# STUDY ON FERTILIZER APPLICATION METHODS IN THE SUSTAINABLE PRODUCTION OF HIGH QUALITY AND HIGH YIELDING RICE TOWARDS BIO-ORGANIC STANDARDS

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## ABSTRACT

*In order to establish a model of sustainable rice production in accord with bio-organic and VietGAP standards of Tra Vinh province, research was done on high-yielding and high quality rice varieties of OM 4900, OM 6976, OM 5472, OM 8017 and OM 6600 at 6 farmers' fields in Chau Dien commune, Cau Ke district, Tra Vinh province in two seasons of DS 2011-2012 and WS 2012. The results show that fertilizer treatments that followed the Site Specific Nutrient Management (SSNM) and Leaf Color Chart (LCC) methods and applied 0.5 ton of bio-fertilizer/ ha and the treatment that applied 80% of chemical fertilizer dose of SSNM and LCC with additional application of bio-organic fertilizer at 0.5 t/ha increased the grain yield by 170-290 kg/ha, improved the quality of milled rice, especially the percentage of head rice by 48.4 % in WS and 55.2% in DS. In addition, these fertilizations helped to increase farmer's net benefits from 3.1 to 4.12 million VND/ ha in DS 2011 - 2012 and from 2.06 to 2.44 million VND/ ha in WS 2012 compared with Farmer Fertilizer Practice. They were selected as the most efficient fertilization in establishing a model of sustainable rice production towards bio-organic and VietGAP standards of Tra Vinh.*

***Keywords:*** *bio-fertilizer, bio-organic, farmer fertilizer practice, leaf color chart, sustainable rice production, site specific nutrient management, Vietnamese good agricultural practices.*

## INTRODUCTION

Fertilizer plays an important role in the intensification of rice production. Research on improvement of fertilizer application methods in the past several years provided Site Specific Nutrient Management (SSNM) that added nutrients as plants needed them, and applied nitrogen fertilizer adjustment by using a Leaf Color Chart (LCC). This fertilization method helped to reduce fertilizer costs, increased grain yield and net benefit for farmers (Tan *el al.*, 2004; Buresh *et al*., 2005). With the objective of establishing a model of sustainable rice production that meets bio-organic and VietGAP standards of Tra Vinh province, the research on fertilizer application methods is an essential component mounted throughout the process of production for achieving high quality products and sustainable performance.

## MATERIALS AND METHODS

The experiment was laid out in the split-plot design. The main plot was 4 varieties which included OM 4900, OM 6976, OM 6600 and OM 5472 (DS 2011-2012) and OM 8017 (WS 2012). The sub-plot was 6 fertilizer treatments that were shown in Table 1.

The experiment was conducted on 3 farmers fields at Chau Dien commune, Cau Ke district, Tra Vinh province in DS 2011-2012 and WS 2012.

Data were collected and processed by the procedures of IRRI, 1992; 1994; 1996 and 2002. Statistical tests were run using SPSS 10.05 and IRRISTAT for WINDOW 5.0 with Duncan test (DMRT).

