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Influence of Chemical Fertilizer Applications on Water Quality in Paddy Fields in Nong Harn, Sakon Nakhon Province, Thailand

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ABSTRACT

This study investigated the effect of chemical fertilizer on water quality in paddy fields. Six experiments were conducted using chemical fertilizer (formula 16-16-8; N-P-K) and urea fertilizer (46-0-0) using two different fertilizer applications at varied concentrations in Nong Harn, Sakon Nakhon province, Thailand: 1) 218.75 kg.ha^{-1} of 16-16-8 at 30 d after planting and 93.75 kg.ha^{-1} of 46-0-0 at 60 d and 90 d after planting by broadcasting (T1), deep placement at 10 cm (T2) and at 20 cm (T3); and 2) 437.50 kg.ha^{-1} of 16-16-8 at 30 d after planting and 187.50 kg.ha^{-1} of 46-0-0 at 60 d and 90 d after planting by broadcasting (T4), deep placement at 10 cm (T5) and at 20 cm (T6). The results showed that at 90 d, the lowest dissolved oxygen level was 3.21 mg.L^{-1} in T4. The NH_4^+-N levels decreased with time. The highest and lowest levels of NH_4^+-N were in T4 (60 d) and T3 (90 d), respectively, whereas the highest and lowest levels of NO_3^--N were in T4 and T1 (90 d), respectively. The levels of NO_3^--N in T4, T5 and T6 were higher than those in T1, T2 and T3. Additionally, the level of PO_4^{3-}-P decreased due to the growing season of rice. The concentrations of phosphate by broadcasting were higher than those of deep placement at 10 and 20 cm. The rice yield was higher ($P < 0.05$) in T4, T5 and T6 than in T1, T2 and T3 and the rice yields using deep placement at 10 cm were higher than those at 20 cm and by broadcasting. Nitrogen fertilizer application affected the utilization efficiency, influencing the rice yields and nitrogen loss. However, the recommendation of an appropriate nitrogen fertilizer application was deep placement at 10 cm based on the rice yield and the levels of NH_4^+-N, and NO_3^- -N. Furthermore, water should be retained in the rice field, leading to reduced nutrients escaping and interfering with the environment.

Keywords: broadcasting, chemical fertilizer, deep placement, paddy field, water quality, Nong Harn, Sakon Nakhon

INTRODUCTION

Thailand is one of the major agriculture countries and recently agriculture in Thailand has been changing to conventional or chemical agriculture in order to increase the yield (Sunantapongsak, 2008). With the increase in population and economic development, farmers are being encouraged to increase chemical fertilizer inputs in order to increase yields, especially in

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paddy fields. According to Office of Agricultural Economics (2009), In Thailand, rice farming has been a major, longstanding occupation with 11.04 million ha of paddy fields which consist of 9.12 million ha of wet season rice and 1.92 million ha of dry season rice (Department Pollution Control, 2011).

Sakon Nakhon is one of the northeastern provinces of Thailand with 322,768 ha of paddy fields (6% of this region). It is located on the Khorat Plateau, not far from the Mekong River and includes mountainous and forested areas as well as the Nong Harn Lake the biggest natural lake in Northeast Thailand which is an important wetland used for agriculture especially paddy fields (Sakon Nakhon Rice Research Center, 2009). However, in 2008, the gross rice yield in Sakon Nakhon province was 566,649 t and the average production yield was 2,025 $kg.ha^{-1}$ (Sakon Nakhon Rice Research Center, 2009). The natural soils in this region are of low quality with rapid water runoff; therefore, chemical fertilizers are used intensively to increase production yields. Chemical fertilizers can enrich the soil with macronutrients and micronutrients and have been traditionally applied in Thailand to maintain soil fertility (Office of Agricultural Economics, 2009). Farmers always used more nitrogen fertilizer than required to gain a high crop yield and this increases the cost of agricultural management, decreasing the efficiency of fertilizer use and the quality of products (Gong *et al*., 2011). Additionally, this can cause environmental pollution, as the movement of N fertilizer from agricultural activities into the surface water and groundwater contributes to water quality degradation and eutrophication through runoff and leaching, (Xing and Zhu, 2000; Konnerup *et al*., 2009; Luo *et al*. 2011). Nitrogen emissions from ammonia volatilization following N fertilizer application to soils have been also investigated (Das *et al*., 2009; Cao *et al.,* 2013; Xu *et al*., 2013). The application of nitrogen fertilizers to rice contributes to the formation of large amounts of ammonium ions which eventually are converted into non-ionized ammonia that escapes in gas form and this constitutes a large proportion of the nitro fertilizer lost from rice growing soils (Hui *et al*., 2006). Nitrate produced in the surface layer of flooded rice paddies can be lost through denitrification, as it diffuses into the reduced soil zone where it serves as an electron acceptor for microbial anaerobic respiration (Ponnamperuma, 1972; Reddy and Patrick, 1984, 1986). Nitrate in floodwater or aerobic soil layers moves easily by percolation and diffusion into the underlying reduced layers, where it is rapidly denitrified (Reddy and Patrick, 1986; Datta, 1987). Das *et al*. (2009) reported that fertilizer applications to rice can lead to significant emissions of NH_3 and NH_4^+ and NO_3^- ions. The fertilizer applications also affect the movement of nutrients. Iqbal (2011) reported that nitrate concentrations in leachate at a soil depth of 30 cm were higher than that at 60 cm depth. Xu *et al*. (2013) found that the ammonia concentration in the surface water or in soil solution and ammonium volatilization by the deep placement of fertilizer were lower than those using fertilizer broadcasting. Moreover, the nitrogen levels directly affected the rice yield at different growth stages, especially from the transplanting to jointing stages (Yu *et al*., 2013). Therefore, effective nutrient management has played a major role in accomplishing an enormous increase in rice yield. However, the application of imbalanced nutrients has led to decreasing nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects in the environment.

