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Nutrient Losses Through Runoff from Several Types of Fertilisers Under Mature Oil Palm

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ABSTRACT

This study was conducted to understand the effects of fertiliser type (straights, compounds and controlled-release fertilisers) on N, P, K and Mg losses by surface runoff. The study was conducted in a mature oil palm field using three 20 m by 6 m erosion plots containing two palms per plot with the soil type being Typic Kandiudults and slopes ranging from 5.5° to 7.5°. Nutrient losses were measured in the eroded sediment and runoff water for every rainfall event over a period of 24 months. Nutrient losses were higher in the runoff water than in the eroded sediments. Broadcast application of controlled-release fertilisers and its slow dissolving nature made it prone to washing down the slope. Hence, higher nutrient losses were observed in the controlled-release fertilisers compared to other treatments. Compound fertilisers showed lower total losses for N (4.96%), K (3.95%) and Mg (0.65%) compared to straight fertilisers. Lower P losses were observed in the straights compared to the compound fertilisers due to higher percentage of soluble P in the compound fertilisers. Controlled- release fertilisers recorded high nutrient losses in the sediments caused by the washout Except for nitrogen, controlled-release fertilisers recorded higher losses for P (56.56%), K (19.83%) and Mg (10.36%) compared to straight fertilisers. Nitrogen losses were 18.15% lower in the controlled-release fertilisers compared to straights. Compound fertilisers showed lowest losses for N and K compared to straight fertilisers. Based on the data, it is postulated that compound fertilisers can lead to better nutrient uptake compared to straight fertilisers. However, this hypothesis needs to be tested through field experiments measuring nutrient uptake and its effect on oil palm productivity.

Keywords: Nutrient loss, surface runoff, oil palm, fertilisers, erosion.

INTRODUCTION

Cultivation of oil palm (*Elaeis guineensis Jacq.*) in the tropics requires a large input of fertilisers to achieve high and sustainable yields. On average, oil palm requires about 120 kg N ha^{-1} yr^{-1}, 16 kg P ha^{-1} yr^{-1} and 286 kg K ha^{-1} yr^{-1} to achieve yields of 30 t fresh fruit bunch (FFB) yields per ha (Tarmizi and Mohd Tayeb 2006). Fertilisers account for 60% of field upkeep cost and is the highest cost

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factor in oil palm production (Goh, Hardter and Fairhust 2003). Hence, most agronomic trials have focused on studies related to nutrient uptake, response and losses.

Studies on soil and nutrient loss through surface runoff and erosion under the oil palm environment have been carried out by several scientists namely Maene *et al*. (1979), Malaysian Palm Oil Board (PORIM 1994) and Chew *et. al.* (1999). These studies provide vital information for agronomists on the magnitude of nutrient losses through surface runoff for consideration in the formulation of fertiliser recommendations for oil palm. In addition, results of such trials also help planters and agronomists to implement various field management strategies to minimise soil and nutrient losses. However, in the early studies, type of fertiliser was not given due consideration.

The current study quantified N, P, K and Mg losses through surface runoff for mature oil palms fertilised with straights, compounds and controlled-release fertilisers.

METHODOLOGY

The study used erosion plots at United Plantation Berhad's Lima Blas Estate located at Selangor, Malaysia (3° 45' 15.762" N, 101° 20' 23.798" E) for 24 months from 1 February 2013 to 31 January 2015.

Three erosion plots measuring 20 by 6 m were established on a rolling terrain of a mature oil palm field. Slopes ranged from 5.5° to 7.5° for all three plots. Soil type at the study site was Typic Kandiudult (Serdang Soil Series). Each plot contained two mature oil palms planted in the year 2000.

Palms in each plot were fertilised with straights, compounds or controlled-release fertilisers at equivalent amounts (in split applications of three times per year) of nutrients N, P, K and Mg as provided in Table 1.

Prior to the start of the experiment, the palms in all three plots were not fertilised for a period of 12 months to avert effects of residual nutrients from the previous fertiliser application conducted in October 2011. This intervening period was used to measure nutrient losses for an unfertilised plot. Nutrient losses for an unfertilised plot was recognised when the nutrient content in both the eroded sediment and runoff water had minimal variances between erosion event and this was achieved about 10 months following the previous fertilisation.

