MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT VIETNAM
ACADEMY OF AGRICULTURAL SCIENCES

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EVALUATION OF DIRECT EFFECT AND RESIDUAL EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM FERTILIZER ON THE YIELD AND QUANTITIES OF HIGH-YIELD RICE IN MEKONG DELTA

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SUMMARY OF PHILOSOPHY DOCTORAL THESIS IN AGRICULTURE

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INTRODUCTION

1. The necessity of the study

In agricultural production, fertilizer is one of the important supplies and is used in large quantities annually. Fertilizers are key to maintaining productivity, increasing crop yields and quatities by increasing crop intensification and using more and more fertilizer (Alexandratos and Bruinsma, 2012). In the rate of the fertilizer usage for many kind of different crops, the highest is for rice (over 60%). In 2011, rice in Mekong Delta was used 395,000 tons of N, 200,000 tons of P_2O_5, 200,000 tons of K_2O (Chu Van Hach, 2012).

The trend of chemical fertilizer abuse in agriculture was increasing but the efficient use of fertilizer was low (Bui Ba Bong, 2013). If it reached 50%, the amount of fertilizer was wasted about US $ 2 billion per year (Nguyen Van Bo, 2014). Residual chemical fertilizers have increased the risk of diseases, reduced the quality of agricultural products, polluted water and air sources, and increased greenhouse gas emissions (Truong Hop Tac, 2009).

Many studies have been perform to improve use efficiency of fertilizer for rice in Mekong Delta. However, studies on the residual and cumulative effect of N, P, and K fertilizers on rice farm have not been studying much. Therefore, it will have being necessary and scientific basic for the study “Evaluation of direct effect and residual effect of nitrogen, phosphorus, potassium fertilizer on the yield and quantities of high-yield rice in Mekong Delta” to improve rice yield and qualiies in Mekong Delta, increase the efficiency of rice production, minimize environmental pollution.

2. The purposes of the study

- Determine the direct effect of N fertilizer, P fertilizer, and K fertilizer into the rice yield with triple-crop at alluvial soil and two-crop rice on acid sulphate soil in Mekong Delta.
- Determine the residual and cumulative effect of P fertilizer into the rice yield with triple-crop at alluvial soil and two-crop rice on acid sulphate soil in Mekong Delta.

- Determine the residual and cumulative effect of K fertilizer into the rice yield with triple-crop at alluvial soil and two-crop rice on acid sulphate soil in Mekong Delta.

- Evaluating the direct effect of N fertilizer, the direct effect and residues of P fertilizer and K fertilizer into some milling charecteristics of rice with triple-crop on alluvial soil and double-crop on acid sulphate soil in Mekong Delta.

- Offering to adjust the amount of N, P, and K fertilizers suitable for achieving high rice yield on alluvial soil and acid sulfate soil in order to improve the use efficiency of multiple fertilizers for rice in Mekong Delta.

3. The significance of science and practice

3.1. The significance of science

- Identifying scientific base and proposing solutions to improve the efficiency of using N, P, K fertilizers, reduce investment costs, increase economic efficiency for rice production in Mekong Delta.

- Contributing to provide data on supply and demand of fertilizer for rice production in Mekong Delta

3.2. The significance of practice

The mount of fertilizer is used more reasonable, its residue in soil is less to reduce soil, water and air pollution.

3.3. The novelty of the study

- This is the first systematic study to determine the direct and residual effect of N, P, K inorganic fertilizers for rice with triple - crop system on alluvial soil and double-crop system on acid sulphate soil in Mekong Delta.

- The results showed that K fertilizer with 30 kg $K_2O.ha^{-1}.crop^{-1}$ did not increase rice yield, comparing to no K fertilizing during of 4 years of cultivation. The results were consistent in both the triple-crop on alluvial soil in Can Tho and the double-crop on acid sulphate soil in Hau Giang.

- The study determined that the P (re_1) fertilizing had an insignificant influence into the rice yield of all experimanrtal crops on the triple-crop in Can Tho and the doule-crop in Hau Giang. In the case of 2-4 previous seasons without applying P but when applying again, the rice yield was equivalent to that of applying P continuously.

- No fertilizer and no N fertilizing reduced the quality of milled rice recovery and increased the percentage of chalkiness. They were not affected by no P and K fertilizing treament on both systems with triple-crop and double-crop in Mekong Delta.

4. The object and scope of the study

*** The object of the study:**

- Kind of crop: short-term high yield rice on the system of three rice crops.year^{-1} and two rice crops.year^{-1}.

- Type of soil:

(i) Alluvial soil is located in Thoi Lai, Can Tho (the West of Hau river).

(ii) Acid sulfate soil is located in Hau Giang (the Ca Mau Peninsula area).

- Fertilizers: N fertilizer, P fertilizer and K fertilizer.

*** The scope of the study:**

- Direct effect of N, P, K fertilizer with triple-crop in alluvial area and double-crop in acid sulphate soil in Mekong Delta.

- The residual and cumulative effect of P fertilizer and K fertilizer into rice yield on triple-crop and double-crop in Mekong Delta.

5. The structure of the thesis

The thesis consists of 149 pages and appendix of 85 pages. in the content, there are 51 tables, 22 figures, 152 references (97

Vietnamese documents and 55 English documents). In the appendix, there are 224 tables and 18 illustrations. There are 3 scientific article relating to the thesis that the PhD student major author publiced in Vietnam agricutural specialized journals.

Chapter 1. LITERATURE REVIEW

1.1. Scientific basic of the study

According to the evaluation of the International Plant Nutrition Institute, fertilizer contributed about 30-35% of total crop production. In China, fertilizer contributed 40%, new varieties contributed 30%, plant protection contributed 20% and mechanization contributed 10% for increasing crop productivity (Dongxin FENG, 2012). In conclusion, fertilizer plays the most important role in the technical group to improve crop productivity.

According to Nguyen Van Luat (2009), in order to achieve the maximum and optimal rice yield, it was necessary to study the correlation between soil, fertilizer and rice yield. It determined the ability to provide nutrition for rice in each soil type, how and how much fertilizer must apply which was suitable? The public of Phan Lieu (1994) studied about the relationship between soil nutrition, fertilizer amount and crop yield showed that the soil with high rice productivity and profit thanked to soil fertility, but soil fertility was dependent on soil nutrient status and the role of fertilizer.