This study investigated the effect of chemical fertilizers on water quality and rice yield in paddy fields. The water quality and nutrients (NH_4^+-N, NO_3^--N and PO_4^{3-}-P) were determined. The field experiments were conducted using two different fertilizer applications (broadcasting and deep placement) at varied concentrations on dry season rice in Nong Harn. This study may help to select the optimal chemical fertilizer application to reduce environmental pollution and improve chemical fertilizer application and rice yield.

MATERIALS AND METHODS

Site preparation and experimental design

The field experiment was conducted in 2013 in Nong Harn, Sakon Nakhon province (17°15′N, 104°09′E) as illustrated in Figure 1.

The climate is subtropical with an annual average air temperature and annual mean precipitation of 26.1 °C and 1,694 mm, respectively (Sakon Nakhon Rice Research Center, 2009). Six treatments (as described in Table 1) were established to investigate the effect of chemical fertilizer applications with varied concentrations and time. The six treatments were applied in 4 × 4m plots and were tilled to a depth of 30 cm. For seedling preparation, the seeds of sticky rice (*Oryza sativa* L.) were soaked in water for 12 h and then covered with gunny sacks for 48 h. The seeds that sprouted were sown into small plots and were maintained for 25–30 d and then were transplanted to the experimental treatments. Two granular commercial chemical fertilizers 16-16-8

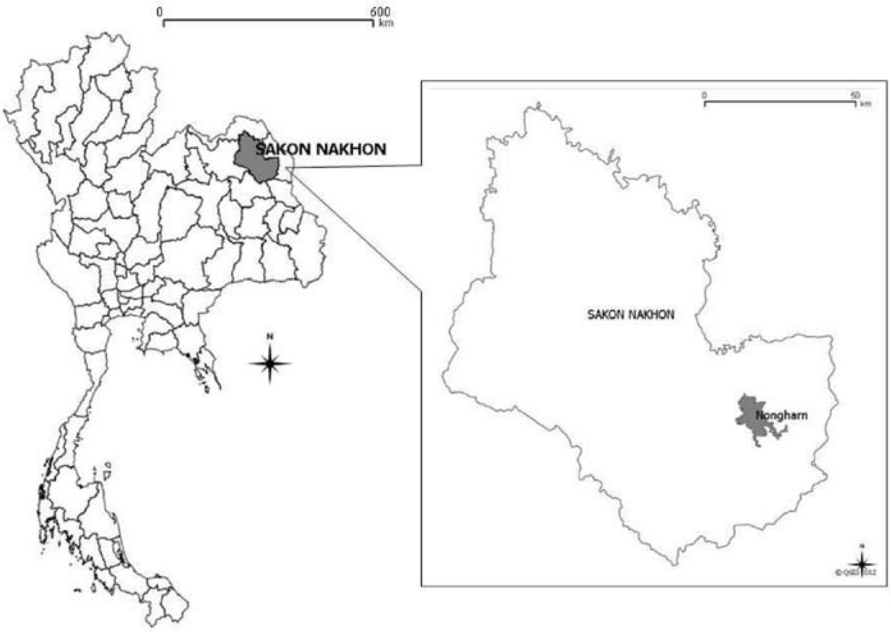

Figure 1 Location of study area (Nong Harn, Sakon Nakhon province)

