# INFLUENCE OF LONG -TERM APPLICATION OF N, P AND K LEVELS ON SOIL PROPERTIES AND RICE YIELD IN THE CUU LONG DELTA, VIETNAM

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## ABSTRACT

*Double-cropped, high-yield rice with NPK fertilizer has been practised in the Mekong River Delta nearly 20 years, but long-term effects on soil properties have not been examined. A long-term experiment that commenced in 1986 was used to examine the effect of nitrogen (N), phosphorus (P) and potassium (K) applications after 34 consecutive crops in intensive rice monoculture at CLRRI, Thoi Lai, Can Tho City, Vietnam. It showed that soils is good in development, soil texture is loam clay, bulk density varied from 0.93- 1.03 g/cm$^3$, organic matter in height. Soil porosity is relative high and no consistency and structural stability is low. EC, pH ($H_2O$) and pH (KCl) are decreased dramatically over initial. Removal all of rice straw on the field led to soil organic carbon decreasing. N, P, K elements in soil were analyzed to know the influence of long term application by N,P,K to soil properties and rice yield. Our results showed that after 34 rice seasons it decreased stronger. Total N content in soil increased in applying of P alone, and NK, PK, and NP combined treatments and slightly increased in treatment of NPK. Total N in soil was not changed in any treatments applying with N and decreased in control (without applying fertilizer) and K alone treatments. Bray extractable P content increased in treatments with P alone or PK and NP but not in the NPK treatment. Total P was not affected by long term N, P, K fertilizer application. Total K was still high in plots with and without K fertilizer. Exchangeable K was high in the plots supplied K. Overall, the levels of N, P and K in soils after 34 consecutive crops indicated minimal decline in total N, a 25% decline in total P and no change in total K for plots which had no fertilizer added. By contrast, with the recommended fertilizer rates of N, P and K, the total levels of these elements in the soil remained unchanged. However, recommended NPK fertilizer appears to increase nitrate N, and Bray-2 P but not exchangeable K. Cation exchange capacity (CEC) was not much changed. Cation exchange capacity (saturation) of soil was low, cation exchange capacity (unbuffer) was high, cation exchange capacity (buffer pH 8.1) was rather high, exchangeable $Ca^{++}$ and $Mg^{++}$ remained high. The main change in soil quality after 34 crops of rice and continuous fertilizer application caused the decline in soil organic matter, which was removed after every rice crop. There is yield declining phenomenon in rice with time in wet seasons and increase in dry seasons. In order to overcome this phenomenon, it is necessary applied P and returned rice straw to the field.*

***Keywords**: cation exchange capacity (CEC), long term experiment, organic carbon model, soil fertility, yield decline*

## INTRODUCTION

Rice production in the Mekong Delta is an important factor for food security in Vietnam and rice exports. However, it is little known about the sustainability of the current production systems, particularly systems with double or triple rice cropping and minimum tillage. Intensive rice mono-culture may lead to increased weeds, disease, and insect pressure. Poor seed quality, low N- use efficiency, deteriorating soil fertility, and stagnating or declining rice productivity are other major concerns (Phung *et al*. 1998). Further, rapid urbanization is decreasing the available rice production area.

During the past 25 years, the fluxes of nutrients within a typical irrigated rice field have increased 5 to 7 folds and cannot be met by natural sources alone such as sediments provided by the Cuu Long River. Mineral fertilizer has become a dominant input to the overall nutrient balance, but their use is often unbalanced and the efficiency of their use remains below optimum levels. Managing the variability in soil nutrient supply that has resulted from intensive rice cropping is one of the major challenges to sustaining and increasing rice yields in the Cuu Long River Delta (Dobermann *et al*. 1996).

Aside from soil pH, organic matter in soil can improve soil structure as well as the store of major and trace elements. Tuyen and Tan (2001) showed that returning organic matter as rice straw had improved soil fertility and the increased exchangeable $Na^+$, $Ca^{++}$ and $Mg^{++}$ on rice soils in the Cuu Long River Delta.

The objectives of this study are as followed:

(1) To assess some important soil physic properties, the major soil elements;

(2) To assess EC, soil pH, organic matter, CEC, exchangeable cations.

(3) To determine organic carbon content in order to warn exploit soil resources of human, not only use but also reclaimed and replenish soil

## MATERIALS AND METHODS

The long-term fertility experiment with the rice- rice system was established on an experimental field of Cuu Long Delta Rice Research Institute, Thoi Lai district, Can Tho city from 2000 to 2007. A randomized complete block design with eight treatments of N, P, K with 4 replications were used. Two dosages of each N, P, and K (0 and 80 kg N $ha^{-1}$, 0 and 17.5 kg P $ha^{-1}$, 0 and 25kg K $ha^{-1}$) were applied in a factorial combination. Eight treatments comprised of control (no fertilizer), N, K, NK, P, PK, NP, and NPK. Same doses of fertilizer were used for both wet and dry seasons. From the dry season 1994-1995, K rate was increased to 75 kg K $ha^{-1}$. After harvesting mature crops, rice straw and stubbles were removed from the field. Fertilizer sources were urea (46 % N), super phosphate (18 % $P_2O_5$) and muriatic potash (60 % $K_2O$).