The amount of nutrients present in the soil was not often sufficient for the plant to achieve the desired yield and quality. Therefore, fertilizing to provide enough nutritional needs for plants is essential. The additional fertilization for plants depended on the characteristics of each variety, barefoot, crop and farming techniques. Research on fertilization according to the needs of plants, taking into account the ability to supply nutrients from soil sources has been Dobermann and Witt. (2004) accurately assessed through the use of defect technology. To calculate the N, P, and K fertilizer requirements, specific square nutrient management (SSNM), an improved QUEFTS model (Janssen et al., 1990) was used.

According to Buresh (2010), fertilizer N did not contribute anything to rice soil and had no residual effect on subsequent crops. Meanwhile, excess P and K fertilization after crop uptake may still persist in the soil. Specific nutrition management with the use of nutrient balance to determine the needs of P and K fertilizer to quickly calculate the amount of P and K fertilizer needed to apply equilibrium with the amount of P and K crops removed .

1.2. Overview of fertilizers in rice production in Mekong Delta

The effect of fertilizer depends on the soil properties, fertilizer properties, amount of fertilizer, crop status, ... There are fertilizers that only work in one crop, but also the fertilizer that works in two or many cases. Therefore, assessing the effects of fertilizers on crops not only at the time of fertilizing but also to consider the effects of fertilizers in the following crops. The effect of a fertilizer nutrient on the level of an increase in crop yields at the time of fertilizing is called direct effect, and the effect of the fertilizer applied in the previous crop to the increase in crop productivity in subsequent cases is called residual validity. It is important to determine the direct and residual effect on crops in general and rice in particular under different conditions, to make reasonable recommendations to improve fertilizer efficiency. , avoid eutrophication in the soil, affecting the environment.

Prior to 1995, researches in the field of rice manure soil focused on finding solutions to reduce N losses, improve the efficiency of using N fertilizer and fertilizer in general, and proposed many solutions such as using urea. root pellets, using urea-coated materials such as sulfur, neem oil, rubber, plastic .... It is possible to limit the loss of N by fertilizing into the deep layer of the soil which can limit the loss of N- NH4 + (Bumb and Baanante, 1996). The use of slow-release urea helps to reduce the amount of N used compared to the appropriate level of fertilizer for rice, reducing the number of fertilizers compared to conventional urea (Trinh Thi Thu Trang and Vo Thi Mirror, 2002). However, these solutions are difficult to apply in the field, mainly due to low economic efficiency due to the high cost. Using N-coated agrotain can reduce the recommended fertilizer rates by 25% without reducing rice yield but the cost of agrotain-coated fertilizers remains high (Nguyen Van Bo et al., 2016). Using fertilizer-wrapped avail, the yield was similar to the amount of fertilizing of 30-60 kg P2O5 / ha and improved the efficiency of fertilizer P (de la Cruz, 2008) but the avail was not able to release the P seeds. It is immobilized by soil reactions and this polymer alone will not improve the effective P.

Studies turn to balanced fertilization and fertilizer application according to the needs of plants to increase yield and agronomic efficiency. The study of fertilizer application according to the needs of plants, taking into account the ability to provide nutrients from soil sources has been conducted correctly through the application of defect technology (Dobermann and Witt, 2004). The needs-based fertilizer research program has built a software that calculates the recommended fertilizer rates for farmers fairly accurately and is widely used (Buresh, 2010). Fertilizing according to SSNM not only helps adjust the amount of fertilizer according to the needs of the tree in each specific field but also calculates the amount of fertilizer according to the optimal ratio and the number of appropriate fertilization times to achieve high yield and investment efficiency. high fertilizer (Witt et al., 2002). The research cooperation program between Mekong Delta Rice Institute and IRRI continues the second phase (2001-2004) focusing on developing application software on "Nutrition management for rice in Mekong Delta". The software has been developed, completed and tested in many localities in Mekong Delta and is highly appreciated (Pham Sy Tan and Chu Van Hach, 2013).

In order to improve the efficiency of using N, P, and K fertilizers on rice, it is necessary to study solutions to reduce fertilizer losses or make optimal use of the amount of fertilizer used to reduce the amount of fertilizer input while still ensure rice productivity but not apply measures to increase the amount of fertilizer to increase rice yield per unit area. The studied solutions are all aimed at improving the efficiency and efficiency of using N, P, and K fertilizers on rice. These solutions can be applied by farmers during rice cultivation but cannot be developed by the whole population. The limitation of the above measures is that the implementation process is not really simple for all farmers because it depends a lot on the ability of farmers to absorb and living conditions. On the other hand, the recommended conditions that apply generally to a large area or area may not be completely consistent with the farming conditions of each field, so sometimes the results are not as expected. Therefore, the application of recommendations is the simplest, most common way for farmers to follow the farming process. It is important that the recommendations are accurate and effective.

These recommendations are based on the results of a study on the effect of N, P, and K on high yielding seasonal rice from short to long term and taking into account the possibility of nutrient return to the soil. For short-term studies, the experiment follows seasonal crops over a year. The results of which fertilizers are the most effective at each crop will be recommended for that crop. For long-term experiments, the deficient plots or the full application of N, P, K were carried out continuously from crop to crop. The results of the experiment only investigated the rice yield decreased when N, P, and K elements were lost over time due to continuous non-supply of fertilizer but could not be assessed when fertilizing one crop, then not applying one. or many crops, then fertilize again, how the growth and yield of rice will be affected. If the fertilizer is applied in the cropping season but still ensures the productivity of rice compared to the continuous fertilizing, the amount of fertilizer will be reduced, the fertilizer efficiency will be improved, and the economic efficiency will be higher.

Chapter 2. MATERIAL, CONTENT AND METHODOLOGY

2.1. Materials

- Experiment on alluvial soil was located at Tan Thanh commmumn, Thoi Lai cistrict, Can Tho city, carried out continuously for 4 years with triple-crop rice system (Winter-Spring (WS), Spring-Summer (SS) and Summer-Autumn (SA)), starting from crop of 2011 SS (1^{st} crop) to crop of 2014-2015 WS (12^{th} crop).

-Experiment on acid sulphate soil: was arranged in the experimental at Vi Thang commumn, Vi Thuy district, Hau Giang province, carried out continuously for 4 years on double-crop rice sytem, (WS and SA), starting from crop of 2011-2012 WS (1^{st} crop) to crop of 2015 SA (8^{th} crop).