Table 1 Experimental treatments

Code	Fertilizer application	Application (days after planting) of fertilizer (N-P-K)			
		0-d	30-d	60-d	90-d
T1	Broadcasting	-	16-16-8:	46-0-0:	46-0-0:
T2	Deep placement at 10 cm	-	218.75 kg.ha^{-1}	93.75 kg.ha^{-1}	93.75 kg.ha^{-1}
T3	Deep placement at 20 cm	-			
T4	Broadcasting	-	16-16-8:	46-0-0:	46-0-0:
T5	Deep placement at 10 cm	-	437.50 kg.ha^{-1}	187.50 kg.ha^{-1}	187.50
T6	Deep placement at 20 cm	-			kg.ha^{-1}

(N-P-K) and 46-0-0 (urea fertilizer) were purchase locally and were applied at rates equivalent to 218.75 and 437.5 $kg.ha^{-1}$ and at 93.75 and 187.50 $kg.ha^{-1}$, respectively. Broadcasting and deep placement methods with different concentrations and soil depths of 10 and 20 cm were conducted. The fertilizer applications were conducted three times at the seeding stage (30 d after planting), the vegetative stage (60 d after planting) and the panicle-formation stage (90 d). Surface water was maintained at a depth of 10 cm until the maturation period for all treatments. The plots were drained before harvesting.

Sample collection and measurement

Water samples were collected 2 d after each fertilizer application (before transplanting (0 d), at seeding (30 d), at the vegetative stage (60 d) and at panicle-formation (90 d). The water samples were analyzed for temperature, pH, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD) and nutrients (NH_4^+-N, NO_3^- -N, PO_4^{3-}-P) using the standard methods (American Public Health Association et al., 1998). NH_4^+-N concentrations were measured based on the determination of ammonium in water using a flow injection analyzer (FIAstar 5000; U.S. Environmental Protection Agency, 1991). The rice yields were measured using a moisture meter and reported based on 14% moisture content as presented in Equation 1:

$$\text{Rice yield at 14\% moisture content} = \frac{a \times (100 - b) \times 10{,}000}{(100 - 14) \times c} \quad (1)$$

where *a* is the rice weight (measured in kilograms) at moisture content *b* (measured as a percentage) and *c* is the harvested area (measured in hectares).

Statistical analysis

The statistical significance of differences among treatments of NH_4^+-N, NO_3^- -N, PO_4^{3-}-P and rice yield after fertilization was assessed using analysis of variance and significant differences were determined using Duncan's new multiple range test, at $P < 0.05$ by using different letter

RESULTS AND DISCUSSION

Effect of chemical fertilizer on water quality

Electrical conductivity and pH

The values for the water samples collected at the four stages during the rice crop rotation are presented in Figure 2.

The results showed that the mean (± SD) pH levels of the water in all treatments at 0 d after planting were in the range 5.79±0.03 to 6.61±0.03. After the fertilizer applications in the paddy field at 60 d after planting, the pH levels increased (7.85±0.01 – 8.71±0.06) because of the addition of urea fertilizer in the paddy field to promote rice growth. The urea fertilizer dissolved in the water forming NH_4^+ ions. Consequently, algae and aquatic plants in the paddy fields absorbed CO_2 gas for photosynthesis due to the increase in the pH. The highest pH level was 8.71±0.06 in T4. It should be noted that the pH level following fertilizer application by broadcasting was significantly higher than that of the deep placement application, whereas there were no significant differences in the pH levels between the deep placement applications at 10 and 20 cm. The optimal pH level in paddy fields is 6–8 (Alexander, 1977) and phosphorus is available in most plants at a pH level between 6.5 and 7.0. The range in electrical conductivity at 0 d after planting was 137.03±0.8 – 163.67±10.3 $\mu S.cm^{-1}$ and the electrical conductivity in T4 (1,638±101.05 $\mu S.cm^{-1}$) at 30 d after planting was significantly higher than in T1, T2, T3 and T6 after chemical fertilization. At 60 d after planting, ions were released into the water applied as irrigation, so that the nutrients were mostly released into the water. The highest electrical conductivity was 1,638±101.5 $\mu S.cm^{-1}$ at 30 d after planting in T4. Otherwise, there were no significant differences in conductivity at 60 and 90 d after planting.