**Soil physical properties:** Soil profile was described that based on guidelines from FAO (1990), soil color determination based on Munsell soil color charts (2000) and soil classification by FAO/UNESCO (1979). Soil texture were determined using pipette method and soil bulk density metal cylinder ring, respectively. Soil particle density was determined by pycnometer. Soil porosity was calculated from formula of bulk density and particle density. Soil consistency was described by Klute (1986) and structural stability was determined by Verplancke (2002).

**Soil chemical analysis:** Soil samples were collected at the end of the 34th crop season of the N, P, K long- term experiment from the eight treatments. Total N in soil was analyzed by Kjeldahl method (Bremner *et al*., 1982). Available N with $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ forms, determined by Peech *et al*., (1947). In order to determine total P, soil samples were digested by $H_2SO_4$ and $HClO_4$ (Olsen *et al*., 1954) and measured with spectrophotometer. Determined available P by Bray 2 method ($NH_4F$ 0,03N in HCl 0,1N solution) (Bray and Kurtz, 1945). Determined total K, soil samples were digested by $H_2SO_4$ and $HClO_4$ measured with atomic absorption spectrophotometer (Tiem and Tau 1983). Determined EC using a 1:1 soil: water ratio by electric conductivity meter, pH ($H_2O$) by 1:1 soil: water and pH (KCl) by 1:1 soil: KCl 1N solution ratio by pH meter (Dobermann 1997). Determined organic carbon by Walkley-Black (1934) method. Determined cation exchange capacity (CEC) by saturated extraction, unbuffered and buffered and extracted by $BaCl_2$ 0.1M at pH 8,1 and exchange cations ($K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$) (0.1M

$BaCl_2$) measured with atomic absorption spectrophotometer (NISF 1998).

## RESULTS AND DISCUSSIONS

**Typical soil profile:** Below layer of the plow soil had formed the plow pan. There is no structure in the layer, very heavy clay. Soil is classified as gleyic fluvisols. Soil texture is silty clay, very suitable for growing rice plant. Clay fraction occupied the highest ratio (57.41 to 59.91%), followed by silty fraction (40.39 to 42.18%). The sandy fraction was lowest (0.25 to 0.52%) and no significant difference among treatments (Fig. 1).

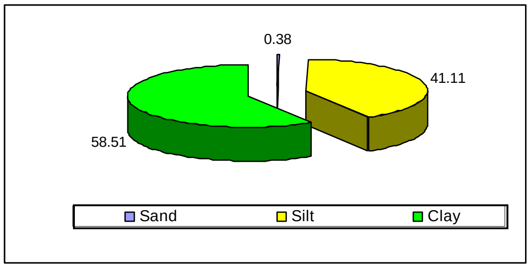


**Figure 1.** Soil texture in fraction

**Some soil physic properties:** Soil bulk density varied from 0.93 to 1.03 g/cm$^3$ and no significant difference among treatments. According to Ngo Ngoc Hung (2004), for rice plant, soil bulk density is not important criteria. Low bulk density sometime destroys plant because it cannot hold water. Soil bulk density > 1.2 g/cm$^3$ and plow pan > 1.4 g/cm$^3$ is very suitable for growing rice plant. Soil particle density was not significantly different among all treatments and varied from 2.18-2.45 g/cm$^3$. Soil porosity of all treatments were not significantly different and varied from 57.6- 61.8%. This was poroxy soil, very suitable for rice roots development and nutrient uptake.

Soil bulk density and soil porosity are important in soil physic properties to evaluate soil physic fertility. Some of these parameters indirectly reflect soil detraction such as soil compact, infiltration rate, water hold capacity of soil and the other important criteria in evaluation soil variations. Soil consistency on three players (0-20 cm, 20-40 cm and > 40 cm) gradually decreased with the depth and was not significantly different in the same player in all treatments. Structural stability was measured after rain or mechanical force or irrigation. Application of potassium alone for a long time caused soil instability, even without fertilizer. Application of nitrogen and phosphorus alone for a long time was not increased stability, but combination of nitrogen and potassium for a long time increased the stability of soil. Application of phosphorus for a long time did not decreased stability. In contrast, combination of phosphorus and potassium for a long time would be decreased stability. Application of NPK enough for a long time maybe made soil the most stability.

**Some soil chemical properties:** Some chemical properties of soil surface layer (0-20 cm) after 34 consecutive crops in intensive rice mono-culture on plots which different of N, P and K fertilizer regimes at CLRRI, Thoi Lai, Can Tho city, Vietnam were monitored.

**EC (mS/cm) in soil:** In the surface soil, EC ranged from 0.20 to 0.26 mS/cm (Table 1), it did not limit to rice growth and was evaluated no effect after long-term rice growing (USDA, 1983). Nevertheless, EC values of all treatments declined compared to the initial EC value (0.74 mS/cm). This suggests that after cultivating two crops/year, the irrigation decreased the soluble salt concentration. In control plot, EC was lower than those supplied with fertilizer. This indicates that fertilizer increases the salt concentration in soil, but not to a harmful extent.

**Soil pH:** In soil surface of all treatments, pH ($H_2O$) values were dramatically decreased as compared with initial (pH= 5.2) by more than one unit after 34 rice crops in all treatments. PH was lowest in control (no fertilizer) and N alone and highest in K and NK treatments. After harvesting in dry season, the field was fallowed for two months which caused deep cracks of more than 1 m from soil surface. This is favorable for oxidization of pyrite in soil and increasing Fe sulfate. Fe sulfate turned on jarosite leading to reduce pH.