TABLE 1

Nutrient inputs for erosion plot palms

Nutrient	Rate (kg $palm^{-1}$ $year^{-1}$)
N	1.10
P	0.44
K	1.49
Mg	0.20

A manifold tippling tumbler collection system was adapted to measure soil and runoff water losses from each plot for every rainfall event (Figure 1). The randomised complete block design was adopted for this study using every rainfall event that generated soil and runoff losses as a replicate for the study.

Samples of the collected eroded sediment and runoff water were analysed in the laboratory. The Kjeldahl method was adopted for the analysis of nitrogen (N), phosphorus (P) was determined using the Bray and Kurtz No 2 method while potassium (K) and magnesium (Mg) were determined using the Atomic Absorption Spectrophotometer (AAS).

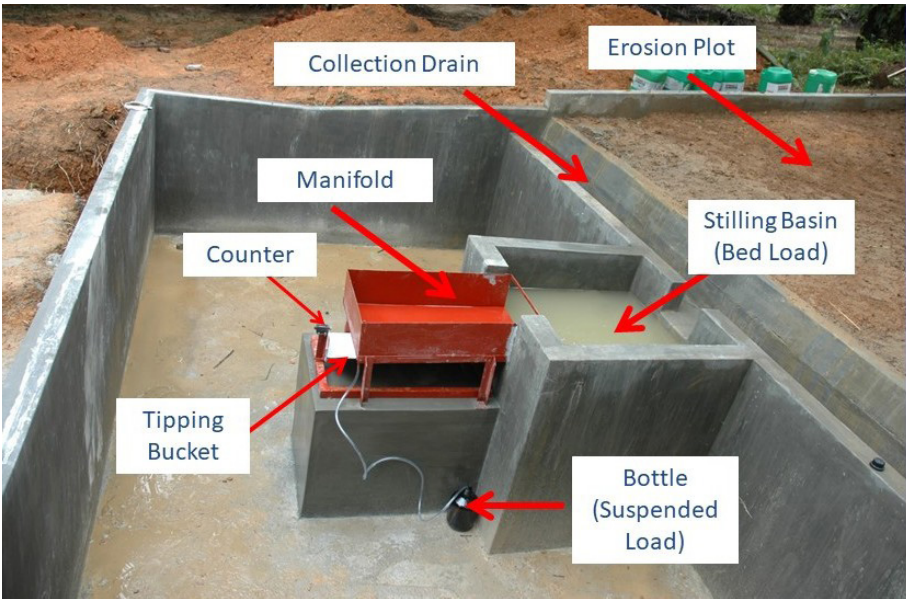


Fig. 1: Soil and runoff loss collection mechanism layout

RESULTS AND DISCUSSION

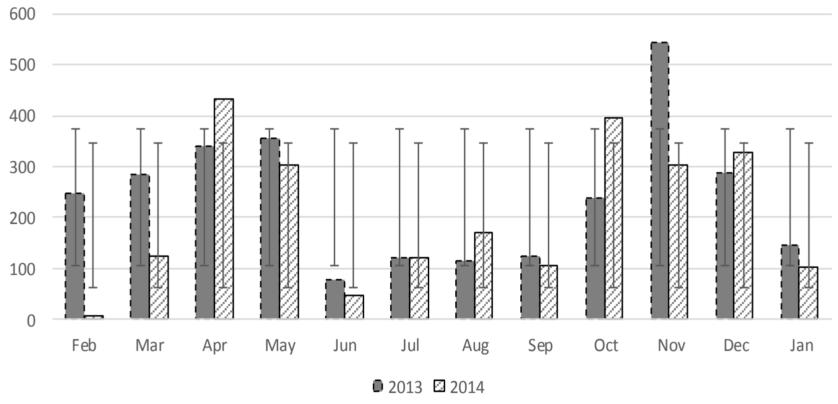
Rainfall

Total annual rainfall recorded for 2013 and 2014 was 2883 and 2441 mm, respectively. In the first year of study (2013), highest rainfall was recorded in the month of November at 546 mm while the highest rainfall in the second year was 434 mm in the month of April. The third trimester in both years had higher cumulative rainfall coinciding with the annual monsoon season. Figure 2 below shows the rainfall pattern during the study period.