The DO levels at 0 d after planting were in the range 2.5±0.1 to 2.93±0.06 $mg.L^{-1}$ and increased after chemical fertilizer application

(3.21±1.01 – 7.87±0.82 mg.L^{-1}), whereas in contrast, the DO level decreased after urea fertilization as shown in Figure 3a. The DO level at 30 d after planting in T2 was significantly higher than in T1 and T3. In contrast, the DO level at 30 d after planting in T3 was significantly lower than in T4, T5 and T6. Additionally, the DO level at 30 d after planting was the highest of all stages, whereas the lowest DO level was in T4 at 90 d after planting (3.21±1.01 mg.L^{-1}). At DO concentrations of 1.0 mg.L^{-1} or more, nitrification occurred only under aerobic conditions, whereas it was minimal at DO concentrations of less than 0.5 mg.L^{-1}. However, the DO concentrations at 0, 60 and 90 d after planting were not significantly different. The BOD decreased after chemical fertilization as shown in Figure 3b. At 30 d after planting, the BOD was lowest (6.83±0.21 – 12±1.2 mg.L^{-1}). At 60 d after planting, in all treatments the BOD was highest at T4 which was significantly higher than in T1, T2, T3, T5, and T6. In contrast, the BOD at 90 d after planting was significantly higher than in T1, T2, T3, T4 and T6. It was also observed that the BOD at 30 d was the lowest whereas in contrast, the DO level was highest.

NH_4^+-N

The NH_4^+-N levels in the six treatments at 30, 60 and 90 d after planting were 67.76±1.23 to 204.44±1.18, 96.24±1.82 to 256.40±6.19 and 41.45±7.20 to 216.25±3.40 mg.L^{-1}, respectively, as illustrated in Figure 4.

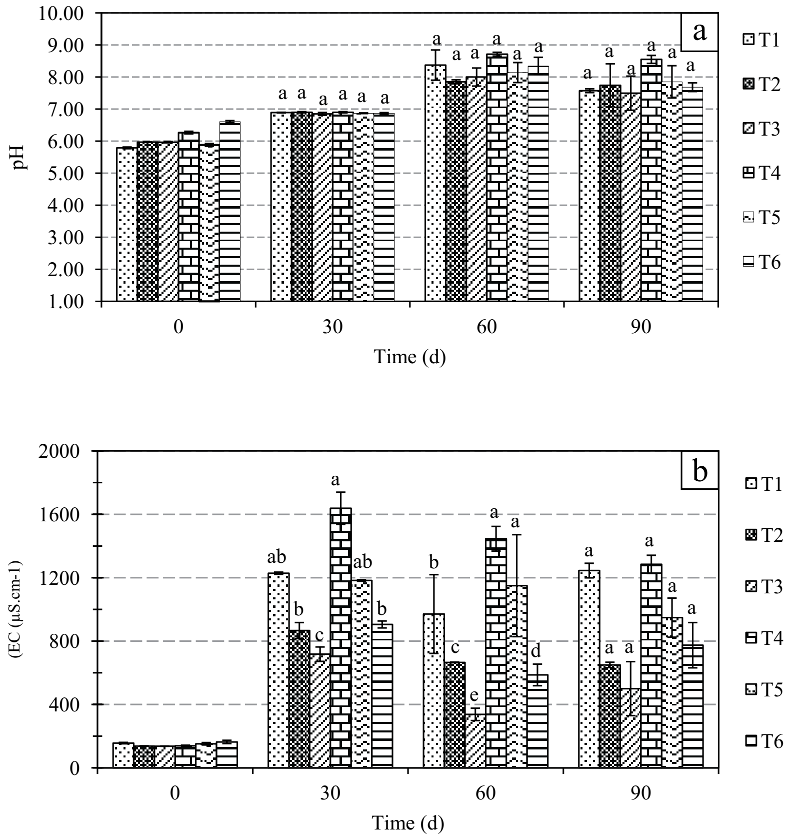

Figure 2 Electrical conductivity (EC) and acidity (pH) in water of paddy fields at different times after planting and levels of fertilization: a) pH; and b) EC. T1–T6 are the experimental treatments shown in Table 1. Error bars show ± SD. Different letters above each column are significantly different according to Duncan's new multiple range test, at $P < 0.05$).

