# EFFECT OF N AND K FERTILIZERS ON NUTRIENT LEACHING AND GROUNDWATER QUALITY UNDER OIL PALM

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## Introduction

The major nutrients required for oil palm are mainly nitrogen, phosphorus and potassium. When applying fertilizers to the palms, our goal is to maximize nutrient uptake by the palms from the fertilizers for optimum growth and production. Unfortunately, losses of applied fertilizer to the atmosphere or through runoff and leaching generally occur as unintended consequences of fertilization. One of major pathway of fertilizer losses is by leaching in which nutrients are moved down the soil profile until they reach a depth where there are no palm roots. Consequently this can be of serious environmental concern in areas where nutrients can enter groundwater. Nitrogen and potassium are the most nutrients at risk, because of the rather weak adsorption of ammonium and potassium ions and nil adsorption for nitrate (Corley and Tinker, 2007). It has been reported that leaching losses for a clay loam soil under mature palm were about 2-6% of the applied N and K fertilizers and 1-3% for P fertilizer (Foong, 1993).

## Objective

The main objective of this project is to study the leaching losses of nitrogen (N) and potassium (K) nutrients in the oil palm plantation and the other specific objectives are;

i) To evaluate the vertical profile of leaching of N and K
ii) To relate the amount of leaching of N and K with rainfall and fertilizer application rates
iii) To examine the effect of fertilizer application on groundwater quality

## Research Methodology

### Site description

This experiment was conducted in the oil palm plantation in Sri Kunak Estate in Tawau, Sabah, East Malaysia. The planting density of the area is 132 palms/ha. The palms were planted in 1982 which were originated from planting material of Dura (D) x Psifera (P). The site was described as undulating to rolling with slope of $0^o$ to $6^o$. The soil type was of Kumansi soil series or Orthic Acrisols under the FAO classification.

### Treatment Plots

For the purpose of this study, 15 treatment plots where A, B and C were replicates, were selected from the existing fertilizer response trial in this estate as shown in Table 1. The fertilizer was applied on the palm circle at about 1-2 m from the trunk for both N and K fertilizers at the frequency of 3 rounds/year (3x) and 2 rounds/year (2x) respectively and P was broadcast evenly on the inter row or frond heaps. The source of fertilizer for N is ammonium chloride (AC) and the rates are 0 kg AC/palm/year (N0), 3.75 kg AC/palm/year (N1) and 7.5 kg AC/palm/year (N2). Muriate of Potash (MOP) is the source of fertilizer for K which is applied at 0 kg MOP/palm/year (K0) and 4.5 kg MOP/palm/year (K1). Jordanian Rock Phosphate (JRP) is the source for P and the rate is 4.0 kg JRP/palm/year (P2) and 0 kg JRP/palm/year at P0.

Table 1: Selected plots

| Treatment | Treatment No | Plot No | | |
|---|---|---|---|---|
| | | A | B | C |
| N0P0K0 | T1 | A9 | B9 | C4 |
| N0P2K1 | T6 | A2 | B2 | C17 |
| N1P2K1 | T12 | A14 | B17 | C5 |
| N2P2K1 | T18 | A5 | B13 | C12 |
| N1P2K0 | T11 | A10 | B10 | C13 |

Note A, B and C is replicates

**Lysimeter and well installation**

The soil water sampler used in this study is a standard vacuum lysimeter used in studying pore liquid sampling from vadose zone (ASTM, 2000) and is also called the suction lysimeter. The lysimeters were installed at each of the 15 treatment plots (Table 1) at depth 30 cm, 60 cm and 120 cm at about 1.5 m from the palm trunk. Due to soil and geological constraint, monitoring wells were only installed at A2, A14, B10, B13, C12 and C4 plots. The lysimeter was installed according to the manufacturer operating manual ( Soil moisture, . The monitoring well was constructed based on the principle described by Bouwer (1978). The water (leachate) from the lysimeter and monitoring well were collected at every 15 days for duration of one year. In addition to the 15 days sampling schedule, 5 rounds of sampling will be conducted the next day after each heavy rainfall (≥10 mm) and the sampling event will be counted after the first day of fertilizer application which will be started after the 2$^{nd}$ round fertilizer application. However for this report results were based on the 10 batches of sampling and 1$^{st}$ round of fertilizer application.

