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CONCENTRATION OF NPK IN SOIL DURING BIODEGRADATION OF OIL PALM TRUNK USING FUNGAL TREATMENT

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ABSTRACT

This study was carried out to evaluate the effectiveness of selected combinations of fungi on the amount of total nitrogen (TN), available phosphorus (AP) and exchangeable potassium (EK) when added as degrading agent to oil palm woodchips in field plot trials. Four different fungal combinations *Trichoderma harzianum* with brown rot SK8/11 (T1), *T. harzianum* with white rot SK7/5 (T2), *T. reesei* with brown rot SK8/11(T3), and *T. reesei* with white rot SK7/5 (T4)] were used as biodegradation agents added to the oil palm woodchip heaps; while an untreated woodchip heap (T5) was the control. The results from this study showed the addition of fungal combinations has significantly increased ($p< 0.05$)the concentration of TN and EK in the soil beneath the oil palm woodchip heaps as compared to control.

Key words: Available phosphorus, biodegradation, exchangeable potassium, degrading fungal, shredded oil palm woodchips, total nitrogen

ABSTRAK

Kajian ini dijalankan untuk menilai keberkesanan gabungan kulat terpilih ke atas nitrogen jumlah (TN), fosforus tersediada (AP) dan kalium salingtukar (EK) apabila ia ditambah sebagai agen pengurai kepada ricikan batang kelapa sawit di lapangan percubaan. Empat gabungan kulat, iaitu *Trichoderma harzianum* bersama pereput perang SK8/11 (T1), *T. harzianum* bersama pereput putih SK7/5 (T2), *T. reesei* bersama pereput perang SK8/11 (T3), *T. reesei* bersama pereput putih SK7/5 (T4) sebagai agen biopengurai yang ditambah ke atas longgokan ricikan batang kelapa sawit, manakala T5 ialah longgokan kawalan (tanpa kulat). Hasil kajian ini menunjukkan penambahan kombinasi kulat telah meningkatkan kepekatan TN dan EK dengan signifikan ($p<0.05$) di dalam tanah di bawah ricikan batang kelapa sawit berbanding dengan kawalan.

Kata kunci: fosforus tersediada, biopengurai, kalium salingtukar, kulat pengurai, ricikan batang kelapa sawit, nitrogen jumlah

INTRODUCTION

Palms planted in inland soils in Malaysia require nutrients such as nitrogen (N), phosphorus (P) and potassium (K), which are generally supplied as fertilizers (Tarmizi, 2000). The palms planted on soils with poor nutrient status typically grow to be short and small, with smaller fronds and lower yield. Recently, interest has grown in using crop residues for improving soil productivity while reducing the use of inorganic fertilizer. With the adoption of a policy of zero burning in replanting oil palm, chipped palm trunks are piled between planting rows and left *in situ* to rot (Khalid *et al.,* 2000). The main utilizable oil palm biomass was derived from the trunk, which contained high nutrient concentrations of N (0.58%), K (1.86%), P (0.06%), lignin (18.14%) and holocellulose (83.06%) (Khalid *et al.*, 2000).

Crop residues are important sources of organic matter that can be returned to soil for nutrient recycling and to improve physical, chemical and biological properties of the soil (Kumar and Goh 2000). Decomposition of biomass provides humus

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and plays an important role in improving nutrient recycling in the soil. The nutrients in the biomass can be recycled as fertilizer to the growing crops, thus reducing the need for application of chemical fertilizers (Mohd Noor 2003).

The organisms predominantly responsible for lignocelluloses or wood degradation are Basidiomycetes and various soil fungi (Watanabe *et al.*, 2003). The fungus *Trichoderma* is well-known for their ability to degrade cellulose and other compounds in cell walls by producing cellulase and can grow rapidly in natural and artificial substrates (Nsereko *et al.*, 2002). White-rot fungi is considered to be the primary degraders of lignin and lignocellulosic materials in terrestrial ecosystems (Kersten and Cullen, 2007). The white rot fungus *Phanerochaete chrysosporium* produces complex arrays of cellulases, hemicellulases, and lignin-degrading enzymes for the efficient degradation of all three major components of plant cell walls; cellulose, hemicellulose, and lignin (Henriksson *et al.*, 1999).