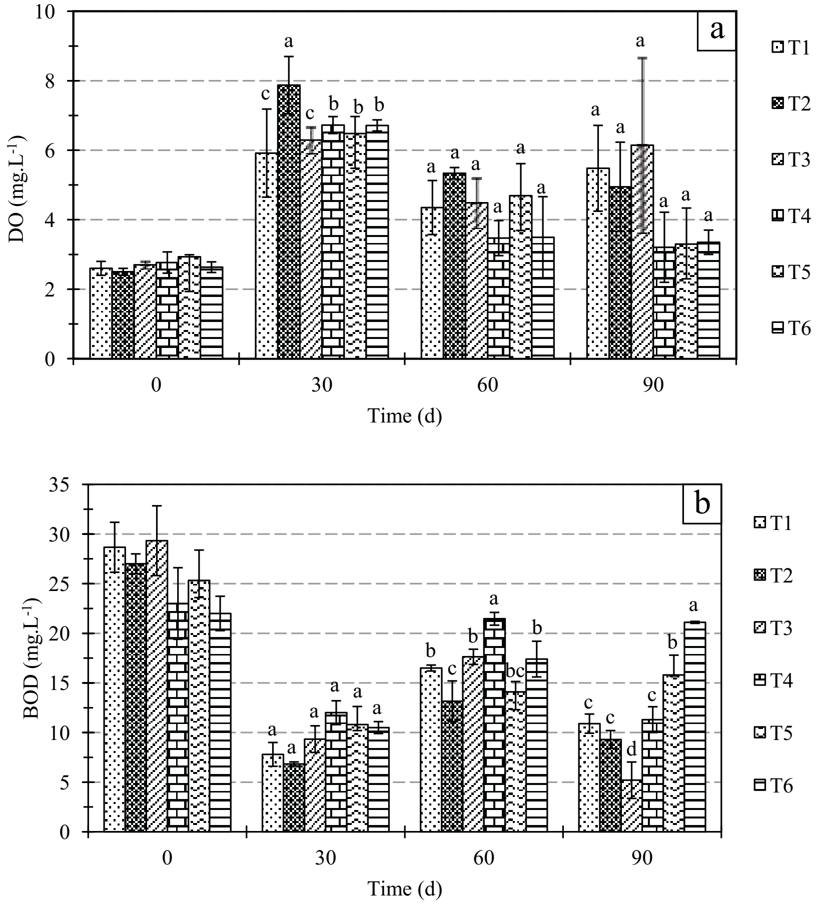

Figure 3 Dissolved oxygen (DO) and biochemical oxygen demand (BOD) concentrations in water of paddy fields at different days after fertilization: a) DO; and b) BOD. T1–T6 are the experimental treatments shown in Table 1. Error bars show ± SD. Different letters above each column are significantly different according to Duncan's new multiple range test, at $P < 0.05$).

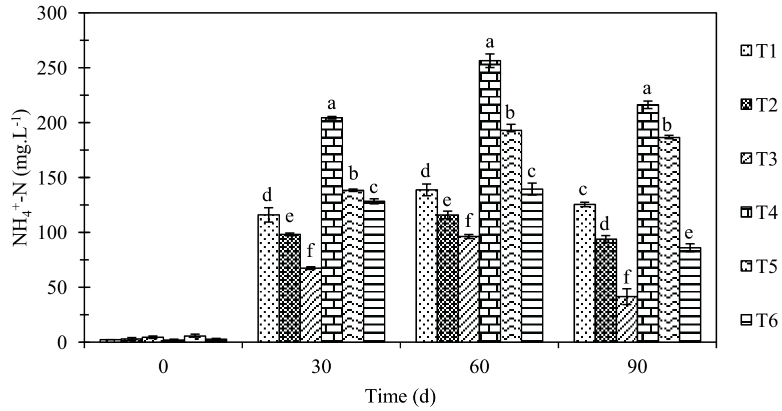

Figure 4 NH_4^+-N concentrations in water of paddy fields at different days after fertilization. T1–T6 are the experimental treatments shown in Table 1. Error bars show ± SD. Different letters above each column are significantly different according to Duncan's new multiple range test, at $P < 0.05$).

The NH_4^+-N concentration in the paddy water was significantly higher in T4 than in T1, T2, T3, T5 and T6 at 30, 60 and 90 d after planting. The highest NH_4^+-N concentration was in T4 because the concentration of fertilizer in T4 was higher than in T1, T2 and T3. Ji *et al*. (2007) reported that total nitrogen and NH_4^+-N in water increased after the application of urea fertilizer. In contrast, the concentration of NH_4^+-N was low in the treatments applied in T3 and T6 due to the deep placement application at 10 and 20 cm, respectively. The NH_4^+-N concentration in the surface water after urea fertilization at 90 d after planting was lower than that at 60 d after planting. Lin *et al.* (2012) reported that the NH_4^+-N concentration after panicle fertilization to at least the 2-leaf stage was lower than that at the 4-leaf stage. Consequently, the concentration of NH_4^+-N in T3 and T6 was significantly lower than in T3 and T5. NH_4^+ is one of two nitrogen forms that plants can use and as NH_4^+-N carries a positive charge and is absorbed onto soil particles, leaching of nitrogen can be ignored (Robertson and Groffman, 2007). The results also found that the concentrations of NH_4^+-N in treatments of broadcasting (T1 and T4) were higher than with deep placement. It was possible that the application of urea fertilizer by broadcasting could be easily dissolved and NH_4^+-N was released into the water faster than that by deep placement. Therefore, NH_4^+-N was found at a high concentration in the surface water. The release of NH_4^+-N from urea fertilizer can occur after hydrolysis as presented in Equations 2 and 3 (Mikkelsen, 2009; Azeem *et al*., 2014):