The value of pH (KCl) in soil was reduced stronger than pH ($H_2O$) after 34 rice crops. pH (KCl) value in soil also dramatically decreased compared to the initial pH value {pH (KCl) = 4,08}. The effects of treatments on pH (KCl) were similar to those for pH ($H_{2-}O$). However, these pH values did not affect on rice yield because they were measured in dry condition. Alluvial soil has low pH value because of the process of leaching of Ca, Mg and accumulation of $SiO_2$, Al, Fe. Rice is highly adaptable ability to different conditions of environment, thus rice can grow and produces high yield in various soil pHs, largely due to pH increase under flooding. However, Lap, (1990) reported that soil with pH < 6.6 is the best condition for growing rice, and it can produce higher yield than neutral or alkaline. Alluvial soil has low pH value, not excreted organic acid from rice roots, also not due to apply single fertilizer forms that has chemical acidic property such as single super phosphate and muriatic potash. Because of pH of plots with P or with K were not lower than compared control plot.

**Table 1.** EC, pH ($H_2O$) and pH (KCl) of soil after 34 rice crops. Values are means of four replicates. Apart from the initial value, means in a column followed by the same letter were not significantly different.

| Treatment | EC (mS/cm) | pH ($H_2O$) | pH (KCl) |
|---|---|---|---|
| Initial | 0.74 | 5.2 | 4.08 |
| Control | 0.20 a | 3.94 a | 3.63 ab |
| N | 0.25 b | 3.94 a | 3.55 a |
| K | 0.24 b | 4.18 b | 3.71 ab |
| NK | 0.24 b | 4.18 b | 3.78 b |
| P | 0.26 b | 4.02 ab | 3.59 ab |
| PK | 0.24 b | 4.11 ab | 3.70 ab |
| NP | 0.26 b | 4.01 a | 3.71 ab |
| NPK | 0.25 b | 4.11 ab | 3.68 ab |
| CV (%) | 23.7 | 3.5 | 9.8 |

**Total N (%) in soil:** After 34 rice crops, the total N in all treatments ranged from 0.248 % to 0.303 % N (Table 2). Total N in control treatment (0.248 % N) was lower than at the initial status (0.26 % N). Total N in treatments supplied only K fertilizer was not different from control and lower than other treatments except NPK.

**Extractable N as $NH_4^+$ and $NO_3^-$ forms:** Extractable N as $NH_4^+$ form was not significantly different among treatments. By contrast extractable $NO_3^-$ was about twice as high in plots fertilized with N as in those without N application. Overall, 3-6 times more extractable N was in $NH_4^+$ form as in $NO_3^-$. According to Nguyen Vy (2003), $NH_4^+$ also strongly changed at different humid levels. The increase of humidity leads to strongly reduce oxidation and increase $NH_4^+$ content. Also according to Nguyen Vy (2003), there is very different between temperate and topical zone in many soils in Vietnam. Extractable N is presented almost quite few in $NO_3^-$ form, usually less than 1mg/g soil and very low compare with $NH_4^+$ form even in neutral soil.

**Table 2.** Total N (%N), N extractable (mg/kg), total P (% $P_2O_5$) và P extractable (mg $P_2O_5$/100g) in soil after 34 consecutive rice crops in intensive mono culture fertilized with N, P and K. Values are means of four replicates. Means in a column followed by the same letter were not significantly different (P < 0.05)

| Treatment | Total N (%) | $N\text{-}NH_4^+$ (mg/kg) | $N\text{-}NO_3^-$ (mg/kg) | Total P (% $P_2O_5$) | P-Bray 2 (mg$P_2O_5$/100g) |
|---|---|---|---|---|---|
| Initial | 0.26 | | | 0.05 | |
| Control | 0.248 a | 26.04 | 4.39 ab | 0.037 a | 0.254 a |
| N | 0.266 ab | 29.29 | 8.77 b | 0.038 a | 0.275 ab |
| K | 0.249 a | 23.78 | 5.82 ab | 0.037 a | 0.281 ab |
| NK | 0.284 bc | 32.04 | 6.42 ab | 0.039 a | 0.309 ab |
| P | 0.297 bc | 27.81 | 2.80 a | 0.060 c | 0.784 c |
| PK | 0.289 bc | 30.82 | 4.43 ab | 0.056 c | 0.473 ab |
| NP | 0.303 c | 28.18 | 8.15 b | 0.053 bc | 0.526 b |
| NPK | 0.278 abc | 25.24 | 8.33 b | 0.045 ab | 0.498 ab |
| CV (%) | 7.5 | 17.8 | 46.3 | 13.6 | 36.8 |

**Total and extractable $P_2O_5$ in soil:** The data in table 2 shows that total $P_2O_5$ in all treatments ranged from 0.037 to 0.060 % $P_2O_5$. This indicates that $P_2O_5$ in soil was poor. The total $P_2O_5$ in all treatments supplied fertilizer P were equivalent to or higher than the initial P value. Treatments without P were 25 % lower than the initial value.

Bray - 2 extractable P was lowest in the control treatment and highest in the treatment supplied P alone (Table 2). The values in all other treatments apart from NP were not significantly different from the control.