The objective of this study was to evaluate the effectiveness of the fungal combinations on total nitrogen (TN), available phosphorus (AP) and exchangeable potassium (EK) added to the soil through decay of oil palm woodchips.

MATERIALS AND METHODS

This biodegradation study was performed in the field of Phase 1, Malaysian Palm Oil Board (MPOB) Research Station Keratong, Pahang. One palm trunk was chipped by a chipper and was then pooled into a heap. Each experimental plot comprised a heap of palm wood chips covering 4.73 m x 4.73 m in area (Fig. 1a). The experimental design consisted of a random complete block with four treatments of different fungi combinations. Four fungal mixtures were used for degradation treatment of oil palm wood chips, namely T1, T2, T3, and T4 (Table 1). The fungal materials used in this study were obtained from the MPOB culture collection. The four fungal mixtures consisted of combinations of one fungus, either *Trichoderma harzianum* or *T. reesei*, with one degrader, either brown rot SK/8/11 or white rot SK/7/5. The combinations of selected degraders were inoculated to the heaps of oil palm wood chips. The treatment was done in four replicates.

The fungal isolates were cultured on malt extract agar (MEA) and incubated at 30ºC for three days as a source of inoculum. About 20 discs of mycelia for each fungus were cut from the MEA plate using a 6-mm cork borer, and these were then inoculated for seeding into 1000 mL of 1% malt extract broth (MEB), pH 7.5 in a conical flask and incubated at 30ºC with continuous gentle shaking at 170 rpm for three days. Subsequently, fermentation was scaled up 10-fold in 2.5% corn broth (25 g ground dry corn, pH 7.5 in 1000 mL water) using a fermenter (Biostat B Braun). The culture was incubated at 30ºC and agitated continuously at 300 rpm for five days.

Table 1. Combinations of biodegrading fungi in the treatment plots

Plot	Combination of fungi
T1	*T. harzianum* and Brown rot SK/8/11
T2	*T. harzianum* and White rot SK/7/5
T3	*T. reesei* and Brown rot SK/8/11
T4	*T. reesei* and White rot SK/7/5
T5	Control (no fungal treatment)

(a) (b)

Fig. 1. Degradation of oil palm trunk. (a) A heap of oil palm woodchips treated with biodegrading fungi; (b) A treatment plot of decomposed oil palm woodchips.

For every plot, about 25 L of the fungal mycelia for each inoculum suspension was poured onto the oil palm woodchips heap and covered with palm fronds to enhance fungal growth. The amount used was sufficient to cover the whole woodchips heap with fungal cocktail, and the fungal growth was monitored monthly by observing the fruiting bodies of the inoculated fungi during the 12 months of degradation period. At the end of each month, a soil sample was taken from a depth of 0-10 cm below each treated woodchip heap for analysis (Fig 1b).

In the laboratory, soil samples were spread on the tray; stones were removed while large aggregates of soil were broken into small pieces, air-dried in a ventilated room for two days, and then crushed gently using a mortar and pestle, finally sieved through a 0.5 mm mesh sieve.

Soil Nutrient Analysis

Total nitrogen (TN) in the soil sample was determined using a macro-Kjeldhal method (SIRIM 1980), while exchangeable potassium (EK) was determined by ammonium acetate extracting method (SIRIM 1980), and available phosphorus (AP) by the molybdenum blue method (SIRIM 1980).

Data analysis

One way ANOVA Tukey multiple comparison was used to evaluate the difference between before biodegradation (0 month) with measurements of total nitrogen, available phosphorus and exchangeable potassium in the soil after 2, 4, 6, 8, 10 and 12 months of biodegradation. This test was also used to compare differences between various fungal treatments and the control plots, at $P<0.05$ significant level.