**Table 1.** Description the fertilizer treatments

| No | Fertilizer treatments | Description |
|---|---|---|
| T1 | Farmer Fertilizer Practice (FFP) | 100% of NPK by farmers' fertilizer practices (DS: 120-60-48 kg N-$P_2O_5$-$K_2O$/ha, WS: 100-60-50 kg N-$P_2O_5$-$K_2O$/ha) |
| T2 | General Fertilizer Recommendation (GFR) | 100% of NPK by General recommendation Fertilization for high-yielding rice varieties (DS: 100-40-40 kg N-$P_2O_5$-$K_2O$/ha, WS: 80-50-50 kg N-$P_2O_5$-$K_2O$/ha) |
| T3 | Site Specific Nutrient Management and nitrogen fert. adjustment by LCC (SSNM +LCC) | 100% NPK by SSNM+LCC (DS: 100-40-30 kg N-$P_2O_5$-$K_2O$/ha, WS: 70-50-40 kg N-$P_2O_5$-$K_2O$/ha) |
| T4 | 100% NPK (SSNM+LCC) + bio-fertilizer (0.5 t/ha) | 100% NPK by SSNM+LCC (DS: 100-40-30 kg N-$P_2O_5$-$K_2O$/ha, WS: 70-50-40 kg N-$P_2O_5$-$K_2O$/ha) + bio-fertilizer at 500 kg/ha |
| T5 | 80% NPK (SSNM + LCC) + bio-fertilizer (0.5 t/ha) | 80% by SSNM+LCC (DS: 80-32-24 kg N-$P_2O_5$-$K_2O$/ha, WS: 56-40-32 kg N-$P_2O_5$-$K_2O$/ha) + bio-fertilizer at 500 kg/ha |
| T6 | 60% NPK (SSNM + LCC) + bio-fertilizer (1 t/ha) | 60% by SSNM+LCC (DS: 60-24-18 kg N-$P_2O_5$-$K_2O$/ha, WS: 42-30-24 kg N-$P_2O_5$-$K_2O$/ha) + bio-fertilizer at 1,000 kg/ha |

## RESULTS AND DISCUSSIONS

Effect of fertilizer application methods on grain yield of high yielding and high quality varieties.

Yields of rice varieties that were tested in two seasons of DS 2011-2012 and WS 2012 were very different due to their genetic characteristics. The average yield of 6 fertilizer treatments of OM 6976 was highest: 6.99 t/ha in the DS 2011-2012 and 5.51 t/ha in the WS 2012. OM 4900 was next, yielding 6.83 t/ha and 5.40 t/ ha, respectively. The priority of these two varieties is entirely consistent with similar evaluations in recent years by CLRRI (Le Thi Du *et al.*, 2009a; 2009b; and 2010). Generally, OM 6976 proved superior in productivity and adaptability to other varieties in the Mekong Delta. OM 4900 is superior in seed quality with slightly aromatic characteristics compared with others. The fertilizer treatment that followed the SSNM and LCC method gave a yield of 6.93 t/ha. This is higher than the FFP treatment by 310 kg/ha in DS 2011 -2012 (4.7%), and by 260 kg/ha in WS 2012 (5%). Treatment T4 that followed the SSNM and LCC method and applied 0.5 ton of bio-fertilizer/ ha gave the highest grain yield of 7.20 t/ha in DS 2011 - 2012 and 5.63 t/ha in WS 2012, respectively 8.9% and 7.4% greater than FFP. The grain yield of T5 treatment that used 20% less chemical fertilizer than T4 was also greater than the FFP treatment by 170 kg/ha in WS 2012 and 290 kg/ha in DS 2011-2012, (3.2% and 4.4%), respectively (Table 2 and 3). These results affirmed that the potential yield of rice varieties was very high; however crop management was also an important factor for achieving higher yield. Under good field management condition, seeding rate of 120 kg seed/ha was recommended and a method of fertilizer application that met the plant needs helped to produce higher yield (Tran Thi Ngoc Huan *et al*., 1999a; Trinh Quang Khuong *et al.*, 2001). The additional fertilization by bio-organic materials also increased the yield and quality of rice (Pham Sy Tan *et al*., 2007; Tran Thi Ngoc Huan *et al*., 2009).