- Fertilizers: Phu My urea (46% N), super phosphate (16% P_2O_5) and fused phosphate (16% P_2O_5), potassium chloride (60% K_2O);
- Rice variety: OM5451 high-yeild rice variety.

2.2. Research contents

- Evaluating the direct effect of N fertilizer, residual and cumulative effect of P fertilizer and K fertilizer into rice yield and milling quality with triple-crop system on alluvial soil in Can Tho.
- Evaluating the direct effect of fertilizer N, residual and cumulative effect of fertilizer P and K fertilizer into rice yield and milling quality with double-crop system on acid sulphate soil in Hau Giang.

2.3. Methodology

The experiment is pernament on exactly position of the soil in 4 years long-term, maked edge between plots and covered nylon to ensure no disturbance from the first crop to the last crop.

- Layout type: the experiment was arranged in a completely random block (RCBD), with 13 treatments (T) and 4 replicates in Can Tho and 3 replications in Hau Giang.

Bảng 2.1 Fertilizing treatments were applied in the experiment

T	Fertilizing	The method of treatments
1	-NPK	Non fertilizer
2	-N	Fertilizing P, K (non-N)
3	-P	Fertilizing N, K (non-P)
4	-K	Fertilizing N, P (non-K)
5	NPK	Fertilizing NPK (adcording to the procedure)
6	P (re1)	Adcording to T5 but P in 1 crop, non-P in 1 crop
7	P (re2)	Adcording to T5 but P in 1 crop, non-P in 2 crops
8	P (re3)	Adcording to T5 but P in 1 crop, non-P in 3 crops
9	P (re4)	Adcording to T5 but P in 1 crop, non-P in 4 crops
10	K (re1)	Adcording to T5 but K in 1 crop, non-K in 1 crop
11	K (re2)	Adcording to T5 but K in 1 crop, non-K in 2 crops
12	K (re3)	Adcording to T5 but K in 1 crop, non-K in 3 crops
13	K (re4)	Adcording to T5 but K in 1 crop, non-K in 4 crops

- Fertilizer for alluvial areas in Can Tho:

+ In WS crop: 100N - 40 P_2O_5 - 30 K_2O ($kg.ha^{-1}$).

+ In SS crop: 90N - 50 P_2O_5 - 30 K_2O ($kg.ha^{-1}$).

+ In SA crop: 80N - 50 P_2O_5 - 30 K_2O ($kg.ha^{-1}$).

- Fertilizer for acid sulphate soil in Hau Giang

+ In WS crop: 90N - 50 P_2O_5 - 30 K_2O ($kg.ha^{-1}$).

+ In SA crop: 80N - 60 P_2O_5 - 30 K_2O ($kg.ha^{-1}$).

- Time of fertilizing:

7-10 days after sowing (DAS): 25% N + 100% P + 50% K.

22-25 DAS: 40% N.

40 - 45 DAS: 35% N + 50% K.

The evaluated parameter:

- The productivity components and yield of every treatment in each experimental crop.

- Sample of tested soil in the first crop.

- Grain samples of year 4 to analysis some of rice qualities (milling pertage and chakiness).

Methods of data collection and processing: Data was caculated by EXCEL software and statistical processing by SAS software.

For each experiment, dividing the treatments into 3 group to analyze data on direct validity, residual validity and cumulative.

- The first group was analyzed for the direct effect of N, P, K fertilizer with 5 treatments -NPK, -N, -P, -K and NPK
- The second group was analyzed for the P residual and cumulative effect with 7 treatments -NPK, -P, NPK, P (re1), P (re2), P (re3), P (re4).
- The third group was analyzed the K residual and accumulation effect with 7 treatments -NPK, -K, NPK, K (re1), K (re2), K (re3), K (re4).

Chapter 3. RESULTS AND DISCUSSION

3.1. Characteristics of the study area

Experiments in Can Tho: The results of soil analysis at the beginnin of 2011 SS crop showed that the experimental soil with total N of 0.16% (rather) (Kyuma (1976); total P of 0.027% (medium) (Le Van Can, 1978) and total K of 1.28% (medium), exchangeable P of 1.96 mg.kg^{-1} (poor) and exchangeable of 77.36 mg.kg^{-1} (medium) (Kyuma, 1976).

Experiment in Hau Giang: Results of soil analysis at the beginning of the 2011 WS crop showed that the experimental soil with total N of 0.22% (rich) (Kyuma (1976); total P of 0.029% (medium) (Le Van Can, 1978) and total K 1.465% (medium), exchangeable P of 4.36 mg.kg^{-1} (poor) and exchangeable K of 213.28 mg.kg^{-1} (medium) (Kuyma, 1976).

In 2011, floodwaters early returned and was higher than other years. The time of highest water level at the flowering stage of rice in the second crop (2011 SA crop). Therefore, the experiment was conducted in 4 years with 4 SA crops but only recorded results in 3 years (2012, 2014, 2015 SA crops), no data of 2011 SA crop.

3.2. Evaluating the direct effect of N fertilizer, P fertilizer and K fertilizer into rice yield with triple-crop system on alluvial soil in Can Tho and double-crop system on acid sulphate soil in Hau Giang

3.2.1. Evaluating the direct effect of N fertilizer, P fertilizer and K fertilizer into rice yield with triple-crop system on alluvial soil in Can Tho

The -NPK and the -N treatment had lowest yields in all crops but -K treatment had the equivalent yield as NPK treatment. The yield of treatments which were supplied without P fertilizer were reduced in all SA and SA crops because of deficiency of P for rice. They no significant difference comparing with NPK treatment in third crop (2011 – 2012 WS) and the sixth crop (2012 – 2013 WS). After 6 crops without P fertilizing, the yield were decreased compared to the continously applied fertilizer. This indicated that the amount of fixed P in the soil which was released in the WS responding the rice demand. However, when P fertilizer was not applied for a longer time, P in the soil was not depleted to negative effect of rice yield (in 9^{th} and 12^{th} crops).

After 4 years, with 4 SS, 3 SA and 4 WS crops, -NPK treatment and –N treatment were mostly reduced rice yields comparing to NPK treatment, responding 42.6% và 40.0% in 4 SS; 49.6% and 43.5% in 3 SA; 35.1% và 33.9% in 4 WS. The yield reduction of – P in 4 SS at 30.1%; it in 4 SA at 27.1% and it in 4 WS at 13.6%. The total yield in 11 crops of -K treatment was only lost 2.0%.