**Sampling and laboratory analysis**

All leachates and groundwater water samples were collected and stored in a narrow mouth polyethylene bottle. The sample was preserved with 2-4 mL of chloroform per litre to retard bacteria decomposition followed by refrigeration at 4$^{o}$C. Samples were then analysed for ammonium-N ($NH_4$-N), nitrate N ($NO_3$-N), nitrite N ($NO_2$-N) and potassium (K) according to APHA standard method (APHA, 1998). The total N is the sum of N components ($NH_4$-N + $NO_3$-N + $NO_2$-N).

**Experimental design and statistical analysis**

For this study, a split plot design was chosen for the cumulative data whereby fertilizer treatment was taken as the main plot and depth as the sub plot. On the other hand for measurement over time, a split split plot design was used. For this design, the fertilizer treatment was taken as the main plot, depth of lysimeter as the sub plot and time as the sub-sub plot. The statistical method used was the analysis of variance (ANOVA) for cumulative data and ANOVA repeated measures for measurement over time data. However, for this semester only results by measurement over time for 10 rounds of sampling data will be discussed.

**Results & Discussion**

**Leaching losses at 120 cm soil depth:** The amount of leaching losses measured at 120 cm soil depth over 150 days was based on the volume of soil solution and nutrient concentrations for two replicates only to avoid missing values (Table 2). The leaching losses of inorganic N ranged from 0.043 $gm^{-2}$ to 0.589 $gm^{-2}$. For treatment, N1P2K1, it translated into a leaching loss of N of only 1.6% of the applied N fertilizer. This was agreeable with the results of Foong[10] for mature palms. Most of the N loss was in the form of $NH_4$-N since nitrification rate seemed low in the soils.

Without the application of K fertilizer, the leaching losses of K were only 0.09 g $m^{-2}$ (Table 2). Applications of K fertilizer increased the leaching losses of K over 150 days to 6.35 g $m^{-2}$ and 2.92 g $m^{-2}$ for N0P2K1 and N1P2K1, respectively (Table 2). These were equivalent to 5.3% and 2.4% of the applied K fertilizer for the above treatments, respectively. The higher K losses from the applied fertilizer in the absence of N (N0P2K1) might be attributed to the poorer yield compared with N1P2K1 and thus, lower K uptake from the soils by the palms (Table 2).

Table 2: Cumulative leaching losses of N and K fertilizers under mature oil palms as influenced by fertilizer treatments

| Fertilizer treatment | Leaching losses ($g/m^2$) | | | | Leaching losses (%) | | Yield (kg/palm/year) |
|---|---|---|---|---|---|---|---|
| | $NH_4$-N | $NO_3$-N | Total N | K | N | K | |
| N0P0K0 | 0.036 | 0.0061 | 0.043 | 0.089 | | | 175 |
| N0P2K1 | 0.051 | 0.0055 | 0.057 | 6.349 | | 5.3 | 203 |
| N1P2K0 | 0.300 | 0.0194 | 0.320 | 0.09 | 1.0 | | 209 |
| N1P2K1 | 0.554 | 0.0342 | 0.589 | 2.922 | 1.6 | 2.4 | 264 |
| $LSD_{0.05}$ | 1.212 | 0.0408 | 1.251 | 11.43 | | | |

**Groundwater quality:** The $NH_4$-N concentrations in the groundwater of the monitoring wells were similar for N treatments at 0 or N1 rate regardless of K application rate (Figure 1). They were mainly below the WHO's maximum admissible limit of drinking water of 0.5 mg/L. However, when excessive N rate, which was about twice the optimal N rate for oil palm, was applied, the $NH_4$-N concentration in the groundwater was increased to 2.7 mg/L. This indicated that contamination of the groundwater of monitoring well might occur if large amount of unabsorbed N from soluble N fertilizer was present in the soils during the monsoon period.