Soil and Runoff Losses

Soil loss and runoff losses were measured at every rainfall episode that yielded runoff or soil loss. In 2013, of 120 erosion events were recorded whilst 116 events were recorded in 2014. Table 2 highlights the mean soil and runoff losses recorded.

Soil losses were generally high in all three plots as minimal erosion control measures and vegetation were in place in the plots in order to amplify the nutrient loss effects on application of the various forms of fertilisers. Soil loss recorded is noted to be within the soil loss range reported by previous authors (Soon and Hoong 2002; Chew *et al*. 1999; PORIM 1994). Mean runoff losses ranged from 19.23% to 23.20% of the mean rainfall for the two years (1 February 2013 to 31 January 2015) and were comparable to the range reported by Kee and Chew (1996).



Bars indicate standard deviation

Fig. 2: Rainfall distribution

TABLE 2
Mean (±SE) soil and runoff losses recorded

Year	Soil Loss (t ha^{-1} $year^{-1}$)		
	Plot A	Plot B	Plot C
2013	9.36 ± 0.18	17.87 ± 0.32	8.19 ± 0.15
2014	8.66 ± 0.20	16.25 ± 0.35	7.28 ± 0.16
Mean	**9.01[a]**	**17.06[b]**	**7.73[a]**
	Runoff Loss (mm)		
Year	Plot A	Plot B	Plot C
2013	625 ± 9.62	524 ± 7.23	555 ± 8.71
2014	566 ± 11.91	500 ± 10.01	529 ± 11.25
Mean	**596[a]**	**512[a]**	**542[a]**

Plot A: Straights, Plot B : Compounds, Plot C : CRF
Means not sharing a common letter are significantly different by Tukey ($p \leq 0.05$).

During the study period, Plot B consistently showed significantly higher soil losses compared to plot A and plot C. This is due to the differences in texture. Plot B had a higher percentage of fine sand in the top soil layer compared to plot A and plot C (Table 3).

TABLE 3
Soil texture analysis

Sampling Depth	0-15 cm			15-30 cm			30-45 cm		
	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C
Particles	Percentage (%)								
Clay (<0.002mm)	36.70	23.50	25.10	38.10	26.10	25.10	33.80	29.80	27.60
Silt (0.002–0.05 mm)	17.30	11.40	10.40	17.70	14.30	10.40	21.70	12.10	12.60
Coarse Sand (0.5-2.0 mm)	0.40	0.37	23.90	2.70	0.49	15.80	0.36	10.90	4.60
Fine Sand (0.05 - 0.5 mm)	45.50	64.80	43.60	41.40	59.10	48.70	44.10	47.30	55.20
Total Sand	45.90	65.17	67.50	44.10	59.59	64.50	44.46	58.20	59.80

Nutrient loss was measured based on nutrient content in the eroded sediments and as dissolved nutrients in the runoff water. Generally, it was noted that nutrient losses were much higher in the runoff water compared to the eroded sediments (Table 4), similar to the findings of Kee and Chew, (1996). During the data collection process, granules of the controlled-release fertilisers were observed to be washed down together with the eroded sediments even after a week of fertilisation.

Controlled-release fertilisers are generally resin-coated to achieve the control release properties where the resin dissolves at a slow rate in water. The broadcast application of these fertilisers around the palm circle and its slow dissolving rate makes it prone to washing down a slope. Hence, a higher loss of nutrients was recorded in the eroded sediments for the plot fertilised with controlled-release fertilisers compared to other treatments. Concomitantly, there were lower nutrient losses in the runoff water.

Broadcast application of controlled-release fertilisers on slopes under oil palm is not a viable option as a large amount of fertiliser is likely to be washed down from the targeted area due to the physical nature of the fertiliser. In contrast, straight and compound fertilisers which are generally hygroscopic, absorb moisture from both the atmosphere and the soil as soon as they are applied causing them to disintegrate from their original physical form and become part of the soil colloids, thus preventing any physical movement of the compound fertilisers.