**Total K (%$K_2O$) and exchangeable K (meq/100g) in soil:** Although the soil had uniformly high in total K, exchangeable K was low. Hoa (1998) reported that total K in Cuu Long River Delta soils is from 1.41 to 1.91 % $K_2O$, which is comparable to the present site. Exchangeable K quantity in alluvial soil was evaluated from medium to high, with a limiting value for rice of 0.21 cmol/kg. Thai (1994) studied on clay mineral components and show that it is rich in hydromica, vecmiculite and illite which are absorbed K strongly.

Exchangeable K and available K are major nutrient sources for the crops. Exchangeable K in all treatments varied from 0.105 to 0.249 meq/100g. Exchangeable K was highest in K treatment (0.249 meq/100g), followed by NK treatment (0.236 meq/100g). Exchangeable K was not significantly different among control, N, P, NP, and NPK treatments and they were lower than other treatments (Table 4).

Total K was very abundant (Table 4) and exchangeable K is an important nutrient source for plant. The levels of exchangeable K seem to reflect the opposing effects of fertilizer K application and K depletion by straw and grain removal. The K and NK treatments had highest exchangeable K presumably because yield was low in these treatments and hence the fertilizer K was able to accumulate over time. By contrast, in the highest yield treatments, which had K, fertilizer added, NPK, crop removal of K appears to have prevented any accumulation of exchangeable K over time. Alternatively, there may have been differences in K fixation among treatments, related to crop yields.

**Cation exchange capacity (CEC) (meq/100g) and exchangeable cations in soil:** Quantity and quality of CEC are important criteria of soil fertility which reflect contain capacity and nutrient regulation, its concern to suitable applied fertilizer method. Soil that is rich in organic matter and high CEC are considered as nutrient stored capacity of soil.

Cation exchange capacity (saturation) of soil was low. It varied from 4.49 to 5.55

meq/100g. Cation exchange capacities (unbuffer) were high in all treatments and it varied from 16.5 to 17.4 meq/100g but no significant differences. Cation exchange capacity (buffer pH 8.1) was rather high, varied from 27.39 to 28.44 meq/100g. It was not different among treatments (Table 3).

**Table 3.** Cation exchange capacity (meq/100g) in soil after 34 consecutive rice crops in intensive mono culture fertilized with N, P and K. Values are means of four replicates. Means in a column followed by the same letter were not significantly different ($P < 0.05$)

| Treatment | CEC (saturation) | CEC (unbuffer) | CEC (buffer pH 8.1) |
|---|---|---|---|
| Control | 4.49 a | 17.36 | 27.47 |
| N | 4.50 a | 16.58 | 28.32 |
| K | 4.53 ab | 16.94 | 27.39 |
| NK | 5.13 abc | 17.03 | 27.64 |
| P | 5.18 abc | 16.66 | 28.44 |
| PK | 5.05 abc | 16.75 | 27.99 |
| NP | 5.55 c | 16.46 | 28.26 |
| NPK | 5.29 bc | 16.93 | 27.71 |
| CV (%) | 9.5 | 5.8 | 4.1 |

**Exchangeable K in soil (meq/100g)**

Exchangeable K in all treatments varied from 0.105 to 0.249 meq/100g. Exchangeable K was highest in K treatment (0.249 meq/100g), followed by NK treatment (0.236 meq/100g). Exchangeable K was not significantly different among control, N, P, NP, and NPK treatments and they were lower than other treatments (Table 4).

**Table 4.** Total K, exchangeable cations (meq/100g) in soil after 34th rice crop seasons in intensive mono culture fertilized with N, P and K. Values are means of four replicates. Means in a column followed by the same letter were not significantly different.

| Treatment | Total K (%$K_2O$) | Exchangeable cations | | | |
|---|---|---|---|---|---|
| | | $K^+$ | $Na^+$ | $Ca^{2+}$ | $Mg^{2+}$ |
| Control | 1.95a | 0.126 a | 0.913 abc | 11.3 ab | 9.95 a |
| N | 1.94a | 0.134 a | 0.754 ab | 11.7 b | 9.30 a |
| K | 1.99a | 0.249 c | 1.070 bc | 11.1 ab | 10.4 a |
| NK | 1.99a | 0.236 bc | 0.936 abc | 9.82 a | 10.2 a |
| P | 1.93a | 0.136 a | 0.847 abc | 11.3 ab | 9.95 a |
| PK | 1.96a | 0.193 b | 0.881 abc | 11.0 ab | 9.80 a |
| NP | 1.95a | 0.105 a | 0.704 a | 10.8 ab | 10.0 a |
| NPK | 1.96a | 0.111 a | 1.11 c | 11.2 ab | 10.2 a |
| CV (%) | 2.5 | 18.9 | 22.3 | 10.0 | 10.3 |

**Exchangeable Na in soil (meq/100g)**

Exchangeable Na was lowest in NP treatment and highest in NPK treatment. This value in NP treatment was lower than those in K treatment and not different from other treatments (Table 4)

**Exchangeable Ca in soil (meq/100g)**

Exchangeable Ca was lowest in NK treatment and highest in N treatment. Exchangeable Ca value in NK treatment was lower than those in

N treatment and was not different from other treatments (Table 4)

**Exchangeable Mg in soil (meq/100g)**

Exchangeable Mg was lowest in N treatment and highest in K treatment, but it was not statistically different among all treatments. In general, exchangeable Ca and Mg were high although the experiment was not supplied with Ca and Mg fertilizer for 17 years (Table 4).