After 4 year of growing rice, N used efficiency was 21.5 kg grain.$kg^{-1}N$, P used efficiency was 24.0 kg grain.$kg^{-1}P_2O_5$; K used efficiency was only 3.5 kg grain.$kg^{-1}K_2O$.

Table 3.5. Effect of N, P, K treatments to rice yield, with triple-crop system in Can Tho

Time	**Rice yield (tons.ha^{-1})**				
	1st year 2011-12	2nd year 2012-13	3rd year 2013-14	4th year 2014-15	Average
Treatment	**SS crops (1st, 4th, 7th, 10th crop)**				
-NPK	2.80 c	2.10 c	2.47 b	2.21 c	2.40
-N	2.75 c	2.42 bc	2.45 b	2.39 bc	2.50
-P	3.25 b	3.02 b	2.78 b	2.62 b	2.92
-K	3.61 a	4.20 a	4.46 a	4.03 a	4.08
NPK (C)	3.75 a	4.38 a	4.46 a	4.10 a	4.17
F	*	*	*	*	-
CV (%)	5.5	13.4	10.4	8.3	-
Treatment	**SA crops (2nd, 5th, 8th, 11th crop)**				
-NPK	-	2.10 b	2.84 c	1.89 c	2.28
-N	-	2.79 b	2.56 c	2.31 c	2.55
-P	-	3.02 b	3.62 b	3.24 b	3.29
-K	-	4.10 a	4.43 a	4.13 a	4.22
NPK (C)	-	4.57 a	4.72 a	4.26 a	4.52
F	-	*	*	*	-
CV (%)	-	18.1	7.0	10.4	-
Treatment	**WS crops (2rd, 6th, 9th, 12th crop)**				
-NPK	4.56 b	4.27 c	4.22 c	4.00 c	4.26
-N	4.41 b	4.38 bc	4.20 c	4.35 c	4.34
-P	5.93 a	5.45 ab	5.66 b	5.65 b	5.67
-K	6.54 a	6.45 a	6.56 a	6.85 a	6.60
NPK (C)	6.48 a	6.39 a	6.69 a	6.70 a	6.57
F	*	*	*	*	-
CV (%)	9.2	13.7	8.1	10.5	-

*The means in the same column which were followed by the same characters were not significantly different at 5% in the Duncan test; ns: the difference is not statistically significant. *: the difference is statistically significant.*

3.2.2. Evaluating the direct effect of N fertilizer, P fertilizer and K fertilizer into rice yield with double-crop system on acid sulphate soil in Hau Giang

The yield of NPK treatment achieved highest in 8 crops, variability form 6.36 t 7.21 tons.ha^{-1} in WS crops anf from 4.40 to 4.81 tons.ha^{-1} in SS crops. –NPK treatment got lowest yield, average from 4.38 tons.ha^{-1} in in WS crops and 2.74 tons.ha^{-1} in SS crops. Next to, -N treatmnet got rice yield at 4.74 tons.ha^{-1} in WS and 2.95 tons.ha^{-1} in SA. The yeild of -K treatment in 8 crops had no significantly difference from the yield of NPK treatment.

In 2011-2012 WP (the 1st crop), the yield of -P treatment had been similar to its NPK treatment. Howerver, the yield began reducing from 2012 SA crop (the 2st crop).

The highest total yield in 8 crops achieved in NPK treatment, next to -K treatment, -P treatment. -N and -NPK treatments got the lower yield. Comparing the yield of NPK treatment, -N and -NPK had reduced grain quantities about 36.3% and 31.1% in 4 WS crops; 39.9% and 30.7% in 4 SA crops. With –P trearment in 4 SA crops, quantity lost 16.2% while it was 12.3% in 4 WS crops.

Table 3.14 The yield of the fertilizer treatments from 2011-2012 WS to 2015 SA with double-crop system on acid sulphate soil, in Hau Giang

Time	Rice yield ($tons.ha^{-1}$)				
	1st year 2011-12	2nd year 2012-13	3rd year 2013-14	4th year 2014-15	Average
Treatment	**WS crops (1st, 3rd, 5th, 7th crop)**				
-NPK	4.91 b	3.86 c	4.37 c	4.39 c	4.38
-N	5.06 b	4.10 c	4.74 c	5.06 c	4.74
-P	6.75 a	5.55 b	5.84 b	6.00 b	6.04
-K	7.12 a	6.23 a	6.74 a	6.86 ab	6.74
NPK (C)	7.21 a	6.36 a	6.98 a	6.97 a	6.88
F	*	*	*	*	-
CV (%)	6.3	6.9	6.1	8.3	-
Treatment	**SAcrops (2rd, 4th, 6th, 8th crop)**				
-NPK	2.74 b	3.20 c	2.54 d	2.48 c	2.74
-N	2.83 b	3.62 bc	3.08 c	2.28 c	2.95
-P	4.09 a	3.90 b	3.58 b	3.71 b	3.82
-K	4.37 a	4.83 a	4.31 a	4.51 a	4.51
NPK (C)	4.47 a	4.81 a	4.40 a	4.56 a	4.56
F	*	*	*	*	-
CV (%)	7.1	8.4	8.0	9.8	-

*The means in the same column which were followed by the same characters were not significantly different at 5% in the Duncan test; ns: the difference is not statistically significant. *: the difference is statistically significant.*

With $90N\text{-}50P_2O_5\text{-}30K_2O$ ($kg.ha^{-1}$) in WS crop, N fertilizer increased 2.14 $tons.ha^{-1}$ yield, used N efficiency was 23.8 kg $grain.kg^{-1}N$. P fertilizer increased 0.85 $tons.ha^{-1}$ yield, used P efficiency was 16.9 kg $grain.kg^{-1}P_2O_5$. K fertilizer increased 0.14 $tons.ha^{-1}$ yield, used K efficiency was 4.8 kg $grain.kg^{-1}$ K_2O.

With $80N\text{-}60P_2O_5\text{-}30K_2O$ ($kg.ha^{-1}$) in SA crop, N fertilizer increased 1.61 $tons.ha^{-1}$ yield, used N efficiency was 20.1 kg $grain.kg^{-1}N$. P fertilizer increased 0.74 $tons.ha^{-1}$ yield, used P efficiency was 12.3 kg $grain.kg^{-1}P_2O_5$. K fertilizer increased 0.06 $tons.ha^{-1}$ yield, used K efficiency was 1,9 kg $grain.kg^{-1}$ K_2O.

