Ilmu Pertanian (Agricultural Science)
http://journal.ugm.ac.id/jip
Vol. 5 No. 2 August, 2020: 110-116| DOI: doi.org/10.22146/ipas.36823

The influence of urease and nitrification inhibitor on loss of N and oil palm harvest in peat

Aldy Slamet Riyadi[1], Eka Tarwaca Susila Putra[1*], and Eko Hanudin[2]

[1]Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada
Jln. Flora no. 1, Bulaksumur, Sleman, Yogyakarta 55281, Indonesia
[2]Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada
Jln. Flora no. 1, Bulaksumur, Sleman, Yogyakarta 55281, Indonesia
*Corresponding author: eka.tarwaca.s@ugm.ac.id

Received: 09th July 2018; **Revised**: 02nd September 2019; **Accepted**: 10th Februrary 2020

Keywords:
DMPP, N-fertilization, NBPT

ABSTRACT
Oil palm is one of intensively planted in Indonesia, large-managed for industrial oil palm. This study aimed to know the influences of urease and nitrification inhibitor on loss of N and oil palm harvest in peat. The research was conducted at Sukamandang Village Coconut Plantation, Seruyan Tengah District, Seruyan Regency, Central Kalimantan Province. The research used a single factor of field experimental method with Randomized Completely Block Design (RCBD). Urea and ZA fertilizer were used in this study with the following treatment: N0= Without N, N1= Urea (195 kg.ha^{-1} N), N2= Urea + 0.12% NBPT-NPPT (195 kg.ha^{-1} N), N3= Urea (156 kg.ha^{-1} N), N4= Urea + 0.12% NBPT-NPPT (156 kg.ha^{-1} N), N5= Ammonium Sulfate (427 kg.ha^{-1} N), N6= Ammonium Sulfate + 0.8% DMPP (427 kg.ha^{-1} N), N7= Ammonium Sulfate (324 kg.ha^{-1} N), N8= Ammonium Sulfate + 0.8% DMPP (324 kg.ha^{-1} N). The research result indicated that the use of NBPT and DMPP inhibitors did not affect N levels in the leaves and the free fatty acids. Urea + NBPT treatment had no N loss for about 30–50% which was lower than urea without N, whereas ammonium sulfate + DMPP had smaller N loss than all treatments without N fertilization. Fertilization using urea + NBPT and ammonium sulfate + DMPP increased the production of FFB and yield of oil palm.

INTRODUCTION

Oil palm is one of the main plantation commodity in Indonesia. Regardless being one of the foreign exchanges, oil palm plantation opens wide employment for community (Sudrajat dan Fitriya, 2015). Compared to other plantation commodities, oil palm is one of the fastest growing plantation commodities. The vegetable oil trade/Crude Palm Oil (CPO) in the international market is also is very competitive. It can be seen from the last few years in which CPO from Indonesia still has its competitiveness compared to other countries (Susila, 2006). To meet the market needs, a good quality of CPO is needed. One of the parameters used as a standard for palm oil quality is the content of free fatty acids. That is, palm oil contains the lowest possible free fatty acids, not less than 2%. Factors affecting free fatty acid levels in palm oil are inadequate harvesting, delay in collection, and transport of fruit to palm oil mills, longer time of fruits in piles and fruit shipment (Andreas et al., 2017).

The increasing production of palm oil can be done by land expansion. One of the efforts to increase productivity of oil palm plantation is the use of peatlands. The results of the research indicated that fertilization and water management can improve peatland productivity and increase the growth of oil palm crops (Gusmawarti and Wardati, 2012). Fertilization of oil palm is one of the major components in oil palm plantation management which requires intensive attention. Fertilization takes up about 24% of the total production cost or is equal to 40%–60% of the total maintenance of oil palm crops (Darmosarkoro et al., 2003). Good fertilization can increase production and achieve standard productivity based on the land suitability class (Arsyad et al, 2012).

Urea is a widely used type of fertilizer to provide N in oil palm crops. However, N fulfillment urea can also be obtained from ammonium sulphate (ZA) fertilizer. Nitrogen losses in the field reach 40% mainly due to volatilization. Fertilization on peatland should be done gradually in low doses due to the low absorption power of peatland. It makes fertilizer does not lose easily. The use of slow release fertilizer will be more efficient because N will release slowly and increase uptake N (Hartatik and Wibowo, 2018).