**Table 2.** Effect of fertilizer application methods on yield (t/ha) of 4 rice varieties in DS 2011-2012 at Chau Dien commune, Cau Ke district, Tra Vinh province

| Fertilizer treatments (kg N-$P_2O_5$-$K_2O$/ha) | Varieties (Vars.) | | | | Mean (Fert.) |
|---|---|---|---|---|---|
| | *OM4900* | *OM6976* | *OM5472* | *OM6600* | |
| T1:120-60-48 (FFP) | 6.62 c | 6.70 d | 6.53 c | 6.59 d | **6.61 d** |
| T2: 100-40-40 (GFR) | 6.71 c | 6.92 c | 6.68 bc | 6.78 bc | **6.77 c** |
| T3: 100-40-30 (SSNM+LCC) | 6.87 b | 7.09 b | 6.82 b | 6.91 b | **6.92 b** |
| T4: 100-40-30 + 0.5 t bio-fert./ha | 7.19 a | 7.35 a | 7.11 a | 7.15 a | **7.20 a** |
| T5: 80-32-24 + 0.5 t bio-fert./ha | 6.95 b | 7.08 b | 6.83 b | 6.74 cd | **6.90 b** |
| T6: 60-24-18 + 1.0 t bio-fert./ha | 6.64 c | 6.79 cd | 6.65 c | 6.60 d | **6.67 d** |
| **Mean (Vars.)** | **6.83 b** | **6.99 a** | **6.77 c** | **6.79 bc** | **6.85** |
| **F (Vars.)**** | | **F (Fert.)**** | | **F (Vars x Fert) $^{ns}$** | |
| **CV% (Vars.) = 10.9** | | **CV% (Fert.) = 10.4** | | | |

*Values followed by the same letters are not significant difference at 5% level within treatments by DMRT; $^{ns}$non- significant at 0.05; * significant at 0.05 and ** significant at 0.01*

**Table 3.** Effect of the fertilizer application methods on yield (t/ha) of 4 rice varieties in WS 2012 at Chau Dien commune, Cau Ke district, Tra Vinh province

| Fertilizer treatments (kg N-$P_2O_5$-$K_2O$/ha) | Varieties (Vars.) | | | | Mean (Fert.) |
|---|---|---|---|---|---|
| | *OM4900* | *OM6976* | *OM8017* | *OM6600* | |
| T1:100-60-50 (FFP) | 5.24 d | 5.37 c | 5.25 c | 5.11 d | **5.24 d** |
| T2: 80-50-50 (GRF)) | 5.40 c | 5.49 b | 5.36 b | 5.24 c | **5.37 c** |
| T3: 70-50-40 (SSNM+LCC) | 5.53 b | 5.66 a | 5.43 b | 5.39 b | **5.50 b** |
| T4: 70-50-40+ 0.5 t bio-fert./ha | 5.64 a | 5.74 a | 5.64 a | 5.49 a | **5.63 a** |
| T5: 56-40-32 + 0.5 t bio-fert./ha | 5.40 c | 5.54 b | 5.43 b | 5.28 c | **5.41 c** |
| T6: 42-30-24 + + 1.0 t bio-fert./ha | 5.18 d | 5.28 d | 5.24 c | 5.07 d | **5.19 e** |
| **Mean (Vars.)** | **5.40 b** | **5.51 a** | **5.39 b** | **5.26 c** | **5.39** |
| **F (Vars.)**** | | **F (Fert.)**** | | **F (Vars x Fert) $^{ns}$** | |
| **CV% (Vars.) = 12.2** | | **CV% (Fert.) = 11.0** | | | |

*Values followed by the same letters are not significant difference at 5% level within treatments by DMRT. $^{ns}$ non-significant at 0.05; * significant at 0.05 and ** significant at 0.01*

***Effect of fertilizer application methods on milling quality characteristics of high-yielding rice varieties***

Among the fertilizer application methods, applying between 60 and 100% of the recommended chemical fertilizer of SSNM combined with bio-fertilizer helped to significantly increase the percentage of brown rice and white rice in both seasons, compared with the strictly chemical fertilizer treatments. The mean percentage of brown rice varied from 77.9% to 80.1% in DS 2011 -2012 and 77.5% to 78.5 % in WS 2012. OM 4900 gave the highest percentage. The mean percentage of white rice varied from 70.8% to 72.1% in DS 2011 -2012 and 67.2% to 68.6 % in WS 2012.