3.3. Evaluating residual and cumulative effect of P fertilizer and into rice yield with triple-crop system on alluvial soil in Can Tho and double-crop system on acid sulphate soil in Hau Giang

3.3.1 Evaluating residual and cumulative effect of P fertilizer into rice yield and with triple-crop system on alluvial soil in Can Tho

*** In SS crops:**

In 1st crop (2011 SS), compared with NPK treatments, the yield reduced 18.7% in the –P treatment, 25.3% the -NPK treatment. In the 4th crop (2012 SS), no fertilizer (-NPK) or NK fertilizing (-P) treatments in 4 consecutive crops, the yield compared to that of control decreased 52.1% and 31.1%, respectively. Without P fertilizer in 1 crop, the yield only decreased by 0.2% comparing to the NPK fertilizing. Non-P fertilizer in 2 previous crops but when it was applied again in the next WS crop, its yield was not lower than its control treatment (NPK). However, when the previous two crops had not applied P fertilizer and continued to not apply P (only applied N and K) in SS, the yield decreased from 18.9%-20.5%.

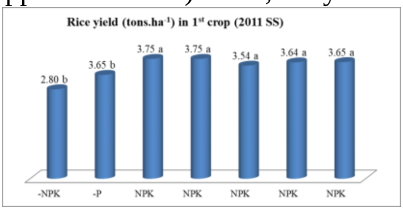

Figure 3.3 The effect of treatments of P fertilizing on rice yield in 1st crop

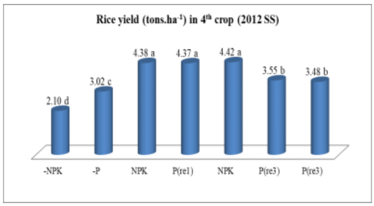

Figure 3.4 The effect of treatments of P fertilizing on rice yield in 4th crop

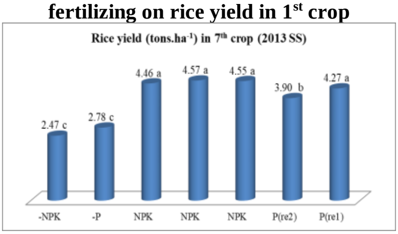

Figure 3.5 The effect of treatments of P fertilizing on rice yield in 4th crop

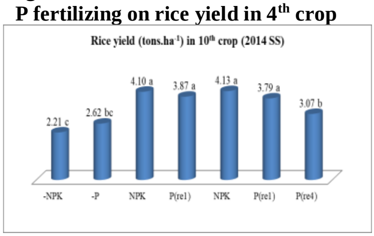

Figure 3.6 The effect of treatments of P fertilizing on rice yield in 10th crop

Note: -P: only N and K but non-P in all crops; NPK: application of N, P, and K; P (re1): fertilizing P in 1 crop and then removing P in 1 crop; P (re3): applying P in 1 crop and then removing P in 3 crops, P(re4): applying P in 1 crop and then removing P in 4 crops.

*** In SA crops:**

The treatment of -P fertilizer in 8 crops which had the yield were decreased from 23,3% to 33,9 % comparing to NPK in SAs. When P was applid 1 crop ang did not applie the next crop, the yield in SAs had no significant difference comparing to NPK treatment. The frequency of applying P in 1 crop, removing P 2 in next crops and the last crop in SA, the yield decreases from 6.3 to 10.3% comparing to NPK full fertilization. In case of P deficiency from 2-3 crops and the last crop in SA, the yield decreased by 16.4-16.7%. When appling P 1 crop, removing 4 next crops and the last crop in SA, the yield decreased 22.3%.

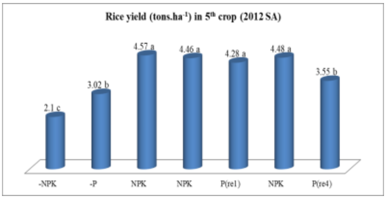

Figure 3.7 The effect of treatments of P fertilizing on rice yield in 5th crop

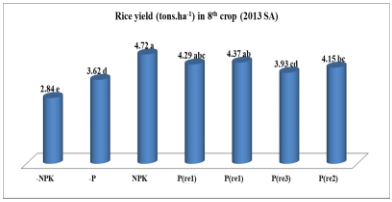

Figure 3.8 The effect of treatments of P fertilizing on rice yield in 8th crop

Note: -P: only N and K but non-P in all crops; NPK: application of N, P, and K; P (re1): fertilizing P in 1 crop and then removing P in 1 crop; P (re2): applying P in 1 crop and then removing P in 2 crops, P(re4): applying P in 1 crop and then removing P in 3 crops.

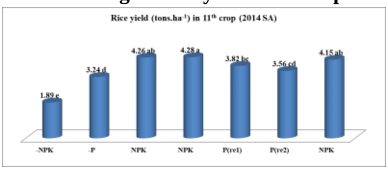

Figure 3.9 The effect of treatments of P fertilizing on rice yield in 11th crop

*** In WS crops:**

The yield varied between the frequency of applying P depending on each fertilizing cycle. In the first cycle, ther was no P application in the SA and continously defected P in WS, it had no the yield difference. However, in the next cycles, when non-P in the 2 former crops and no P fertilizer in later WS crop, there was a sign of significant decrease in rice yield comparing to NPK fertilization. In the case of non-P fertilizer from 3 to 4 crops, and applied P again in SW, the yield was also equivalent to that of NPK fertilizing. Thus, P fertilizer was not the main limiting factor to rice productivity in WS with triole-crop.year^{-1} on alluvial soil, in Can Tho.