**Organic matter (OM):** Organic matter decreased strongly after 34 crops compared to initial status (6.13 %). In the Cuu Long River Delta, the high organic matter in soil surface tends to going down by long term rice cultivation (Tuyen, 1997). However, its content in soil was still high. Do Anh (2002) claimed that the optimum organic matter content in irrigated rice area is 4 %. Organic matter content ranged from 4.48 % to 4.92 % and was not statistically different among the treatments (Table 5). The decline in organic matter is attributed to the removing of rice straw from field after each crop. Ha (1999) and Do Anh (2002) showed that alluvial soil in Red River Delta with unbalanced fertilizer application, a decrease in humus from 814 to 867 kg/ha per crop, and soil fertility are exhausted rapidly. The presence of organic matter is advantageous for good soil structure, high activity of microorganism, available nutrients in soil and absorption ability of soil.

**Soil organic matter content predicting model:** In agricultural production, organic manure plays an important role. Although organic manure has low macro nutrient components, but it contains many nutrient components and some enzymes, which stimulate crop growth and development (Man *et al*., 2007). They increase rice yield and exclaim soils (Tan, 1992), help plants increase resistant vigor to pest (Xuan, 1982), enhance activity of soil microorganisms (Subba Rao, 1989) and save input cost such as fertilizer, chemicals, reduced cost in rice production (Tan, 1992).

**Table 5.** Steps calculate organic matter in soil organic matter content predicting model

| Treatment | OM (%) | OC (%) | OC in soils (t/ha) (a) | OC (2003)/ OC (1986) (= A) | ln (A) | ln (A)/17 (= B) | Exp (B) |
|---|---|---|---|---|---|---|---|
| Initial | 6.13 | 3.56 | 71.2 | | | | |
| Check | 4.58 | 2.66 | 53.2 | 0.747 | -0.292 | -0.017 | 0.983 |
| N | 4.77 | 2.77 | 55.4 | 0.778 | -0.251 | -0.015 | 0.985 |
| K | 4.53 | 2.63 | 52.6 | 0.739 | -0.302 | -0.018 | 0.982 |
| NK | 4.48 | 2.60 | 52.0 | 0.730 | -0.313 | -0.018 | 0.982 |
| P | 4.85 | 2.81 | 56.2 | 0.789 | -0.234 | -0.014 | 0.986 |
| PK | 4.67 | 2.71 | 54.2 | 0.761 | -0.272 | -0.016 | 0.984 |
| NP | 4.92 | 2.85 | 57.0 | 0.801 | -0.219 | -0.013 | 0.987 |
| NPK | 4.74 | 2.75 | 55.0 | 0.772 | -0.257 | -0.015 | 0.985 |
| Average (2003) | 4.69 | 2.72 | 54.4 | 0.765 | -0.268 | -0.016 | **0.984** |

OM: Organic matter; OC: Organic carbon = OM/1.724; (a) was calculate with assume bulk density = 1 Varied from 1986 WS to 2003 WS (17 years).

Besides, organic matter plays role in preventing toxic elements in agricultural products, make agricultural products clearer than (Yem, 1995). Application of organic manure in agricultural production with sense of a sustainable agriculture in future should be practiced. There are many long term experiments in the Philippines show that rice yield gradually decline after growing for a long time due to nitrogen supply do not effective (Cassman *et al.*, 1995).

To establish an estimate model changing of soil organic matter, the following calculation was applied (Watanabe 2007 *personal communication*).

OC content was estimated in a year: OC (N+1) = OC (N) x 0.984

Where, N: beginning year

OC content was estimated for a long time.

OC (estimating year) = OC (1986) x $0.984^{(estimating\ year - beginning\ year)}$

From beginning OC content, after 17 years analyzed again, the data would be calculated and shown in table 5. Application of residues aim to supplied nutrients to plant, increase soil organic carbon content, increase soil aggregate, decrease bulk density, enhance water hold capacity, increase infiltration rate and hydraulic conductivity (Chaudhary *et al*., 1986). In the Cuu Long Delta due to extensive farming which increase rice crop per year, so after rice harvesting, large quantity of fresh rice straw remain on the field that could be produced organic acid, caused toxic for rice plant. Organic carbon content in this predicting model, depend on many factors such as people, environment, soil properties, soil microorganisms population etc.... Calculating is simple, factors are not changed, this result aim at warning exploitation of soil resources and make the farmer to understand about reclamation and replenish soil. In general, rice straw amount left on the field was 30-50% total amount of rice straw. A rice crop with yield of 6t/ha, also produce an approximate rice straw amount of 6t/ha. Nowadays, farmers in the Cuu Long Delta used rice straw for mushroom cultivation, fuel wood, feed for castle, covering for legume, spread out then burning.

Table 6 shows that removing all of rice straws out of the field decreased OC content remarkably. Using soil OC predicting model showed: Initial OC content are 3.56%, after 10 year of two rice crops/year with rice straw amount are taken, only left roots under soil surface, soil OC content still is 3.03%. Up to after 20 years soil OC content is 2.58%. After 50 years soil OC content is 1.59% and up to 100 years of extensive two rice crops/year, soil OC content is very low (0.71%). This leads to other disadvantages need to be considered. Thus, returning rice straw to the field plays very important role in remaining soil fertility when growing rice crops/year in long-term rice mono- culture. Therefore, rice straw removing but not returning organic manure to field, soil fertility gradually reduced lead to soil depletion.