Currently, the absorption and utilization of N by oil palm crop are quite low. Increased N uptake becomes important, because N is easily lost due to volatilization (evaporation). The potential for loss of N can be suppressed by the use of N–(n_butyl) thiophosporic triamide (NBPT) and nitrification of 3,4–dimethyl pyrozole phosphate (DMPP) in ammonium sulphate. NBPT compounds ($C_4H_{14}N_3PS$) and NPPT ($C_3H_{12}N_3PS$) are urease inhibitors that bind urease into the urease active cycle to prevent urea hydrolysis and reduce ammonia formation so urea fertilizer will be available gradually. The treatment of NBPT in urea fertilizers can reduce the loss of ammonia by 68% when compared to urea without NBPT (Suter et al., 2012). Loss of N fertilizer also occurs due to nitrification process. Nitrification is the oxidation of ammonium to nitrate by outotrof bacteria. Compound 3,4–simethyl pyrazole phosphate (DMPP) with chemical formula $C_5H_{11}N_2O_4P$ plays a role in reducing the ammonium conversion to nitrate and the N production in gas and nitrate leaching (Menendez et al., 2012).

This study was conducted to test the ability of NBPT and DMPP to inhibit urease activity on urea fertilization and the ability of DMPP to inhibit nitrification in ammonium sulfate fertilization, especially in oil palm crops. NBPT and DMPP were expected to reduce N loss in gaseous form so as to increase N uptake in plants and increase yields of oil palm crops.

MATERIALS AND METHODS

The research was conducted at Oil Palm Plantation in Sukukai, Seruyan Tengah District, Seruyan Regency, Central Kalimantan Province from November 2016 to Mei 2017. The research used a single factor of field experimental method with Randomized Completely Block Design (RCBD). Urea and ZA fertilizer were used in this study consisted of nine fertilizer combination. The experiment consisted of three blocks and five replication in each treatment. Therefore, total number of plants that used in this experiment were 135.

The fertilizer package consisted of (1) N0 = Without Nitrogen, (2) N1 = Urea (46% N) fertilization dose of N 195 $kg.ha^{-1}$, (3) N2 = Urea + 0.12% NBPT-NPPT fertilization dose of N 195 $kg.ha^{-1}$, (4) N3 = Urea (46% N) fertilization dose of N 156 $kg.ha^{-1}$, (5) N4 = Urea + 0.12% NBPT-NPPT fertilization dose of N 156 $kg.ha^{-1}$, (6) N5 = Ammonium Sulfate (21% N) fertilization dose of N 427 $kg.ha^{-1}$, (7) N6 = Ammonium Sulfate + 0.8% DMPP fertilization dose of N 427 $kg.ha^{-1}$, (8) N7 = Ammonium Sulfate (21% N) fertilization dose of N 324 $kg.ha^{-1}$, (9) N8 = Ammonium Sulfate + 0.8% DMPP fertilization dose of N324 $kg.ha^{-1}$.

The mature oil palms (aged 8–10 years), urea fertilizer, ammonium sulfate, limus, novatec solub 21, TSP 130 $kg.ha^{-1}$, KCl (K_2O) 217 $kg.ha^{-1}$, dolomite 130 $kg.ha^{-1}$, were used in this study. Ring placement were used for fertilization. The parameters that observed included N leaf, the amount of the loss and evaporation of N fertilizer, fresh fruit bunch (FFB), OER, and free fatty acid. The obtained data were analyzed using the Varian Analysis (ANOVA) with α = 5% and Duncan Multiple Range Test (DMRT), if the result of variance analysis showed significant difference.

RESULTS AND DISCUSSIONS

The results of the analysis of variance are presented in Table 1. It indicated that the treatment of the fertilizer package affected to the loss of N in the form of volatilization. The research result showed that the highest nitrogen volatilization was found in urea fertilization without NBPT-NPPT (195 $kg.ha^{-1}$) followed by urea without NBPT-NPPT at a lower dose of 156 $kg.ha^{-1}$. The lowest evaporation of N was in fertilization without N treatment, followed by ammonium sulfate + DMPP (N 324 $kg.ha^{-1}$) treatment. The volatilization of urea + NBPT-NPPT was significantly different from urea volatilization without NBPT. Urea fertilization with NBPT-NPPT inhibitors had a smaller N volatilization for about 30% to 50% from urea fertilization without NBPT. Ammonium sulfate + DMPP fertilization had lower volatilization compared to ammonium sulfate fertilizer without DMPP and urea either without NBPT-NPPT or with urea + NBPT-NPPT. However, the ammonium sulphate fertilization with DMPP or without DMPP were not significantly different, due to the fact that DMPP function was to