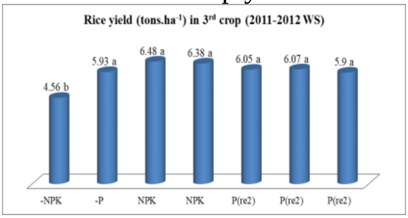

Figure 3.10 The effect of treatments of P fertilizing on rice yield in 3rd crop

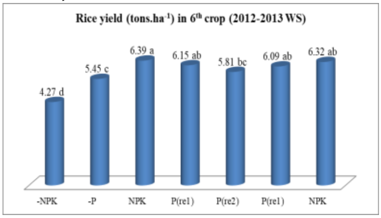

Figure 3.11 The effect of treatments of P fertilizing on rice yield in 6th crop

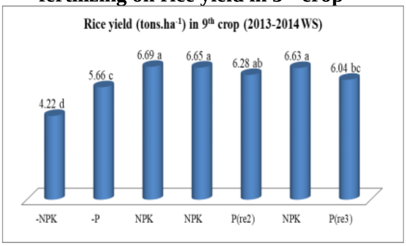

Figure 3.12 The effect of treatments of P fertilizing on rice yield in 9th crop

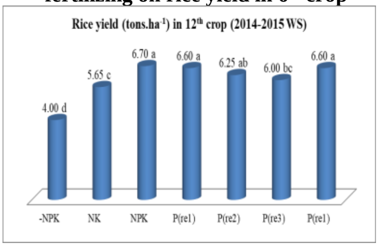

Figure 3.13 The effect of treatments of P fertilizing on rice yield in 12th crop

Note: -P: only N and K but non-P in all crops; NPK: application of N, P, and K; P (re1): fertilizing P in 1 crop and then removing P in 1 crop; P (re2): applying P in 1 crop and then removing P in 2 crops, P(re4): applying P in 1 crop and then removing P in 3 crops

After 4 years of applying only consecutive N and K (deficient P), the yield decreased by 22.8% comparing to NPK. With the frequency of P application in 1 crop and non-P in next 1-2 crops, the yield reduction after 12 crops were low and ranged from 2.1 to 5.1% comparing to NPK treatment. However, non-P application in 3-4 crops, the rates of yield decline were higher, respectively 9.4 in P(re3) and 10.4% (re4) comparing to NPK fertilization.

Table 3.23 Cumulative yield and average yield under the effects of P fertilizing crops according to crops and a total of 11 crops

Treatment	Cumulative yield							
	4 SSs		3 SAs		4 WSs		11 crops	
	Yield (tons.ha^{-1})	% (*)	Yield (tons.ha^{-1})	% (*)	Yield (tons.ha^{-1})	% (*)	Yield (tons.ha^{-1})	% (*)
-NPK	9.58	-42.6	6.83	-49.6	17.05	-35.1	33.46	-40.8
-P	11.67	-30.1	9.88	-27.1	22.70	-13.6	44.25	-21.7
NPK(C)	16.69	0.0	13.55	0.0	26.26	0.0	56.50	0.0
P(re)	16.56	-0.8	12.85	-5.2	25.78	-1.8	55.19	-2.3
P(re2)	16.72	0.2	12.67	-6.5	24.39	-7.1	53.78	-4.8
P(re3)	14.88	-10.8	11.04	-18.5	24.79	-5.6	50.71	-10.2
P(re4)	14.47	-13.3	11.54	-14.8	24.76	-5.7	50.78	-10.1

Note: (*) denotes an increase/decrease yield when compared to NPK(C) treatment; The sign (-) indicated a decrease in productivity compared to NPK treatment.

3.3.2. Evaluating residual and cumulative effect of P fertilizer double-crop system on acid sulphate soil in Hau Giang

*** With the WS crops,**

The influence of the frequency of P fertilizing on the yield in 4 WS crops is shown in Figure 3.14, Figure 3.15, Figure 3.16 and Figure 3.17. Without continuous P application in 2-3 crops, the yield in WS started to decline that indicated the P poor of the soil. Without supplementation, the amount of P in the soil was insufficient to meet the needs of the rice. For treatments of P(re1) or non-P that did not apply P in the previous crops but the P applied again, the rice yield was not significantly different from the NPK treatment.

* **With the SA crops,**

The effect of frequency of P fertilization on the yield in the 4^{h} SA crops were shown in Figure 3.18 to Figure 3.21. In the 2012 SA, without applying P fertilizer in 1 crop would have a negligible effect on the yield, because the amount of residual P in the previous crops was still sufficient for rice to use but when 2 crops did not apply P then the residual P is not enough to maintain rice yield. In the 2013 SA, treatments with continuous non-P from 3-4 crops gave significantly lower yields compared to the NPK control, in the case of P-deficient treatments in the previous crop but when applied P again in that crop, the yield was still equivalent to the control. This suggests that in many continuous rice crops -P fertilizing, the available P content in the soil was no longer sufficient for uptake by rice to maintain productivity. In other words, the P uptake requirement of rice for growth and development was higher than the amount of available P in the soil.

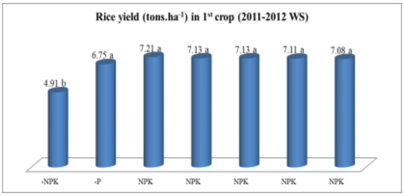

Figure 3.14. The effect of treatments of P fertilizing on rice yield in 1st crop

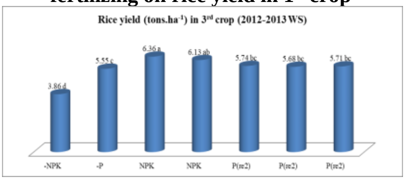

Figure 3.15. The effect of treatments of fertilizing on rice yield in 3rd crop

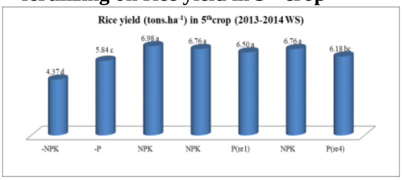

Figure 3.16. The effect of treatments of P fertilizing on rice yield in 5th crop

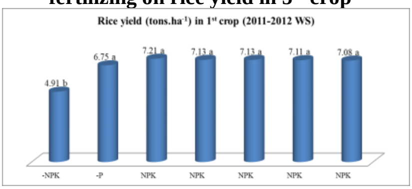

Figure 3.17. The effect of treatments of P fertilizing on rice yield in 7th crop

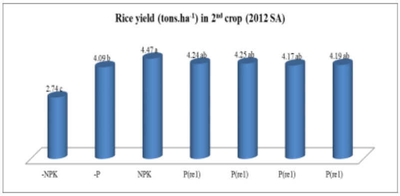

Figure 3.18. The effect of treatments of P fertilizing on rice yield in 2nd crop

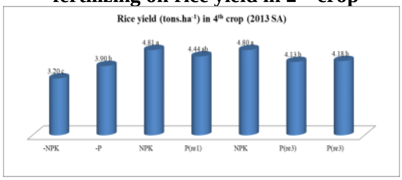

Figure 3.19. The effect of treatments of P fertilizing on rice yield in 4th crop

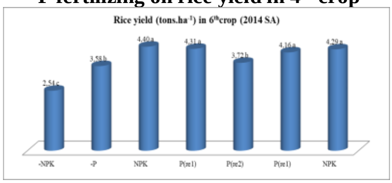

Figure 3.20. The effect of treatments of P fertilizing on rice yield in 6th crop

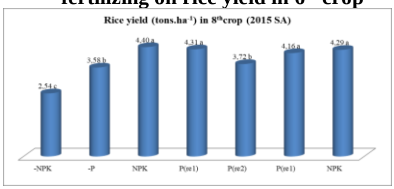

Figure 3.21. The effect of treatments of P fertilizing on rice yield in 8rd crop

Note: -P: only N and K but non-P in all crops; NPK: application of N, P, and K; P (re1): fertilizing P in 1 crop and then removing P in 1 crop; P (re3): applying P in 1 crop and then removing P in 3 crops, P(re4): applying P in 1 crop and then removing P in 4 crops.