**Table 6.** Predicting soil organic carbon in future

| Year | Number of year growing rice | Organic carbon (%) (Beginning) | Multiply* (exponential depend on year) | Organic carbon (%) Predicting |
|---|---|---|---|---|
| 1986 | Initial | 3.56 | - | **3.56** |
| 1996 | 10 | 3.56 | 0.851 | 3.03 |
| 2006 | 20 | 3.56 | 0.724 | **2.58** |
| 2016 | 30 | 3.56 | 0.616 | 2.19 |
| 2026 | 40 | 3.56 | 0.525 | 1.87 |
| 2036 | 50 | 3.56 | 0.446 | **1.59** |
| 2046 | 60 | 3.56 | 0.380 | 1.35 |
| 2056 | 70 | 3.56 | 0.323 | 1.15 |
| 2066 | 80 | 3.56 | 0.275 | 0.98 |
| 2076 | 90 | 3.56 | 0.234 | 0.83 |
| 2086 | 100 | 3.56 | 0.199 | **0.71** |

** Exponential of 0.984 depend on number of growing rice year. Ex: year of beginning growing rice is 1986, organic carbon content is 3.56%, to predict organic carbon content the year of 1996 (mean 10 years after). $3.56^* (0,984)^{10} = 3.03$. So after 10 years growing rice, predicting of organic carbon content is 3.03%.*

## SOIL FERTILITY AFFECTS TO RICE YIELD

### Rice yield:

Up to 2006 wet season crop, the experiment was carried out 20 wet season rice crops and 19 dry season ones. Rice yield trend gradually declined in wet season rice crop (Figure 2) and gradually increased in dry season rice (Figure 3). Some wet season rice crops showed NP and NPK treatments gave high yield up to 5t/ha and even if control treatment also obtained 3.15 t/ha in 1990 wet season crop. It is possible seen the importance of P element from 1992 wet season crop to 1999 one. In this period rice yield strongly declined particularly in without P applied treatments, with P applied treatments rice yield decline less than. Rice yield decline due to unbalance applied fertilizer, soil P is poor and no supply P fertilizer. From 1996 wet season to 1999 one; rice yield strongly declined particularly in without P treatments (N, K, NK and control treatments). This showed rice yield declined due to P shortage. Up to 2001 wet season, IR64 rice variety was replaced by OMCS2000, so that rice yield was improved. In wet season 2004, rice yield in without P increased double compared with 2003 one. Because of dry season crop before (2003-2004), the soil was fallowed to upgrade irrigation network of the experiment zone and soil was mineralized.

In dry season crops, all treatments increased rice yield trend. However, rice yield in first crops were low and application of P were not effective. It seems that the high soil organic matter was not benefit for rice yield (initial soil OC content was 3.56%). According to Oh (1979), if OC content exceeding 2.9% it does not benefit rice. Up to dry season 1990-1991, rice yield was improved much. Supply K alone usually obtain lower yield than supply N alone or combination of N and K.

In 1994-95 dry season crop, when increased N amount (100 kgN/ha), rice yield trend to increased clearly in N, K, NK, P and PK treatments. In dry season crop although supplied with a large phosphorus fertilizer at 17.5 kgP/ha (equal to 40 kg $P_2O_5$/ha), the rice yield did not increase maybe due to P shortage. In case of phosphorus residue in soil, it was taken by rice plants for one or many continuous crops. Therefore, on recommendation of P fertilizer for rice, phosphorus must be supply more amount P fertilizer in dry season crop than the wet season crop. This was suited with results of Tan *et al*. (1995), because of rice yield in dry season crop higher than that wet season crop, so they uptake more nutrients.