Table 1. The amount of N evaporation and N fertilizer losses in the oil palm plantation during 1 month after sowing N fertilizer

Treatments	The amount of N evaporation (ppm)	The amount of N fertilizer losses ($kg.ha^{-1}$)
N0	184.00 d	0.00 d
N1	10528.00 a	94.92 a
N2	7525.00 b	67.85 b
N3	4263.00 a	38.44 b
N4	2263.00 c	28.44 c
N5	483.33 d	4.33 d
N6	233.33 d	2.09 d
N7	207.00 d	1.49 d
N8	203.00 d	1.46 d

Remarks: N0= Without N, N1= Urea (46% N) N 195 $kg.ha^{-1}$, N2= Urea + 0.12% NBPT-NPPT N 195 $kg.ha^{-1}$, N3= Urea (46% N) N 156 $kg.ha^{-1}$, N4= Urea + 0.12% NBPT-NPPT N 159 $kg.ha^{-1}$, N5= Ammonium Sulfate (21% N) N 427 $kg.ha^{-1}$, N6= Ammonium Sulfate + 0.8% DMPP N 427 $kg.ha^{-1}$, N7= Ammonium Sulfate (21% N) N 324 $kg.ha^{-1}$, N8= Ammonium Sulfate + 0.8% DMPP N 324 $kg.ha^{-1}$. The means in one column followed by the same letter were not significantly different according to DMRT (α = 5%).

Table 2. Total N on leaves aged 3 and 6 months after N application on oil palm crop

Treatments	N concentration in the Leafs (%)	
	3 Months after broadcasting N fertilizer	6 Months after broadcasting N fertilizer
N0	2.41 a	2.42 a
N1	2.18 a	2.56 a
N2	2.36 a	2.44 a
N3	2.36 a	2.53 a
N4	2.49 a	2.55 a
N5	2.48 a	2.39 a
N6	2.43 a	2.38 a
N7	2.43 a	2.52 a
N8	2.30 a	2.54 a

Remarks: N0= Without N, N1= Urea (46% N) N 195 $kg.ha^{-1}$, N2= Urea + 0.12% NBPT-NPPT N 195 $kg.ha^{-1}$, N3= Urea (46% N) N 156 $kg.ha^{-1}$, N4= Urea + 0.12% NBPT-NPPT N 159 $kg.ha^{-1}$, N5= Ammonium Sulfate (21% N) N 427 $kg.ha^{-1}$, N6= Ammonium Sulfate + 0.8% DMPP N 427 $kg.ha^{-1}$, N7= Ammonium Sulfate (21% N) N 324 $kg.ha^{-1}$, N8= Ammonium Sulfate + 0.8% DMPP N 324 $kg.ha^{-1}$. The means in one column followed by the same letter were not significantly different according to DMRT (α = 5%).

reduce the loss of N in the nitrification process. The use of NBPT-NPPT as an urease inhibitor showed that NBPT-NPPT can delay urea hydrolysis 2 to 14 days when compared with urea without NBPT. According to Cantarella et al. (2018) urease inhibitors may reduce N-loss rates by 21–53% compared to urea fertilizers without urease inhibitors, whereas according to Menendez et al. (2012) the 3,4–dimethyl pyrazole phosphate nitrification inhibitor (DMPP) plays a role in reducing the conversion of ammonium to nitrate and

N production in the form of gas through denitrification. In addition, Ruser and Schulz (2015) stated that nitrification inhibitors are chemicals that delay or slow the conversion of ammonium to nitrate by affecting the activity of the bacterium Nitrosomonas and provide the potential to reduce nitrate leaching and loss of denitrification.

Table 1 showed that fertilizer treatment also affected the loss of fertilizer. The highest yield after fertilizer application was urea without NBPT-NPPT (195 kg.ha^{-1}), and the lowest was a treatment without N fertilizer. Urea fertilization + NBPT-NPPT had lower fertilizer compared to fertilization urea without NBPT-NPPT. Ammonium sulfate + DMPP fertilization also got lower volatilization when it was compared with ammonium sulfate fertilization without DMPP. The research results indicated that the use of inhibitor on N fertilization was able to suppress the loss of N fertilizer applied to oil palm plantation. This will give a positive impact on oil palm plantation as it decreases the usage of fertilizer dose applied so that it can save the budget used in the fertilization of oil palm plantation.