In the 2014 SA, the treatment of non-P in 2 crops achieved the similar yield with the treatment non-P in 6 crops, but had the lower yield than the treatment non-P in 1 crop and the NPK treatments (in spite of the non-P in the previous crops). Apply P in the previous crop). Compared with the control (applying NPK continuously in 6 crops), the treatment which had applied P in 4 previous crops and applied P again in the next crop, the yield was still guaranteed. In the 2015 SA, all treatments without P fertilizing had the reduced yields compared to the NPK control. Even, the yield of non-P in 8 crops was reduced by 50% with NPK treatment. In acid sulphate soils, alum-producing layers was 0.5m or more from the field surface, when there was air, alum-producing materials in that layer were oxidized to release Fe^{+3}, Al^{+3} ions. Their P fixing caused the P deficiency. Therefore, the absence of P fertilizer in many crops affacted on thr growth and the yield of rice in acid sulphate soil.

The cumulative yield of P fertilizing treatments in 8 crops in ascending order: no fertilizer; -P; P (re3); P (re4); P (re2); P (re1) and NPK treatment. The rates of the yield decline which were compared to NPK treatments were 37.7%; 13.9%; 8.3%, 7.9%, 6.5% and 4.4%. The treatments with more frequency of P fertilization had less yield reduction, indicating that the amount of P applied in the previous crop could be saved and contribute to maintaining the yield when non-P in the later crop. However, the residual effect of P fertilizer depended on the crop and P residual duration. After 8 crops, the total yield of the -NPK treatment was dropped 37.7% and the –P was decreased by 13.9% compared to the NPK control. The treatment -P fertilizing was showed a reduction yield in 4 SA crops of 16.2% while that in the WSs decreased only 12.3% compared to the NPK treatment.

3.4. Evaluating residual and cumulative effect of K fertilizer to rice yield with triple-crop system on alluvial soil in Can Tho and double-crop system on acid sunphate soil in Hau Giang

3.4.1 Evaluating residual and cumulative effect of K fertilizer to rice yield and with triple-crop system on alluvial soil in Can Tho

The results showed that cumulative yield in the 11 crops is highest in the NPK treatment, next to treatments K deficient from 1 to 12 crops. The lowest yield was the –NPK treatment. The yield of NPK unfertilised treatment decreased by 42.6% compared to the control in SSs, 49.6% in SAs, 35.1% in WSs and 40.8% in 11 crops. The –K treatments had a negligible difference in yield compared to the NPK treatment.

3.4.2. Evaluating residual and cumulative effect of K fertilizer double-crop system on acid sulphate soil in Hau Giang

After 8 crops without K fertilizing, the rice yield showed no decrease compared to the NPK control. The treatments with K deficiency from 1crop to 4 crops also showed similar results. This proves that K in the soil ensured offerring for the growth of rice as equal as the level of 30 kg $K_2O.ha^{-1}$.

3.5. The effec of treatment to quality of rice with triple-crop system on on alluvial soil in Can Tho and double-crop system on acid sulphate soil in Hau Giang

The analysis results of rice quality in 2014 SS, 2014 SA and 2014-2015 WS (in 4^{th} experimental year) with triple-crop on alluvial soil in Can Tho shoew that only N fertilizer affected the head rice ratio. P or K fertilizer did not affect the milling rate in all crops. The results of this experiment confirmed that only N fertilizer reduced the head rice ratio and increased the percentage of chalkiness while -P or -K treatments had no decrease the rice milling qualities.

In Hau Giang, no fertilizing and no N fertilizing also resulted in a lower percentage of head rice than other treatments. No P fertilizer P or no K fertilizer after 8 crops had no effect on the percentage of milling rate and chalkiness.

3.6. Proposal of NPK fertilizer amount for triple cropping on alluvial soil, in Can Tho and double cropping in acid sulphate soil, in Hau Giang.

Summary of the research results at both experiments showed that without N fertilizing, the yield of rice significantly decreased comparing to fully P applying. Without P fertilizer in one crop or non-K fertilizer did not reduce the rice yield. Howerver, to be safe in production and avoiding external risk factors, offsetting the amount of P and K for rice which removed from the soil, suggestting to reduce or not apply P and K fertilizer inWS and keep the application of 50-60 kg P_2O_5.ha^{-1}.crop^{-1} and 30 kg K_2O.ha^{-1}.crop^{-1} in SS and SA.

***On triple-crop, on alluvium soil, in Can Tho:**

- In WS crop: 100 kgN.ha^{-1}- (0-20) kgP_2O_5.ha^{-1}- (0-15) K_2O.ha^{-1}.
- In SS crop: 90 kgN.ha^{-1} - 50 kgP_2O_5.ha^{-1} – 30 kgK_2O.ha^{-1}.
- In SA crop: 80 kgN.ha^{-1} - 50 kgP_2O_5.ha^{-1} – 30 kgK_2O.ha^{-1}.

***On double-crop, on acid sulphate soil, in Hau Giang:**

- In WS crop: 90 kgN.ha^{-1}- (0-25) kgP_2O_5.ha^{-1}- (0-15) K_2O.ha^{-1}.
- In SA crop: 80 kgN.ha^{-1} - 60 kgP_2O_5.ha^{-1} – 30 kgK_2O.ha^{-1}.