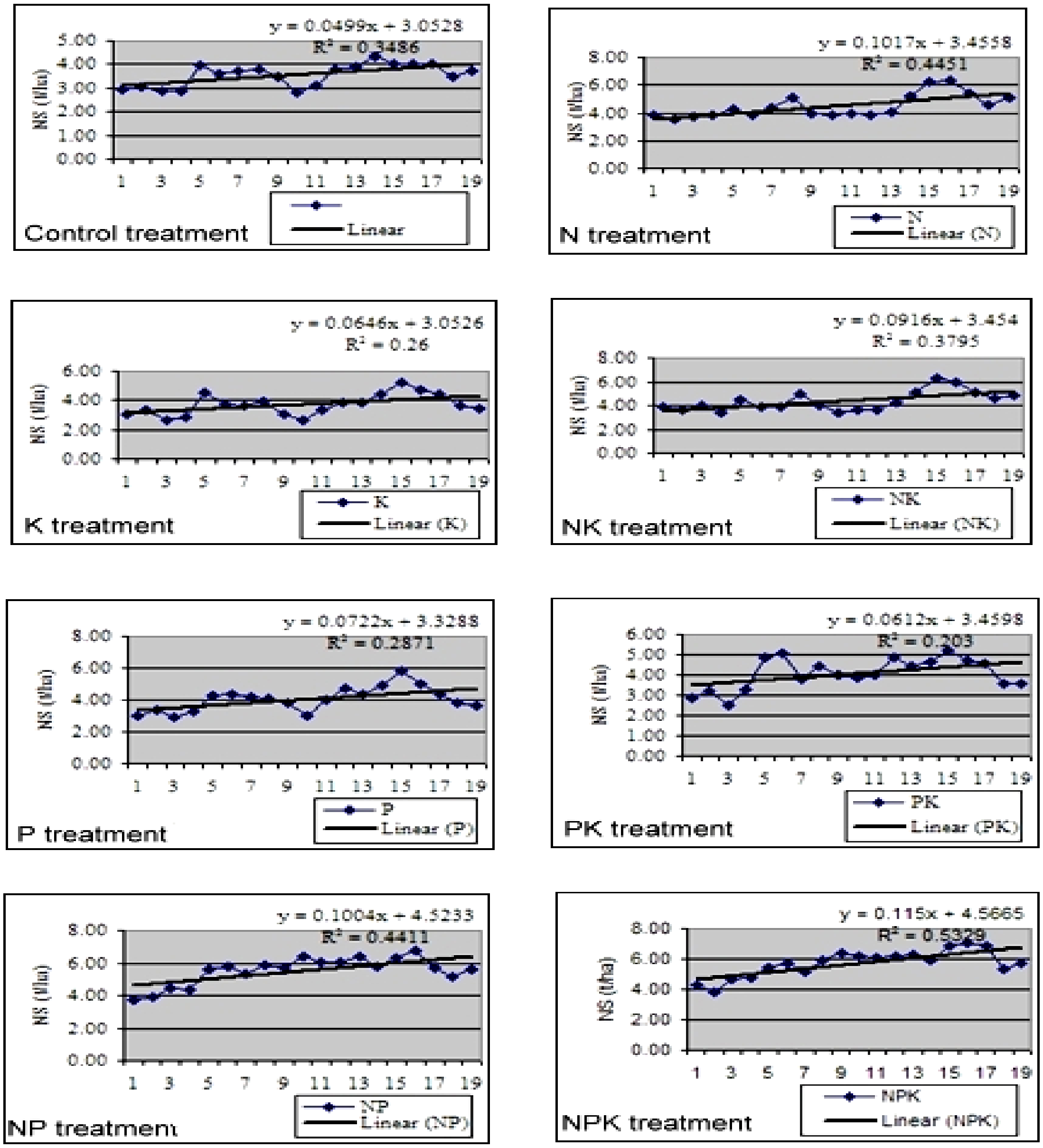


**Figure 2.** Rice yield trends of treatments in dry season crops

**Wet season /dry season rice yield ratio**

Rice yield was divided into two groups clearly, it was showed under ratio of wet season rice yield and dry season rice yield correlative with and without P. Rice plants were supplied phosphorus fertilizer obtained high rice yield in both wet season and dry season crops compared without P supplied (Table 7).

**Table 7.** Rice yield ($t.ha^{-1}$) and wet season / dry season rice yield ratio

| Treatment | Fertilizer rate ($kg.ha^{-1}$) | | | Yield ($t.ha^{-1}$) | | Yield ratio |
|---|---|---|---|---|---|---|
| | N | P | K | WS | DS | WS/DS |
| NPK | 80/100 | 17.5 | 75 | **3.91** | **5.72** | **0.68** |
| NP | 80/100 | 17.5 | 0 | **3.78** | **5.53** | **0.68** |
| PK | 0 | 17.5 | 75 | **2.90** | **4.07** | **0.71** |
| PK | 0 | 17.5 | 75 | **2.93** | **4.05** | **0.72** |
| NK | 80/100 | 0 | 75 | 1.61 | **4.37** | 0.37 |
| K | 0 | 0 | 75 | 1.54 | **3.70** | 0.42 |
| N | 80/100 | 0 | 0 | 1.70 | **4.47** | 0.38 |
| Control | 0 | 0 | 0 | 1.68 | **3.55** | 0.47 |
| Total | | | | 20.05 | 35.46 | 4.44 |
| Average | | | | 2.51 | 4.43 | 0.56 |

***Note:*** *WS: Wet season; DS: Dry season*

Regressions of grain yield shows in wet season crop tend to decline rice yield. Rice yield decreased from 22 to 61 kg $grain^{-1}.ha^{-1}.year^{-1}$. Application of phosphorus lead to grain yield decreased less than no application. In dry season crops, all treatments increased rice yield. Rice yield increased from 50 to 115 kg $grain^{-1}.ha^{-1}.year^{-1}$ compared with the first crop. Nitrogen fertilizer is the main factor that makes the rice yield increased in dry season crops (Table 8).

**Table 8.** Regressions of grain yield with time for twenty wet season and nineteen dry season crops showing effect of nitrogen (N) and phosphorus (P), where yield ($kg.ha^{-1}$) = a + bx year, for means with and without P (1986-2006)

| Treatment | Intercept A ± SE ($kg^{-1}.ha^{-1}$) | Slope b ($kg.ha^{-1}. year^{-1}$) | Correlation coefficient (r) |
|---|---|---|---|
| **Wet-season** | | | |
| K | 1.80 ± 0.38 | $-22^{ns}$ | 0.16 |
| Control | 2.11 ± 0.33 | $-39^{ns}$ | 0.32 |
| PK | 3.31 ± 0.33 | $- 42^{ns}$ | 0.34 |
| P | 3.38 ± 0.35 | $-46^{ns}$ | 0.35 |
| NK | 2.16 ± 0.49 | $-49^{ns}$ | 0.27 |
| N | 2.33 ± 0.49 | $-58^{ns}$ | 0.32 |
| NP | 4.34 ± 0.22 | -58** | 0.60 |
| NPK | 4.50 ± 0.23 | -61** | 0.59 |
| **Dry-season** | | | |
| Control | 3.05 ± 0.19 | 50** | 0.59 |
| PK | 3.46 ± 0.34 | 61* | 0.45 |
| K | 3.05 ± 0.30 | 65* | 0.51 |
| P | 3.33 ± 0.31 | 72* | 0.54 |
| NK | 3.45 ± 0.32 | 92** | 0.62 |
| NP | 4.52 ± 0.31 | 100** | 0.66 |
| N | 3.46 ± 0.31 | 102** | 0.67 |
| NPK | 4.57 ± 0.57 | 115** | 0.73 |