Organic fertilizer is a key factor helping to improve the quality of rice including milling quality. Similar to the percentage of brown rice and white rice, the percentage of head rice of 4 tested rice varieties has improved remarkably in both seasons, particularly in the two treatments using 20 and 40 % reductions of chemical fertilizer plus additional bio-fertilizer of from 0.5 to 1 t/ha. The percentage of head rice ranged from 55.2 to 55.4 % in DS 2011-2012 and was 48.5 % in WS 2012, respectively (Table 4 and Table 5). This had important implications in the

adoption of management practices to improve grain quality under adverse impacts of the environment, especially for the rainy season. The results also showed the same trend regarding the influence of organic fertilizers on the quality of milled rice as past research of Pham Sy Tan *et al*., 2007; Tran Thi Ngoc Huan *et al.*, 2009.

**Table 4.** Effect of fertilizer application methods on the head rice percentage of 4 rice varieties in DS 2011-2012 at Chau Dien commune, Cau Ke district, Tra Vinh province

| **Fertilizer treatments (kg N-$P_2O_5$-$K_2O$/ha)** | **Varieties (Vars.)** | | | | **Mean (Fert.)** |
|---|---|---|---|---|---|
| | ***OM4900*** | ***OM6976*** | ***OM5472*** | ***OM6600*** | |
| T1:120-60-48 (FFP) | 54.8 d | 54.1 d | 53.4 b | 53.7 c | **54.0 d** |
| T2: 100-40-40 (GFR) | 55.4 bc | 54.5 cd | 53.7 b | 54.0 bc | **54.4 c** |
| T3: 100-40-30 (SSNM+LCC) | 55.3 c | 54.6 cd | 53.9 b | 54.4 b | **54.5 c** |
| T4: 100-40-30 + 0.5 t bio-fert./ha | 55.6 bc | 54.9 bc | 54.4 a | 55.0 a | **55.0 b** |
| T5: 80-32-24 + 0.5 t bio-fert./ha | 55.9 ab | 55.3 ab | 54.7 a | 55.1 a | **55.2 ab** |
| T6: 60-24-18 + 1.0 t bio-fert./ha | 56.3 a | 55.6 a | 54.7 a | 55.0 a | **55.4 a** |
| **Mean (Vars.)** | **55.6 a** | **54.8 b** | **54.1 c** | **54.5 bc** | |
| **F (Vars.)**** | | **F (Fert.)**** | | **F (Vars x Fert) $^{ns}$** | |
| **CV% (Vars.) = 10.2** | | **CV% (Fert.)= 8.3** | | | |

*Values followed by the same letters are not significant difference at 5% level within treatments by DMRT; $^{ns}$ non-significant at 0.05; * significant at 0.05 and ** significant at 0.01*

**Table 5.** Effect of the fertilizer application methods on the head rice percentage of 4 rice varieties in WS 2012 at Chau Dien commune, Cau Ke district, Tra Vinh province

| **Fertilizer Treatments (kg N-$P_2O_5$-$K_2O$/ha)** | **Varieties (Vars.)** | | | | **Mean (Fert.)** |
|---|---|---|---|---|---|
| | ***OM4900*** | ***OM6976*** | ***OM8017*** | ***OM6600*** | |
| T1:100-60-50 (FFP) | 46.5 e | 45.8 e | 47.0 d | 46.8 c | **46.5 e** |
| T2: 80-50-50 (GRF)) | 46.8 e | 46.4 d | 47.4 c | 46.9 bc | **46.9 d** |
| T3: 70-50-40 (SSNM+LCC) | 47.3 d | 46.8 c | 47.5 c | 47.3 b | **47.2 c** |
| T4: 70-50-40+ 0.5 t bio-fert./ha | 48.5 c | 47.5 ab | 48.3 b | 47.3 b | **47.9 b** |
| T5: 56-40-32 + 0.5 t bio-fert./ha | 49.1 b | 47.9 a | 48.6 ab | 48.2 a | **48.4 a** |
| T6: 42-30-24 + + 1.0 t bio-fert./ha | 49.5 a | 47.9 a | 48.8 a | 48.0 a | **48.5 a** |
| **Mean (Vars.)** | **48.0 a** | **47.0 b** | **47.9 a** | **47.4 ab** | |
| **F (Vars.)*** | | **F (Fert.)**** | | **F (Vars x Fert)$^{**}$** | |
| **CV% (Vars.) = 11.4** | | **CV% (Fert.) = 10.5** | | | |