RESULTS

Total nitrogen (TN)

The percentage of TN in the soil for all study plots T1, T2, T3 and T4 increased from 0.13%, 0.13%, 0.12% and 0.14% at the start of the experiment to 0.22%, 0.19%, 0.17% and 0.19%, respectively, during 6-month degradation of the oil palm woodchips (Fig. 2). The contents of TN in the experimental plots treated with T2 increased significantly from month 2 until month 12 as compared to month 0 in the same treatment plot (Fig. 2). The highest increment of TN from 0.13% in month 0 to 0.22% in month 10 was observed with T1 treatment, while the lowest increment (0.13% in month 0 to 0.14% in month 10) was recorded in the control plot (T5).

Available phosphorus (AP)

The available phosphorus in plots treated with T2, T3 and T4 increased from 471 cmol/kg, 452 cmol/kg and 428 cmol/kg in month 0 to 599 cmol/kg, 671

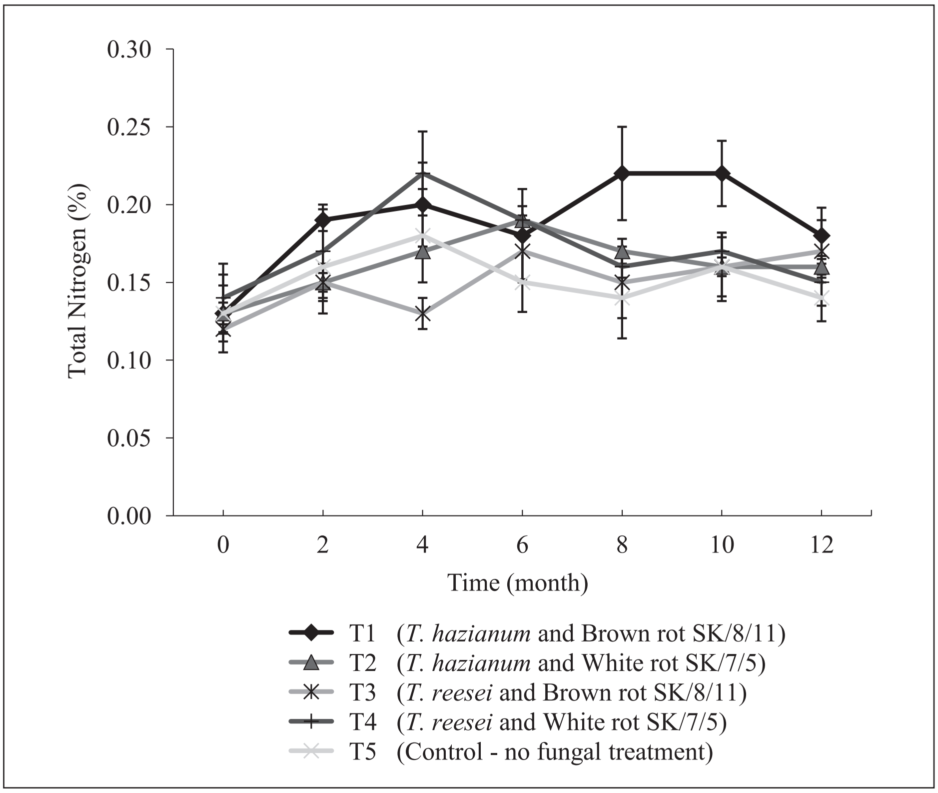

Fig. 2. Nitrogen content in the soil of oil palm woodchips treated with different fungal mixtures.

cmol/kg and 622cmol/kg in month 10, respectively (Fig. 3). Of all the fungal mixtures, the combination of *T. reesei* and white rot SK/7/5 (T4) gave the highest increment in available phosphorus (67% from month 0 to month 8) but it was not significant compared to control. The lowest increment (18% from month 0 to month 8) was observed in T5, the control.