$$CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO_3 \quad (2)$$

$$(NH_4)_2CO_3 + 2H^+ \rightarrow 2NH_4^+ + CO_2 + H_2O \quad (3)$$

After fertilization, the concentrations of NH_4^+-N decreased with time due to the ammonium volatilization and nitrification processes. The release of NH_4^+-N from the 16-16-8 chemical fertilizer and urea proceeded slowly followed by an eventual decline due to ammonium volatilization (Das *et al*., 2009). The NH_4^+-N concentrations in T4, T5 and T6 were significantly higher than in T1, T2 and T3 due to the release of fertilizer by hydrolysis because the pH levels in T4, T5 and T6 were higher than in T1, T2 and T3. The hydrolysis of urea is faster at high pH levels (Chowdary *et al*., 2004). The pH of water during the experiment varied in the range 7.85 to 8.71 which was almost ideal for the release of NH_4^+-N after hydrolysis. The average NH_4^+-N level from the experimental rice field was 0.77±0.39 parts per million (ppm) and the maximum NH_4^+-N level recorded was 1.67 ppm after chemical fertilization (Das *et al*., 2009).

NO_3^- -N

The NO_3^--N levels in six treatments of paddy fields at 30, 60 and 90 d after planting were 0.80±0.24 to 1.49±0.22, 0.72±0.07 to 2.21±0.22 and 0.46±0.09 to 2.39±0.53 mg.L^{-1}, respectively, as illustrated in Figure 5.

The results showed that the highest concentration of NO_3^--N was 2.39±0.53 mg.L^{-1} in T4 at 90 d after planting and the lowest concentration of NO_3^--N (0.46±0.09 mg.L^{-1}) was in T1 at 90 d after planting because the NO_3^--N ion carries a negative charge and is not absorbed onto soil particles; thus, NO_3^- -N is easily leached from the soil. After fertilization, the concentration of NO_3^--N at 30, 60 and 90 d after planting was higher than at 0 d after planting and the concentration of NO_3^--N was lower than for NH_4^+-N because of the conversion of NH_4^+-N to NO_3^--N which is known as nitrification under aerobic conditions (DO >1.0 mg.L^{-1}) as presented in Equations 4 and 5:

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 4H^+ + 2H_2O + \text{energy} \quad (4)$$

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- + \text{energy} \quad (5)$$

The reaction proceeded to the nitrate form; therefore, the NO_3^- -N concentrations at any given time were usually low. Additionally the transformation of NH_4^+-N to NO_3^--N in the surface water using a broadcast fertilizer application was greater than by deep placement. It was also found that the concentrations of NO_3^--N in T4, T5 and

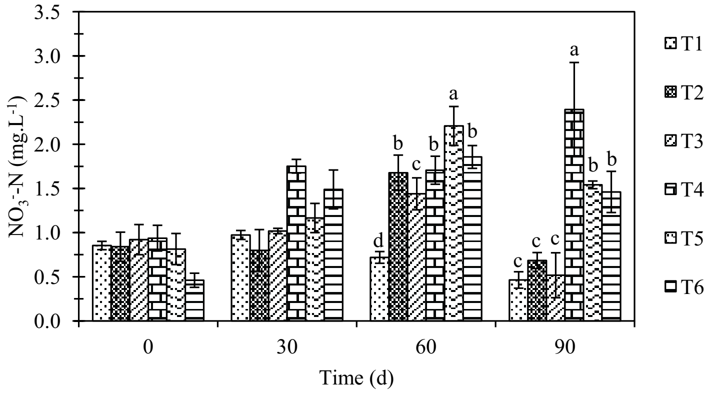

Figure 5 NO_3^--N concentrations in water of paddy fields at different days after fertilization. T1–T6 are the experimental treatments shown in Table 1. Error bars show ± SD. Different letters above each column are significantly different according to Duncan's new multiple range test, at $P < 0.05$).