According to the results of N level analysis on the leaves of oil palm plant (Table 2), N fertilization treatment with or without the use of urease and nitrification inhibitors did not give significant effect on N palm leaves, either in 3 months after application or in 6 months after application. Leaf with the highest N content was in 3 months after application, which was urea + NBPT-NPPT (156 kg.ha^{-1}) and the lowest one was after application urea (195 kg.ha^{-1}). Also, leaf with the highest N content was in 6 months after application of urea by dose of 195 while the lowest one was Ammonium Sulfate + 0.8 % DMPP (427 kg.ha^{-1}).

Generally, N fertilization increased the N content on leaf plants at the age of 6 months after application, although statistically it was not significantly different. Based on the nutrient status of N on the leaves, the applied fertilization package can meet the needs of n crops. Referring to status of leaf nutrient content of oil palm in mature plants or plants with age more than 6 years, Hannum et al. (2014) revealed that the optimum nitrogen nutrient status on oil palm leaves was for about 2.4–2.8% The unavailability of N in crops was caused by the loss of N and it can be used by microbial activity in the soil which affected the absorption of nitrogen.

The result of weight analysis of fresh fruit bunches (Table 3) indicated that the fertilization treatment had no significant effect on the weight of ffb per stem, ton, weight and per hectare. The highest yield of fresh fruit bunches took the use of Ammonium Sulfate + DMPP (427 kg) and urea + NBPT-NPPT (195 kg) treatment, while the lowest fresh fruit bunch was

Table 3. Results of fresh fruit bunches per bunch, per stree, per ton, per hectar, and per year in oil palm crops

Treatments	The weight of FFB per bunch (kg)	The weight of FFB per tree (kg)	The weight of FFB (ton.ha^{-1}.year^{-1})
N0	8.94 ab	9.09 ab	9.09 ab
N1	6.59 b	7.23 b	7.23 b
N2	11.60 a	11.60 a	11.60 a
N3	8.72 ab	8.72 ab	8.72 ab
N4	10.21 ab	10.30 ab	10.30 ab
N5	9.04 ab	9.28 ab	9.28 ab
N6	12.03 a	12.03 a	12.03 a
N7	8.07 ab	8.07 ab	8.07 ab
N8	8.18 ab	8.18 ab	8.18 ab

Remarks: N0= Without N, N1= Urea (46% N) N 195 kg.ha^{-1}, N2= Urea + 0.12% NBPT-NPPT N 195 kg.ha^{-1}, N3= Urea (46% N) N 156 kg.ha^{-1}, N4= Urea + 0.12% NBPT-NPPT N 159 kg.ha^{-1}, N5= Ammonium Sulfate (21% N) N 427 kg.ha^{-1}, N6= Ammonium Sulfate + 0.8% DMPP N 427 kg.ha^{-1}, N7= Ammonium Sulfate (21% N) N 324 kg.ha^{-1}, N8= Ammonium Sulfate + 0.8% DMPP N 324 kg.ha^{-1}. The means in one column followed by the same letter were not significantly different according to DMRT (α = 5%).

by treatment of urea (195 kg.ha^{-1}). At the same urea dose, the use of NBPT-NPPT caused an increase in FFB production per hectare per year by 59% (urea dose 195 kg.ha^{-1}) and 18% (urea dose 156 kg.ha^{-1}). Meanwhile, the use of N sources in the form of ZA, the combination of ZA with DMPP, only had a positive effect on the yield component and the result of TBS compilation of ZA dose was 427 kg.ha^{-1}. At lower ZA doses (324 kg.ha^{-1}), the addition of DMPP did not increase the yield component and FFB yield. It is because the application of ammonium sulfate and urea fertilizers applied with DMPP and NBPT-NPPT inhibitors can reduce N loss, so N is available for plants and can improve crop production.

