.07a ± 0.08	4.22
		Potassium (K)		
Control	3. 70c ± 0.17	0. 45c ± 0.11	3.70c ± 0.34	-
Mixture	12.48a ± 0.87	2.14a ± 0.37	14.62a ± 0.91	13.37
CRFB-60%	5.56b ± 0.13	1.08b ± 0.21	6.64b ± 0.52	3.60
CRFG-60%	5.35b ± 0.17	1.25b ± 0.37	6.60b ± 0.19	3.55
CRFB-100%	5.96b ± 0.16	1.32b ± 0.17	7.28b ± 0.67	4.38
CRFG-100%	6.83b ± 0.35	1.03b ± 0.23	7.86b ± 0.96	5.09
		Magnesium (Mg)		
Control	0.51b ± 0.04	0.11c ± 0.02	0.62c ± 0.05	-
Mixture	1.20a ± 0.14	0.28a ± 0.05	1.48a ± 0.12	14.76

CRFB-60%	0.70ab ± 0.08	0.19ab ± 0.04	0.89b ± 0.10	4.72
CRFG-60%	0.58b ± 0.03	0.29a ± 0.10	0.87b ± 0.08	4.35
CRFB-100%	0.76ab ± 0.07	0.17ab ± 0.02	0.93b ± 0.05	5.43
CRFG-100%	0.68ab ± 0.02	0.21ab ± 0.09	0.89b ± 0.08	4.65
		Boron (B)		
Control	0.020 ± 0.002	n/d	0.020± 0.005	0.00
Mixture	0.093 ± 0.011	n/d	0.093± 0.003	5.65
CRFB-60%	0.027 ± 0.004	n/d	0.027± 0.008	0.93
CRFG-60%	0.026 ± 0.023	n/d	0.026± 0.004	0.80
CRFB-100%	0.029 ± 0.004	n/d	0.029± 0.002	0.61
CRFG-100%	0.033 ± 0.021	n/d	0.033± 0.007	1.01

All analyses are mean ± standard error of mean (SEM). Means not sharing a common letter are significantly different by DNMRT ($p \leq 0.05$). n/d means not determined.

Table 2: Fertilizer loss in surface runoff and eroded sediments and the corresponding economic value of these losses

Fertilizer treatments	Fertilizers	Fertilizer loss (kg ha^{-1} yr^{-1})	Value of loss (MYR ha^{-1} yr^{-1})	Total loss (MYR ha^{-1} yr^{-1})
Control	-	-	-	-
Mixture	AS	22.76	19.35	67.79
	PR	7.63	4.20	
	MOP	29.24	35.09	
	KIE	9.15	6.87	
	BORAX	1.23	2.28	
	Total	70.01	67.79	
CRFB-60%	AS	6.30	5.36	33.02
	$DAP^{N\ source}$	0.88	1.41	
	$DAP^{P\ source}$	3.44	5.50	
	MOP	13.28	15.94	
	KIE	5.50	4.13	
	BORAX	0.36	0.68	
	Total	29.76	33.02	
CRFG-60%	AS	6.48	5.51	33.71
	$DAP^{N\ source}$	0.91	1.45	
	$DAP^{P\ source}$	3.88	6.21	
	MOP	13.20	15.84	
	KIE	5.38	4.04	
	BORAX	0.35	0.66	
	Total	30.20	33.71	
CRFB-100%	AS	8.09	6.87	38.73
	$DAP^{N\ source}$	1.13	1.81	
	$DAP^{P\ source}$	4.73	7.57	
	MOP	14.56	17.47	
	KIE	5.75	4.31	
	BORAX	0.37	0.70	
	Total	34.63	38.73	
CRFG-100%	AS	9.33	7.93	42.35
	$DAP^{N\ source}$	1.31	2.09	
	$DAP^{P\ source}$	5.33	8.52	
	MOP	15.72	18.86	
	KIE	5.50	4.13	
	BORAX	0.43	0.82	
	Total	37.62	42.35	

MYR = Malaysian ringgit, 1 USD = MYR 3.20
AS = Ammonium sulfate, PR = Phosphate rock, MOP = Muriate of potash, KIE = Kieserite and DAP = Diammonium phosphate.

Discussion

Controlled release fertilizers (AJIB® CRF) application in an immature oil palm field potentially decreased surface runoff loss of nutrients. This could be attributed to the fact that nutrient elements in CRFs are readily and slowly available for plant uptake over a given period. Nutrients loss data in this current study are consistent with other studies conducted in Malaysia. For example, studies conducted by Maene *et al.* (1979) showed that 11% N, 3% P, 5% K, 6% Mg, and 5% Ca of applied fertilizers were lost through surface runoff alone on a 9% slope gradient. The findings further indicated that the harvesting paths are the most susceptible areas to surface runoff due to compaction of the soil by machinery. Another study by Kee and Chew (1996) revealed that 5-8% N, 10-15% K, 4-6% Mg and <2% P were lost through runoff. This suggests that soluble nutrients such as N, K, and Mg are more susceptible to runoff losses. According to Wallace et al. (2013), large losses of nutrients via surface runoff are still possible when a large rainfall event occurs soon after application of fertilizers. A study by Blaylock et al. (2005) revealed that the CRF can be applied at considerably reduced dosages (25-35% less) than conventional fertilizer N source without compromising crop yield. It is imperative to note that fertilizers should be applied at the appropriate period of the rainy season in order to limit loss of nutrients. Considering the long term economic viability and environmental factors associated with nutrients loss, oil palm plantations may consider application of CRFs as an improved fertilizer management option. More research is needed to better elucidate mechanism of nutrients loss from oil palm ecosystems under different rainfall intensity situations and oil palm growth stages.

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