Exchangeable potassium (EK)

The treatment plots T1, T2, T3 and the control plot T5 showed EK contents in the range of 0.22 to 0.39 cmol/kg. The concentrations of EK in the soil of all plots including the control significantly increased ($P<0.05$) from month 0 to month 2, which was 0.25 cmol/kg to 2.06 cmol/kg for T1, 0.39 cmol/kg to 2.39 cmol/kg for T2, 0.22 cmol/kg to 1.61 cmol/kg for T3, 0.23 cmol/kg to 2.34 cmol/kg for T4 and 0.28 cmol/kg to 1.55 cmol/kg for T5, (Table 2). The contents of EK decreased after month 6 for all plots. Treatment using T1 and T4 released higher concentrations of EK as compared to T2 and T3 (Table 2).

DISCUSSION

This study investigated the enhanced degradation of oil palm woodchip lignocellulose biomass by application of different combinations of fungi. The study by Siti Ramlah *et al*. (2010) with same fungal treatment as studied in this paper showed that degradation of oil palm woodchips treated with fungi reduced lignin and cellulose by 37%, 59%, 59% and 56% for treatments T1, T2, T3 and T4, respectively, while the untreated control, T5, showed only a 15% reduction in biomass. In this study fruiting bodies were not included for degradation.

The increase in total nitrogen observed in this study suggested that the fungal mixtures of *T. harzianum* and brown rot SK/8/11 (T1), and *T. reesei* and white rot SK/7/5 (T4) were good at degrading oil palm woodchips. Khalid *et al.* (2000) showed in his study that slower release of nitrogen occurred with 76% of the original nitrogen content still remaining in the oil palm woodchips after six months of natural decomposition (without fungal