The $NO_3$-N concentrations in the groundwater were also raised by the applications of N fertilizer ranging from 0.07 mg/L to 0.25 mg/L (Figure 2). However, they were all below the WHO's maximum admissible limit of drinking water of 10 mg/L.

Without K application, the K concentrations in the groundwater were very low at less than 1 mg/L (Figure 3). The applications of K fertilizer increased the K concentrations of groundwater to between 4.28 mg/L and 9.54 mg/L. The higher concentration of K in the groundwater in the absence of N (N0P2K1) compared with N1P2K1 might be contributed by the higher leaching losses due to poorer K uptake by the palm as reflected the poorer yield (Table 2). However, only when excessive rate of N was applied (N2P2K1), the concentration of K in the groundwater was increased which was higher than at N0P2K1 and N1P2K1.

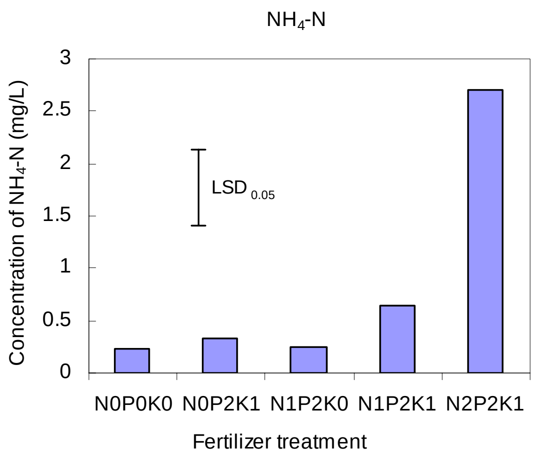


Figure 1: $NH_4$-N concentration in the monitoring well

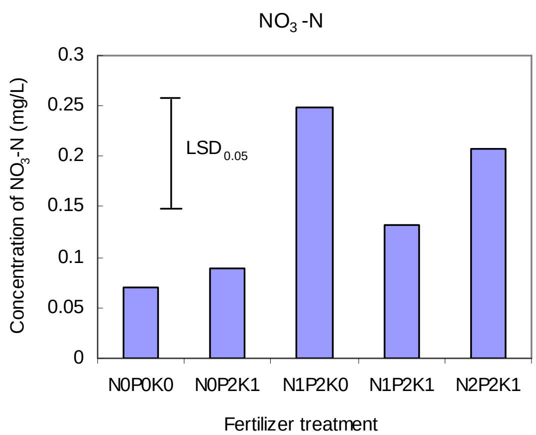


Figure 2: $NO_3$-N concentration in the monitoring well

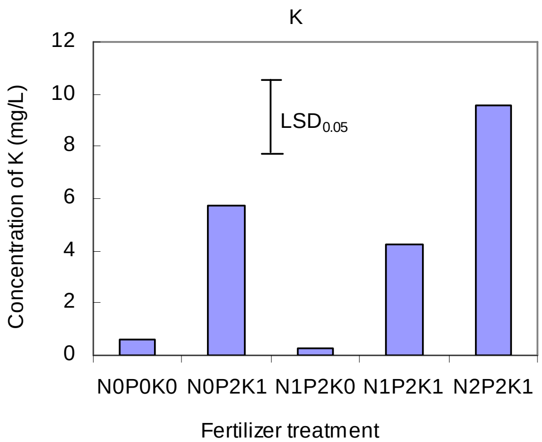


Figure 3: $NO_3$-N concentration in the monitoring well

## Significance of Finding

The N leaching losses of the applied N fertilizer during the monsoon period in Sabah, were 1.0% and 1.6% for treatments, N1P2K0 and N1P2K1, respectively. Higher K leaching losses were obtained at 5.3% and 2.4% for N0P2K1 and N1P2K1, respectively. Groundwater quality was not affected by the applications of N and K fertilizers at the optimum rates for mature oil palms.