*$^{ns}$ non sense* ***** *significant at 5% level* ****** *significant at 1% level*

## CONCLUSIONS

The soil analyses after 34 rice crops from the long term experiment conducted in intensive rice mono-culture indicate that between 1st crop and 34th crop, total N, Bray-2 P and exchangeable K levels differentially reflect the effects of fertilizer application and crop removal. Total N increased in NK, P, PK, and NP treatments, but not in the NPK treatment that has highest grain and straw yield and hence highest N removal. Of the different of N forms, only nitrate N increased in response to fertilizer, but not ammonium N. Total P increased in P, PK, and NP treatments but not in NPK treatment again reflecting the opposing effects of fertilizer input and crop removal. On the other hand, Bray – 2 P in P treatments are higher than the others. Total K are very abundant. The levels of exchangeable K seem to reflect the opposing effects of fertilizer K application and K depletion by straw and grain removal. The K and NK treatments have highest exchangeable K presumably because yield is low in these treatments and hence the fertilizer K is able to accumulate over time. By contrast, in the highest yield treatments which has K and NPK fertilizer added, the crop removal of K appears to prevent any accumulation of exchangeable K over time. Overall, the levels of N, P and K in soils after 34 consecutive crops indicate that minimal decline in total N, a 25 % decline in total P and no change in total K for control plots, which has not fertilizer added. By contrast, with the recommended rates of N, P and K fertilizer, the total levels of these elements in the soil remained unchanged. However, recommended NPK fertilizer appears to increase nitrate N, and Bray-2 P but not exchangeable K. pH ($H_2O$), pH (KCl), and EC decreased very strongly relative to the initial values. The dramatic decrease of soil organic matter is attributed the removal of rice straw after harvesting each crop. Thus, retaining rice straw in the field has the potential minimize the changes to soil fertility. Despite after 34 rice crops, the organic matter in soil reduced, CEC are not much changed and neither is exchangeable cation $Na^+$, $Ca^{++}$ and $Mg^{++}$, which in the latter two cases remained adequate for plant growth. Yield decline in rice over time in wet seasons and increase in dry seasons also recorded. To overcome this phenomenon, it is necessary applied P and returned rice straw to the field.

## SUGGESTIONS

1 In order to overcome rice yield decline phenomenon, it is necessary applied P adequate and returned rice straw to the field. The site-specific nutrient management program on rice is considered as the most attractable approach, especially in rice monoculture system.
2 Rice straws after harvesting need to be returned to field in addition to supply organic source to rice field.
3 Need to adjust phosphorus amount for rice in dry season after a long term in high yielding rice cultivation
4 Application of potassium must be twice for crop to make fertilizer more effective.
5 It is necessary to control irrigation depend on rice growth stage and water drainage after submergence for a long time

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## ẢNH HƯỞNG CỦA CÁC MỨC ĐỘ PHÂN BÓN N, P, K DÀI HẠN ĐẾN ĐẶC TÍNH ĐẤT VÀ NĂNG SUẤT LÚA CAO SẢN Ở ĐỒNG BẰNG SÔNG CỬU LONG

Nghiên cứu ảnh hưởng của bón phân đạm (N), lân (P) và kali (K) dài hạn trên vùng thâm canh lúa tại Viện Lúa ĐBSCL, Tân Thạnh, Thới Lai, Cần Thơ từ 1986 đến 2003 cho thấy về mặt vật lý đất, đất đang trên đà phát triển tốt, có thành phần cơ giới sét pha thịt, dung trọng thay đổi từ 0,93-1,03 g/cm$^3$, giàu chất hữu cơ. Đất có độ xốp tương đối cao và không dẽ chặt, tính bền cấu trúc thấp, đạm tổng số trong đất tăng ở các lô có bón NK, P, PK, và NP và tăng nhẹ ở lô bón NPK. Đạm tổng số không thay đổi ở nghiệm thức có bón N và giảm ở nghiệm thức không bón phân hoặc chỉ bón kali. Lân tổng số tăng ở các nghiệm thức bón lân hoặc lân kết hợp với kali. Lân dễ tiêu cao ở các nghiệm thức có bón lân. Kali tổng số cao ở cả hai nghiệm thức có bón K và không bón K. Tuy nhiên, kali trao đổi chỉ cao ở lô có bón kali. Về EC, pH ($H_2O$), pH (KCl), và chất hữu cơ giảm mạnh so với ban đầu. Đất có khả năng trao đổi cation trích bão hoà thấp, khả năng trao đổi cation (không đệm) khá, khả năng trao đổi cation (đệm pH 8,1) khá cao. Đất có $Ca^{2+}$ và $Mg^{2+}$ trao đổi cao. CEC không thay đổi nhiều và đất còn có thể duy trì và cung cấp tốt dưỡng chất cho cây lúa.

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