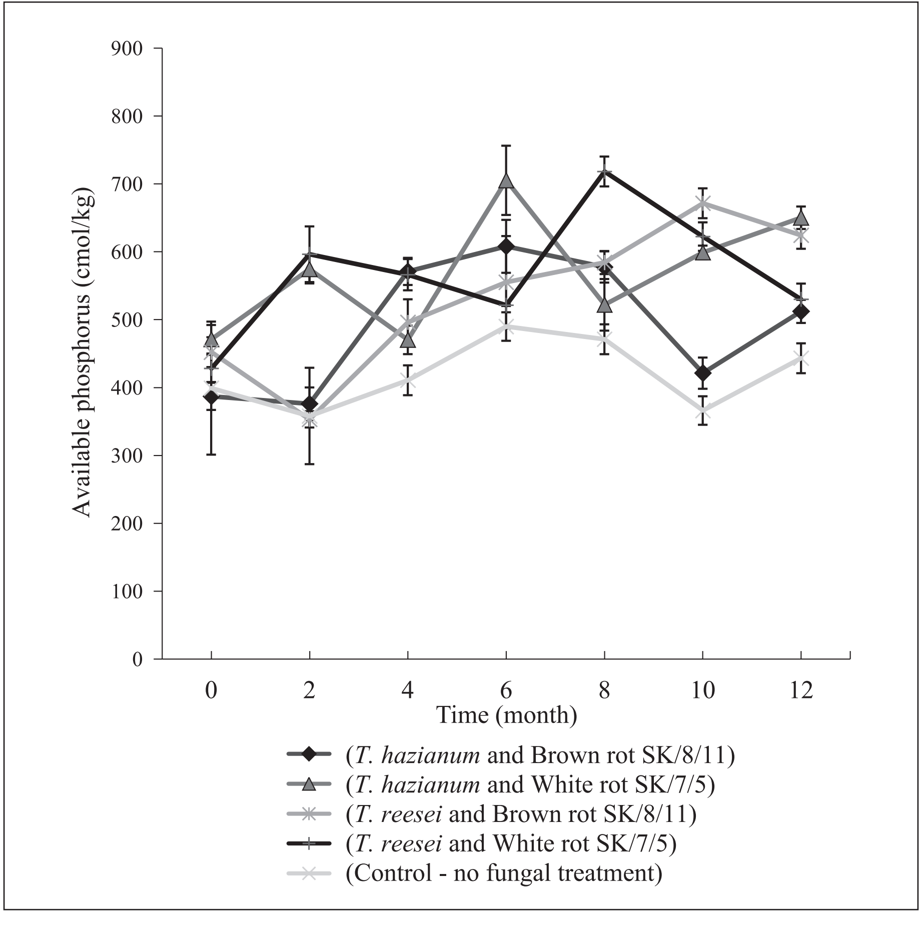

Fig. 3. Available phosphorus content in the soil of oil palm woodchips treated with different fungal mixtures.

Table 2. Exchangeable potassium content in the soil of oil palm woodchips treated with different fungal mixtures

Treatments	Exchangeable potassium (cmol/kg)						
	Month 0	Month 2	Month 4	Month 6	Month 8	Month 10	Month 12
T1	0.25 ± 0.02	2.06 ± 0.25*	2.36 ± 0.08*	2.05 ± 0.13*	1.94 ± 0.19*	1.55 ± 0.15*	1.42 ± 0.38*
T2	0.39 ± 0.01	2.39 ± 0.23*	2.44 ± 0.10*	1.90 ± 0.30*	1.72 ± 0.21*	1.31 ± 0.18*	1.21 ± 0.10*
T3	0.22 ± 0.04	1.61 ± 0.32*	2.53 ± 0.66*	2.32 ± 0.16*	1.55 ± 0.16*	1.54 ± 0.14*	1.56 ± 0.16*
T4	0.23 ± 0.06	2.34 ± 0.51*	2.29 ± 0.47*	2.28 ± 0.25*	2.08 ± 0.15*	1.64 ± 0.16*	1.59 ± 0.27*
Control	0.28 ± 0.07	1.55 ± 0.15*	1.91 ± 0.22*	1.56 ± 0.19*	1.46 ± 0.15*	1.31 ± 0.16*	1.12 ± 0.18*

T1= *T. harzian*um and Brown rot SK/8/11, T2= *T. harzianum* and White rot SK/7/5, T3= *T. reesei* and Brown rot SK/8/11, T4= *T. reesei* and White rot SK/7/5.

* = Significantly increased at $p < 0.05$.

treatment). A study by Lim and Zaharah (2000) of the decomposition of oil palm empty fruit bunches placed under mature palms showed that N compounds were not released in the first 10 months after placement, but was instead released only after 2 years of decomposition.

Phosphorus in organic compounds is held by covalent bonds that prevent its ionization. Phosphorus is usually bonded to oxygen and attached to soil molecules by a carbon-oxygen-phosphorus bond sequence (Frederick & Louis, 2005). Decomposition breaks the carbon-oxygen bond and mineralizes the phosphorus into a form that is available for plant uptake. In this study, the introduction of biodegrading fungi increased the concentration of AP in the soil up to 67% by month 8. A study by Khalid *et al*. (2000) showed that the available P in the soil beneath oil palm woodchip heaps increased to its maximum level after 12 months of decomposition.

In this study, potassium was found to be released rapidly from decomposition oil palm woodchip heaps into the soil. Rosenani *et al.* (1996) reported that increment of EK occurred after 15 months when mulching with empty fruit bunch of oil palm, while Khalid *et al.* (2000) found similar result but at longer time, after 18 months, when using chips of palm trunk residue. However, better results have been achieved in this study using specific combinations of fungi (T2 and T4) to the oil palm woodchip heaps to accelerate the release of inorganic nutrients after 12 months of decomposition.

CONCLUSION

All treatments of oil palm woodchip heaps with selected fungal mixtures had increased the concentrations of total nitrogen, available phosphorus and exchangeable potassium. However, the most optimum treatment using a combination of *Trichoderma reesei* and white rot SK/7/5 (T4) gave the highest increase in nutrient concentrations.

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