There were no significant differences in nutrient losses recorded between all three treatments for both years of study (Table 4). Compound fertilisers showed lower total losses for N (4.96%), K (3.95%) and Mg (0.65%) compared to straight fertilisers. The lower losses in compound fertilisers are mainly due to the lower nutrient losses in the runoff water rather than the eroded sediments. Nutrient losses

TABLE 4

Mean (±SE) NPK losses in eroded sediments and runoff water

Year / Treatment	Plot A (Straights)			Plot B (Compounds)			Plot C (Controlled Release)		
	Soil	Water	Total	Soil	Water	Total	Soil	Water	Total
				kg nutrient ha^{-1} yr^{-1}					
					N				
2013	12.30^{a} ± 0.27	23.44^{a} ± 0.56		16.05^{a} ± 0.29	21.12^{a} ± 0.57		10.49^{a} ± 0.21	20.75^{a} ± 0.54	
2014	4.96^{a} ± 0.16	39.53^{a} ± 1.28		7.94^{a} ± 0.31	31.11^{a} ± 0.78		14.16^{a} ± 0.47	20.24^{a} ± 0.69	
Mean	*8.63*	*31.48*	*40.11*	*12.00*	*26.12*	*38.12*	*12.33*	*20.50*	*32.83*
% Loss vs straights						*-4.96*			*-18.15*
					P				
2013	1.09^{a} ± 0.03	1.92^{a} ± 0.05		2.26^{a} ± 0.06	3.06^{a} ± 0.05		1.32^{a} ± 0.03	1.70^{a} ± 0.05	
2014	2.24^{a} ± 0.09	1.61^{a} ± 0.07		2.13^{a} ± 0.12	1.29^{a} ± 0.06		6.26^{a} ± 0.27	1.47^{a} ± 0.07	
Mean	*1.67*	*1.76*	*3.43*	*2.20*	*2.18*	*4.38*	*3.79*	*1.57*	*5.37*
% Loss vs straights						*27.70*			*56.56*
					K				
2013	2.37^{a} ± 0.07	36.40^{a} ± 0.64		5.85^{a} ± 0.19	29.28^{a} ± 0.76		8.29^{a} ± 0.22	30.54^{a} ± 0.54	
2014	1.95^{a} ± 0.09	39.77^{a} ± 0.89		4.65^{a} ± 0.32	37.54^{a} ± 0.94		20.45^{a} ± 0.97	37.17^{a} ± 0.79	
Mean	*2.16*	*38.09*	*40.25*	*5.25*	*33.41*	*38.66*	*14.37*	*33.86*	*48.23*
% Loss vs straights						*-3.95*			*19.83*
					Mg				
2013	0.20^{a} ± 0.01	1.14^{a} ± 0.02		0.55^{a} ± 0.02	1.10^{a} ± 0.02		0.68^{a} ± 0.02	1.18^{a} ± 0.02	
2014	1.51^{a} ± 0.07	3.31^{a} ± 0.10		1.92^{a} ± 0.08	2.56^{a} ± 0.08		2.68^{a} ± 0.12	2.37^{a} ± 0.07	
Mean	*0.86*	*2.23*	*3.09*	*1.24*	*1.83*	*3.07*	*1.68*	*1.73*	*3.41*
% Loss vs straights						*-0.65*			*10.36*

Plot A: Straights, Plot B: Compounds, Plot C: CRF

Means not sharing a common letter are significantly different by Tukey ($p < 0.05$)

in the runoff water in the compound fertiliser accounted for about 55% of the total nutrient losses. Phosphorus losses were much higher in the compound fertilisers compared to straights as the compound fertiliser used for the study contained about 11% soluble phosphorus in the form of Triple Super Phosphate while in treatment A, phosphate rocks(which dissolve very slowly in water) were used as the source of phosphorus. The findings of these study are somewhat different from the works of Bah *et al*., 2014 who had reported that CRF tend to have lower nutrient losses compared to the conventional mixture. This is attributed to the physical form of the CRF used by Bah *et al*.(2014) which was in the form of nuggets which are more difficult to be washed down the slope unlike the granular CRF used in this study.