CONCLUSION AND SUGGESTION

Conclusions

1. Direct effect of N fertilizer, P fertilizer and K fertilizer:

- *For the triple-crop on alluvial soil in Can Tho*

+With the level of fertilizing 100/90/80 (kgN.ha^{-1}) corresponding to the WS/SS/SA crops, the rice yield increased by an average of 2.23 tons.ha^{-1} in WSs; tons.ha^{-1} in the social crop and tons.ha^{-1} in SAs. The N used efficiency reached 22.3 kg grain.kg^{-1}N in WS; 18.6 kg grain.kg^{-1}N in SSs and 24.5 kg grain.kg^{-1}N SAs.

+With a fertilizing of 40/50/50 (kg P_2O_5.ha^{-1}) corresponding to WS/SS/SA crops, rice yield increased by 0.89 tons.ha^{-1} in WSs; 1.25 tons.ha^{-1} in the social crop and tons.ha^{-1} in the HT crop. The used efficiency of P fertilizer reached 22.3 kg grain.kg^{-1} in WSs; 25.1 kg grain.kg^{-1} P_2O_5 in SSs and 24.4 kg grain.kg^{-1} P_2O_5 in SAs.

+With fertilizing level 30 (kg K_2O.ha^{-1}.crop^{-1}), K fertilizer did not increase rice yield.

-For the double-crop on acid sulphate soil in Hau Giang:

+With the fertilizing rate of 90/80 (kgN.ha^{-1}), respectively in the WSs, the rice yield increased by an average of 2.14 tons.ha^{-1} in the WSs and 1.61 tons.ha^{-1} in SAs. The used efficiency of N fertilizer was 23.8 kg grain.kg^{-1}N in WSs and 20.1 kg grain.kg^{-1}N in SAs.

+With the level of fertilizing 50/60 (kg P_2O_5.ha^{-1}) corresponding to WSs, the rice yield increased by an average of 0.85 tons.ha^{-1} in WSs and 0.74 tons.ha^{-1} in SAs. The used efficiency of P fertilizer was 16.9 kg grain.kg^{-1}P_2O_5 in WSs and 12.3 kg grain.kg^{-1}P_2O_5 in SAs.

+With fertilizing level 30 (kg K_2O.ha^{-1}.crop^{-1}), K fertilizer did not increase rice yield.

2. Residual effect of P fertilizer and K fertilizer

- *For the triple-crop on alluvial soil in Can Tho*

+Frequency of fertilizing P for previous crop and non-P later crop did not affact into rice yield in all of crops. After 2 crops without P, the yield was certainly reduced in SAs when comparing to fertilizing NPK yield. In the case of 2-4 crops without P, but applying it in the following crop, the yield would be equivalent to that continuously applied NPK treatment whether it is SAs or WSs. For WSs, the rice yield only decreased when without applying P after 3 crops.

+ The frequency of K fertilizing and non-K fertilizing did not affect the rice yield.

-For the double-crop on acid sulphate soil in Hau Giang:

+Frequency of fertilizing P 1 in 1 crop was negligible, it would not significantly affect the rice yield in all of crops; 2 consecutive crops without P fertilizing, the rice yield was always reduced (including in WSs and SAs) comparing to fertilizer fully and continuously applied P. In the case of 2-4 previous crops without applying P anf then it was applied again in the next crop (whether it was WSs or Sas), the yield was equivalent to that NPK treatment.

+ The frequency of K fertilizing and non-K treatment did not affect the rice yield.

3. Cumulative effect of P fertilizer and K fertilizer

- *For the triple-crop on alluvial soil in Can Tho*: Cumulative yield in11 crops (in 4 SSs, 3 SAs, 4 WSs) of -P treatment decreased

22.8% comparing to NPK treatment. It was 13.6%; 27.7% and 27.1% in WSs, SSs and SAs, respectively. The rate of decline in the yield which compared to the yield of the P-deficient treatments and that of NPK treatment was 10.4% in P(re4) treatment; 9.4% in P(re3) treatment; 5.1% in P(re2) treatment and 2.1% in P(re1) treatment. No K fertilizing did not reduce rice yield.

-For the double-crop on acid sulphate soil in Hau Giang:

Through 8 crops (4WSs and 4 SAs), the cumulative yield of the non-P treatment decreased by 13.9% compared to that of NPK treatment. It decreased was 12.3% in WSs and 16.2% and SSs. The rate of decline in rice yield compared with -P treatments after 8 crops as 8.3% in P(re3); 7.9% in P(re4); 6.5% in P(re2) and 4.4% in P(re1). No K fertilizer did not reduce rice yield.

4. No fertilization and no N fertilizer (N deficiency) reduced the rate of head rice and increased the percentage of chalkiness in the 7th and 8th crops in Hau Giang experiment and in 10th, 11th and 12th crops in Can Tho experiment. No P or K fertilizer did not affect the milling rate and chalkiness ratio in both experiments.

Suggestion

In order to improve the used efficiency of P fertilizer, P should be applied in SAs for rice with double-crop system in acid sulphate soils, in SSs and SSs for rice with triple-crop system in alluvial soil, non-P fertilizing or reducing the amount of P fertilizer in WSs season in both systems.

NOTABLE PUBLICATIONS RELATED TO THE DISSERTATION

1. **Mai Nguyet Lan**, Chu Van Hach, Nguyan Van Bo, Truong Thi Kieu Lien, Nguyen Thi Thanh Tuyen, Đinh Thi Hai Minh, Chu Thi Hong Anh, Vo Thi Thao Nguyen, Nguyen Thi Hong Nam và Le Thi Hong Hue (2016), "Nghien cuu hieu luc ton du va cong don cua phan P đoi voi lua tren co cau 3 vu/nam o vung phu sa Tay Song Hau cua đong bang Song Cuu Long", *Agriculture & Rural Development No 21/(2016)*, pp. 24-34.

2. **Mai Nguyet Lan**, Chu Văn Hach, Nguyen Van Bo, Tran Van Phuc và Nguyen Thi Hong Nam (2018), "Hieu suat su dung phan N, P, K theo thoi gian và mua vu cho giong lua OM5451 o vung đat phen tren co cau 2 lua tai Hau Giang", *Vietnam Journal of Agricultural Sciences (VAAS) No 3 (88)/2018, pp.* 57-61.

3. **Mai Nguyet Lan**, Chu Van Hach, Nguyen Van Bo, Tran Van Phuc và Nguyen Thi Hong Nam (2018), "Hieu luc ton du va cong don cua phan P voi nang suat lua tren co cau 2 vu/nam, vung phen Ban đao Ca Mau, đong bang song Cuu Long", *Agriculture & Rural Development No 8/(2018)*, pp. 43-48.