POTASSIUM FIXATION AND RELEASE IN ALLUVIAL CLAY SOILS OF MILNE BAY, PAPUA NEW GUINEA: EFFECTS OF MANAGEMENT UNDER OIL PALM

Dissertation submitted by:

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ABSTRACT

Potassium deficiency is pronounced in oil palm and other crops on alluvial clay soils of Milne Bay Province in Papua New Guinea. These clay soils contain clay minerals that can fix K. This, coupled with large amounts of exchangeable Mg and Ca, triggers the K deficiency problem in oil palm growing in this area. Oil palm yield and other growth parameters had responded positively to K fertiliser application for the last 12-13 years in long-term factorial fertiliser trials. However, a K use efficiency study showed that 40% of the added K was taken up by the oil palm while more than 50% had accumulated in the top 60 cm of the soil. There is currently limited information to explain why K accumulated in the soil and the implications for management. Fixation of K could be one of the factors contributing to K accumulation. Therefore, this study was carried out to determine fixation and release characteristics of K in alluvial clay soils under oil palm cultivation in relation to soil and management factors.

All the work was carried out using soil samples collected in 2007 from plots with different K fertiliser history in two long-term fertiliser trials, trial 502b and 504, which had been operating since 1995 and 1994, respectively. Soil mineralogy was predominantly smectite in trial 502b and vermiculite in trial 504. In Experiment 1 (Chapter 3), the effects of management (K fertiliser history and surface management) on the amounts and forms of K in the soil was examined by measuring exchangeable (ammonium acetate extractable) and non-exchangeable (sodium tetraphenyl borate extractable minus ammonium acetate extractable) K. The results showed that in both trial sites, the management zones receiving K fertilizer (frond pile [FP], frond tip [FT] and between other zones [BZ]) had significantly ($p<0.001$) higher concentration of both exchangeable and non-exchangeable K than the other zones (weeded circle [WC] and harvest path [HP]). The exchangeable and non-exchangeable K concentrations differed significantly between sites, and there was a significant interaction between sites and K fertiliser history. In the plots and zones that had received fertiliser, exchangeable and non-exchangeable K contents were higher in trial 502b than 504, whereas in the plots that had received no fertiliser they were higher in trial 504 than 502b. In the plots that had received no K fertiliser, contents of exchangeable and non-exchangeable K were very low and could be considered deficient at both sites. The difference between the two sites was related to the mineralogy of the soils.

In Experiment 2 (Chapter 4), the effects of site and previous management on K fixation were determined. Solutions with nine different concentrations of KCl (equivalent to 0, 3.2, 9.6, 12.8, 16.0, 19.2, 22.4 and 25.6 mmol K kg^{-1} soil) were added to the soil, centrifuged and decanted.

Exchangeable K was then extracted from the soil with 1 M ammonium acetate. The decanted equilibrium solutions and ammonium acetate extracts were analysed for K using an atomic absorption spectrophotometer. Fixed K was determined using the formula: Fixed K = added K minus decanted equilibrium solution K minus ammonium acetate extractable K. Potassium fixation was significantly ($p<0.001$) affected by the K fertiliser history and surface management. In soils and zones that had received no K fertiliser, an average of 27% of added K was fixed in both trials, whereas in the plots with a history of K fertiliser, there was little net fixation or release in the WC zone and a considerable release of non-exchangeable K in the BZ and FP zones.

In Experiment 3 (Chapter 5), the release of K from non-exchangeable form into solution was studied. Firstly, the exchangeable K in the soil was removed by rinsing the soil three times with 0.25 M $CaCl_2$. Then the soil was equilibrated with 0.01 M $CaCl_2$ for 480 hours. At various intervals during that period, the supernatant was removed, analysed for K, and replaced with fresh 0.01 M $CaCl_2$. In the plots that had received no K fertiliser, more K was released from the native non-exchangeable pool in trial 504 than trial 502b. In the plots that had received K fertiliser, a substantial amount of K was released. In those plots more K was released in trial 502b than 504. In both trials, more K was released from the FP zones than the other zones, and K release in both trials increased in the order; HP<WC<BZ<FT<FP. The kinetics of K release from non-exchangeable K pool was described well by the Elovich function in all samples (r^2 = 0.957-0.989; se = 0.002-0.179). Over all samples, the parameters α and $1/\beta$ were linearly related to the amount of non-exchangeable initially present; i.e. the rate of release of non-exchangeable K was positively related to the amount present. The rate of release was greater for trial 502b than trial 504.

This study showed that management has a large effect on the fixation and release of K in alluvial soils of PNG under oil palm cultivation. Soil behaviour differed considerably between management zones, suggesting that K fertiliser placement might have a considerable effect on uptake efficiency.

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