As significant differences were noted in the soil losses between the three treatment plots, nutrient losses were also expressed as per tonne soil loss and per 100mm runoff to provide an equal comparison between the three plots. Table 5 details nutrient losses as per Mg (per tonne) sediment and per 100 mm runoff.

TABLE 5
Mean nutrient loss expressed as per tonne sediment and per 100mm runoff.

Nutrient/	Nutrient loss per tonne sediment			Nutrient loss per 100mm runoff		
Treatment	A	B	C	A	B	C
			kg nutrient ha^{-1}			
N	1.06	0.71	1.56	7.41	6.10	4.91
% diff from A		*-33.02*	*47.17*		*-17.68*	*-33.74*
P	0.29	0.19	0.53	0.29	0.45	0.25
% diff from A		*-34.48*	*82.76*		*55.17*	*-13.79*
K	0.21	0.25	1.51	7.70	7.37	7.19
% diff from A		*19.05*	*619.05*		*-4.29*	*-6.62*
Mg	0.08	0.07	0.20	0.47	0.47	0.54
% diff from A		*-12.50*	*150.00*		-	*14.89*

Compound fertilisers clearly had much lower losses for nitrogen, phosphorus and magnesium compared to straight fertilisers. Potassium losses were marginally higher for the compounds compared to the straights. As for the controlled-release fertilisers, significantly higher losses were recorded for all nutrients analysed, largely caused by the rolling of the fertiliser granules down the slope.

In the runoff water, compound fertilisers showed lower losses of nitrogen and potassium compared to the straights. However, phosphorus losses were higher in the compound fertilisers compared to straights; it is to be noted that the phosphorus in compound fertilisers is water soluble. Magnesium losses were comparable to both straight and compound fertilisers.

CONCLUSION

Compound fertilisers generally recorded lowest losses for N and K compared to straight fertilisers and are therefore postulated to lead to better nutrient uptake compared to straight fertilisers. The lower losses in the compounds also provide the opportunity for the application of a lower nutrient rate compared to straights to meet the nutrient requirements of the oil palm. However, this hypothesis needs to be verified through field experiments to measure nutrient uptake and its effect on oil palm productivity

As nutrient losses are significantly higher in the runoff water for both straight and compound fertilisers compared to losses in the eroded sediments, efforts should focus on minimising runoff water losses as part of erosion control practices for oil palm planting on slopes.

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Essentials of Soil Science: Soil formation, functions, use and classification (World Reference Base, WRB).

Winfried E.H. Blu, Peter Schad, and Stephen Nortcliff. Borntraeger Science Publisher, Stuttgart 70176, Germany. 2018. 171 p. € 27.90. ISBN 978-3-443-01090-4.

This is a book which need to be read by students at all level, and suitable as a quick reference for anyone interested in the field of soil science.

Soil science is a field of study that focus on soil as an integrated system. As it may sound complex, this book made it all *facile à comprendre* to understand the definition, concepts and basics of soil. Information is well organized, written clearly, and profusely illustrated in total of nine (9) chapters, evermore concise and detailed text.

This book simplify many important concepts of soil science for reader to easily comprehend the concepts. Soil formation and functions begins with parent materials, minerals and weathering processes that give rise to secondary minerals are well sorted out with emphasis on soil morphology, 1:1, 2:1 clay, ion exchange (cations and anions), buffering capacity, pedogenesis, soil-plant interactions, soil pollution, etc. Alphabetical index system of the book is neat.

Soil use and classification were based on World Reference Base for Soil Resources (WRB), a system utilized by FAO-UNESO-UNDP in their agriculture related development programs and proved its worth in Africa, Asia, Europe, etc.

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A detailed, highly complex data and scientifically in-depth explanations are not the purpose of this book. If that is what the readers wants, look elsewhere, otherwise: Put this book on your next *"must-read"* list.

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