According to Hartatik and Wibowo (2018), crop production is the result of interaction between the genetic potential and the growing environment. Fertilization can increase soil fertility and nutrient supplement supply in the soil and the availability of nutrients can meet the needs of plants and achieve maximal production (Arsyad et al., 2012). The use of slow release fertilizer significantly influences oil palm production and reduces the amount of fertilizer needs on the plants, but reducing the amount of fertilizer by 50–60% can achieve the same level of FFB production (Wigena et al., 2005). Alonso-Ayuso et al. (2016) mentioned that the application of ammonium sulfate + DMPP at a dose reduction of 23% in the following year after application does not result in the reduction of the corn yield and corn quality. The research results of Kawakami et al. (2012) showed that the use of NBPT improved cotton lint yield by 14% compared to a similar urea application rate without NBPT.

OER is the ratio between the products produced in the form of oil palm (CPO) and FFB as raw materials used (Setyaji, 2016). Table 4 showed that the treatment of fertilizer package with or without urease and nitrification with different dose was not significantly affected to the oil palm yield, but the use of Urea + NBPT-NPPT (195 kg.ha^{-1}), ammonium sulfate + DMPP (427 kg.ha^{-1}) and (324 kg.ha^{-1}) resulted significantly different from the use of urea (159 kg.ha^{-1}) without NBPT. Generally, N fertilization treatment using inhibitor leads to a higher yield of oil palm compared to other treatments. The highest rendement was by the treatment of Ammonium Sulfate + DMPP (427 kg.ha^{-1}) and (324 kg.ha^{-1}) and urea + NBPT–NPPT (195 kg.ha^{-1}), while the lowest rendement was by urea (156 kg.ha^{-1}). The higher fertilization dose application increased the yield of oil palm. It means the higher the dose application of N in the oil palm crop, the more increasing the oil content in fresh fruit bunches of oil palm will be.

The result of analysis variance of free fatty acid (FFA) seen on Table 4 showed that free fatty acid level

Table 4. The result of of oil extraction rate (OER) and free fatty acid in 6 months of age after broadcasting the N fertilizer

Treatments	Oil extraction rate (%)	Free fatty acid (%)
N0	30.04 ab	0.36 a
N1	30.04 ab	1.13 a
N2	33.27 a	0.60 a
N3	28.08 b	0.79 a
N4	32.44 ab	0.62 a
N5	31.64 ab	1.61 a
N6	34.48 a	0.92 a
N7	31.31 ab	1.41 a
N8	34.17 a	1.48 a

Remarks: N0= Without N, N1= Urea (46% N) N 195 kg.ha^{-1}, N2= Urea + 0.12% NBPT-NPPT N 195 kg.ha^{-1}, N3= Urea (46% N) N 156 kg.ha^{-1}, N4= Urea + 0.12% NBPT-NPPT N 159 kg.ha^{-1}, N5= Ammonium Sulfate (21% N) N 427 kg.ha^{-1}, N6= Ammonium Sulfate + 0.8% DMPP N 427 kg.ha^{-1}, N7= Ammonium Sulfate (21% N) N 324 kg.ha^{-1}, N8= Ammonium Sulfate + 0.8% DMPP N 324 kg.ha^{-1}. The means in one column followed by the same letter were not significantly different according to DMRT (α 5%).

was not significantly different to one another. The lowest treatment of AFB was without N fertilization and the highest treatment of ALB used ammonium sulfate (427 kg.ha^{-1}) the application of NBPT-NPPT to urea can suppress free fatty acids. The research observation result presented that the application of NBPT-NPPT to urea generated lower lever of free fatty acid. ALB is formed by the reaction of hydrolysis in oil palm, and ALB is the main parameter to determine the quality of CPO from oil palm FFB (Lukito and Sudrajat, 2017). The higher number of free fatty acids indicates that the quality of oil is reduced (Alifikri, 2019). According to the Department of Industry, (2007), best quality oil palm (SQ, Special Quality) contains free fatty acids of not more than 2% during shipment. Standard quality of oil palm should not contain ALB of more than 5%.

CONCLUSIONS

Urea fertilization combined with NBPT-NPPT can reduce N exposure and N loss by 30–50%. Ammonium sulfate+DMPP treatment increases the yield of TBS per stem, per stand, per hectare, per year and it is not significantly different by applying urea NBPT-NPPT treatment.

REFFERENCES

Alifikri, G. and N. L. P. Hariastuti. 2019. Peningkatan kualitas minyak kelapa sawit dengan pendekatan lean six sigma – (studi kasus di PT. Sawit mas parenggean). *Jurnal Iptek*, 23: 47–54.