T6 were significantly higher than in T1, T2 and T3 at 90 d after planting due to the high concentration of chemical fertilizer, leading to the nitrification process. The concentration of NO_3^--N in T1 was significantly lower than in T2, T3, T4, T5 and T6 at 60 and 90 d after planting, probably because the pH was lower than in the other treatments, resulting in the inhibition of nitrification (Chowdary *et al.*, 2004). The hydrolysis of urea was faster at a high pH level. Otherwise, there were no significant differences in the NO_3^--N concentration in water at 0 and 30 d after planting. The constant rate of nitrification is lower than that of hydrolysis (Chowdary *et al.*, 2004; Liang *et al.*, 2007), resulting in a low concentration of NO_3^--N. Compared to the standard of water quality set by American Public Health Association (1988), the level of NO_3^--N in the surface water should not exceed 5.0 mg.L^{-1} and the NO_3^--N level obtained in this study after fertilization was lower than that requirement. NO_3^--N also can be lost to the atmosphere through denitrification when soils become water saturated as presented in Equation 6:

$$C_6H_{12}O_6 + NO_3^- \rightarrow 6CO_2 + 6H_2O + 2N_2 \quad (6)$$

Water temperature also affects the rate of nitrification and the maximum rate of nitrification occurs at a temperature between 30 and 35°C (Jeyanayagam, 2005). Therefore, the concentrations of NO_3^--N in this study were not high. Namdev *et al.* (2011) found that the nitrate concentration in water was 1.16 to 2.69 mg.L^{-1} after fertilization, which exceeds the permissible limit because of the excessive use of chemical fertilizer.

PO_4^{3-}-P

The PO_4^{3-}-P levels in the six treatments at 30, 60 and 90 d after planting were 6.12±0.06 to 19.61±0.01, 0.89±0.42 to 1.95±1.35 and 1.68±0.52 to 2.39±0.14 mg.L^{-1}, respectively, as presented in Figure 6.

The highest concentration of PO_4^{3-}-P was in T4 because the chemical fertilizer formula 16-16-8 was applied at 30 d after planting which provided 16% available phosphorus (P_2O_5). On the other hand, urea fertilizer (46-0-0) was applied at 60 and 90 d after planting and contained no phosphorus. Urea fertilizer was used to activate the panicle formation and maturation in the rice. Therefore, the PO_4^{3-}-P concentrations after fertilization at 30 d after planting decreased as illustrated in Figure 6. This result was similar to Al-Shami *et al.* (2010) who reported that

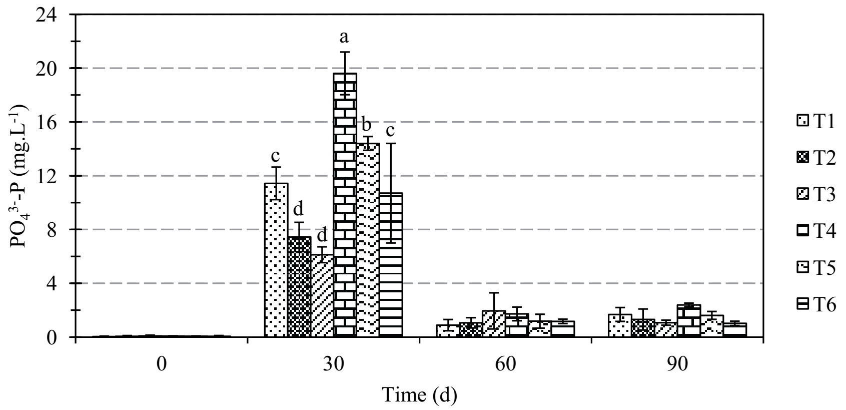

Figure 6 PO_4^{3-}-P concentrations in water of paddy fields at different days after fertilization. (T1–T6 are the experimental treatments shown in Table 1. Error bars show ± SD. Different letters above each column are significantly different according to Duncan's new multiple range test, at $P < 0.05$).

phosphate concentrations were high during the early growing season due to the fertilization process. Low concentrations appeared at the end of the season when most phosphate has been utilized by rice plants. It was possible that the water level in the paddy field decreased.

The concentrations of phosphate following fertilizer broadcasting were higher than from using deep placement but broadcasting phosphate was not as effective as placement because of the likelihood of more rapid conversion to less available phosphorus compounds. Consequently, the concentration of phosphate by deep placement at 10 cm was higher than at 20 cm because phosphorus is relatively immobile in the soil. Thus, it will not leach like nitrate or be carried to plant roots by soil water. The concentration of phosphate increased with increasing concentration of chemical fertilizer.

Therefore, irrigation in paddy fields should be managed to control the water in the paddy field at 30 d after planting and water drainage should be prevented to prevent nutrient removal. The PO_4^{3-}-P concentrations in T4, T5 and T6 were higher than in T1, T2 and T3 due to the higher application levels.

Effect of chemical fertilizers on rice yield

The rice yield was significantly higher in T4, T5 and T6 than in T1, T2 and T3 as presented in Table 2.

Table 2 Rice yields after different fertilizer treatments for 120 d.

Treatment	Rice yield (kg.ha^{-1})
T1	1,462.50^{e} ± 18.75
T2	1.531.25^{d} ± 13.01
T3	1,343.75^{f} ± 20.09
T4	2,156.25^{b} ± 9.54
T5	2,250.00^{a} ± 5.05
T6	1,593.75^{c} ± 16.21

$^{a–f}$ = Values (± SD) with different superscript letters are significantly different according to Duncan's new multiple range test, at $P < 0.05$.

T1–T6 are the experimental treatments shown in Table 1.

The rice yield of T4 was 1.47 fold higher than that of T1 after doubling the fertilizer concentration as occurred in T2 and T5. T5 also produced significantly higher yields (2,250±5.05 $kg.ha^{-1}$) than T4 (2,156.25±9.54 $kg.ha^{-1}$) and T6 (1,593.75±16.21 $kg.ha^{-1}$), proving that the rice yield response was due to available plant nitrogen supplied by the fertilizer. In contrast, the lowest rice yield (1,343.75±20.09 $kg.ha^{-1}$) was in T3. The rice yields in T4, T5, and T6 significantly increased due to the increase of nitrogen fertilizer rate.. In contrast, increasing the concentration of fertilizer by deep placement at 20 cm from 218.75 $kg.ha^{-1}$ (T3) to 437.50 $kg.ha^{-1}$ (T6), resulted in a 1.19 fold increase in the rice yield in T6 compared to T3. Additionally, the rice yields in T3 and T6 where nitrogen fertilizer was applied at a soil depth of 20 cm were significantly lower than that at the 10 cm depth and with broadcasting due to the nutrient available to roots at 10 cm. The rice yields in T4, T5 and T6 increased after increasing the concentration of fertilizer two-fold, due to the nutrient requirement from the tillering stage onward. Fertilizers promoted rice growth and affected the rice yield because nitrate and phosphate are primary nutrients for rice growth in all stages of rice (Maejo University, 2013). This suggests that field experiments should be conducted to allow farmers to precisely predict the effect of nitrogen application on rice growth. The rice yields at the same application rate of fertilizer with deep placement at 10 cm were higher whereas the NH_4^+-N and NO_3^--N concentrations were lower than by broadcasting. Therefore, excessive depth by deep placement and the greater convenience of fertilizer application by broadcasting in the rice field could not increase the rice yield but did result in a greater nitrogen loss.

CONCLUSION

The levels of NH_4^+-N, NO_3^--N, PO_4^{3-}-P and rice yields were determined in paddy fields at different chemical fertilizer concentrations and applications (broadcasting and deep placement) in Nong Harn, Sakon Nakhon province. The results showed that rice cultivation along with fertilizer applications led to significant releases of NH_4^+-N, NO_3^--N and PO_4^{3-}-P. The NH_4^+-N concentration in the water was markedly ($P < 0.05$) higher in T4 than in T1, T2, T3, T5 and T6 under 30, 60 and 90 d after planting. The highest NH_4^+-N and NO_3^--N concentrations were in T4 at 60 d after planting and at T4 at 90 d after planting, respectively because the concentration of chemical fertilizer was higher than in T1. In contrast, the concentrations of NH_4^+-N and NO_3^--N were low in T3 and T6.

Urea fertilizer applied by deep placement was not easily dissolved and NH_4^+-N was released into the water more slowly than with broadcasting. The release of NH_4^+-N from the 16-16-8 chemical fertilizer and from the urea proceeded slowly followed by an eventual decline. The NH_4^+-N level decreased with time. It was also found that the concentrations of NO_3^--N in T4, T5 and T6 were higher than in T1, T2 and T3. The concentration of NO_3^--N in T1 was significantly lower than in the other treatments at 60 and 90 d after planting. Additionally, the highest concentration of PO_4^{3-}-P was also in T4 at 30 d after planting. The concentrations of phosphate using broadcasting were higher than by using deep placement and the treatment at 10 cm had higher phosphate levels than that at 20 cm. Therefore, irrigation in paddy fields should be controlled at 30 d after planting with water drainage from the area not allowed to cause nutrient removal from the paddy. The rice yield was significantly higher inT4, T5 and T6 than in T1, T2 and T3 and the rice yields were higher for the same rate of fertilizer application at deep placement at 10 cm than at 20 cm and by broadcasting. Therefore, nitrogen fertilizer application and the concentration can affect the utilization efficiency of the fertilizer, influencing rice yields and nitrogen usage. The optimum application of nitrogen fertilizer gained from this study was deep placement at 10 cm based on the rice yield and the NH_4^+-N, and NO_3^--N contents of paddy field water. Furthermore, the water should be stored in the rice field to reduce nutrient loss into the environment.

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