Alonso-Ayuso, M., J. L. Gabriel and M. Quemada. 2016. Nitrogen use efficiency and residual effect of fertilizers with nitrification inhibitors. *European Journal of Agronomy*, 80: 1–8.

Andreas, W. K., L. Sutiarso and K. H. Widodo. 2017. Optimasi kualitas tandan buah segar kelapa sawit dalam proses panen-angkut menggunakan model dinamis. *Agritech*, 37: 101–107.

Arsyad, A. R., H. Junaedi and Y. Farni. 2012. Pemupukan kelapa sawit berdasarkan potensi produksi untuk meningkatkan hasil tandan buah segar (TBS) pada lahan marginal Kumpeh. *Jurnal Penelitian Universitas Jambi: Seri Sains*, 14: 29–36.

Cantarella, H., R. Otto., J. R. S. Soares and A. G. B. Silva. 2018. Agronomic efficiency of NBPT as a urease inhibitor: A review. *Journal of Advanced Research*, 13: 19–27.

Darmosarkoro, W., E. S. Sutarta and Winarna. 2003. Teknologi pemupukan tanaman kelapa sawit. *Prosiding Lahan dan Pemupukan Kelapa Sawit*. 113–134.

Department of Industry. 2007. Gambaran sekilas industri minyak kelapa sawit. *http://www.kemenperin.go.id/download/289/Paket-Informasi-Komoditi-Minyak-Kelapa-Sawit& ei=de_,d.bmk.*

Gusmawarti and Wardati. 2012. Pemberian pupuk anorganik dan air pada tanah gambut terhadap pertumbuhan kelapa sawit di pre-nursery. *Jurnal Agrotek Tropika*, 1: 23–26.

Hannum, J., C. Hanum and J. Ginting. 2014. Kadar N, P daun dan produksi kelapa sawit melalui penempatan TKKS pada rorak. *Jurnal Online Agroteknologi,* 2: 1279–1286.

Hartatik, W. and H. Wibowo. 2018. Efektivitas beberapa jenis pupuk N pada pembibitan kelapa sawit. *Jurnal Penelitian Tanaman Industri*, 24: 29–38.

Kawakami, E. M., D. M. Oosterhuis, J. L. Snider, and M. Mozaffari. 2012. Physiological and yield responses of with field-grown cotton to application of urea the urease inhibitor NBPT and the nitrification inhibitor DCD. *European Journal of Agronomy*, 43: 147–154.

Lukito, P. A. and Sudradjat. 2017. Pengaruh kerusakan buah kelapa sawit terhadap kandungan free fatty acid dan rendemen CPO di Kebun Talisayan 1 Berau. *Buletin Agrohorti*, 5: 37–44.

Menendez, S., I. Barrena, I. Setien, C. Gon-Muruna, J. M. Estavillo. 2012. Efficiency of nitrification inhibitor DMPP to reduce nitrous oxide emission under differen temperatur and moisture condition. *Soil Biology and Biochemistry*, 53: 82–89.

Ruser, R. and R. Schulz. 2015. The effect of nitrification inhibitors on the nitrous oxide (N_2O) release from agricultural soils–a review. *Journal of Plant Nutrition and Soil Science*, 178: 171–188.

Setyaji, H. 2016. Kualitas minyak kelapa sawit kaya karoten dari brondolan kelapa sawit. *https://www.researchgate.net/publication/294259006.*

Sudrajat and Fitriya. 2015. Optimasi dosis pupuk dolomit pada tanaman kelapa sawit (*Elaeis guineensis* jacq.) belum menghasilkan umur satu tahun. *Agrovigor*, 8: 1–8.

Susila, W. R. 2006. Peluang pengembangan kelapa sawit di indonesia: perspektif jangka panjang 2025. *Jurnal Sosial Ekonomi Pertanian*, 6: 1-19

Suter, H., D. Chen, W. Walker, R. Davies. 2012. The potential for inhibitor coated nitrogen fertilizers to reduce agricultural fertiliser N losses. *Proceedings of the 16th Australian Agronomy Conference*. 1–2.

Wigena, I. G. P., J. Purnomo, E. Tuherkih and A. Saleh. 2005. Pengaruh pupuk “slow release” majemuk padat terhadap pertumbuhan dan produksi kelapa sawit muda pada xanthic hapludox di Merangin, Jambi. *Jurnal Tanah dan Iklim*, 24: 10–20.