*Values followed by the same letters are not significant difference at 5% level within treatments by DMRT. $^{ns}$ non- significant at 0.05; * significant at 0.05 and ** significant at 0.01*

**Effect of fertilizer application methods on economic efficiency of the sustainable rice production towards bio-organic standards**

Among the fertilizer application methods, treatment T3 (SSNM + LCC) met the plant needs and got a higher economic efficiency than others. The treatments of T4 and T5 that applied the either the same dose, or 80% of the chemical fertilizer dose of T3 (SSNM + LCC) plus an additional application of bio-organic fertilizer at 0.5 t/ha ensured the requirements of the sustainable rice production towards bio-organic standards, and resulted in high milling quality and economic efficiency on the tested varieties of OM 4900, OM 6976, OM 5472, OM 6600 and OM 8017. The difference in net benefit of these fertilizations ranged from 3.54 million VND/ha

to 4.12 million VND/ ha compared with Farmer Fertilizer Practices (FFP) in DS 2011-2012 (Table 6) and from 2.31 million VND/ ha to 3.58 million VND/ha in WS 2012 (Table 7). These fertilizer application methods were therefore selected for establishing the model of sustainable rice production towards bio-organic and VietGAP standards of Tra Vinh province.

**Table 6.** Economic efficiency of the fertilizer application methods in the safety rice production towards bio-organic of OM 6976 at Chau Dien commune, Cau Ke district, Tra Vinh province in DS 2011-2012

*Unit: 1,000 VND/ha*

| Parameters | Fertilizer treatments (kg N-$P_2O_5$-$K_2O$/ha) | | | | | |
|---|---|---|---|---|---|---|
| | ***120-60-48*** | ***100-40-40*** | ***100-40-30*** | ***100-40-30 + 0.5 t bio-fert./ha*** | ***80-32-24 + 0.5 t bio-fert./ha*** | ***60-24-18 + 1.0 t bio-fert./ha*** |
| Grain yield (t/ha) | 6.70 | 6.92 | 7.09 | 7.35 | 7.08 | 6.79 |
| Gross benefit* | 44,890 | 46,364 | 47,503 | 49,245 | 47,458 | 45,515 |
| Seed cost * | 1,740 | 1,740 | 1,740 | 1,740 | 1,740 | 1,740 |
| Fertilizer cost* | 5,151 | 4,042 | 3,825 | 5,825 | 5,060 | 6,295 |
| Pesticide cost | 4,320 | 3,822 | 3,682 | 3,682 | 3,682 | 3,682 |
| Irrigation cost | 1,700 | 1,700 | 1,700 | 1,700 | 1,700 | 1,700 |
| Labor cost | 8,000 | 8,000 | 8,000 | 8,200 | 8,200 | 8,300 |
| Total cost | 20,911 | 19,304 | 18,947 | 21,147 | 20,382 | 21,717 |
| Production Price *(VND/kg rice)* | 3,121 | 2,790 | 2,672 | 2,877 | 2,878 | 3,197 |
| Net benefit | 23,979 | 27,060 | 28,556 | 28,099 | 27,076 | 23,798 |
| Difference in net benefit | - | 3,081 | 4,577 | 4,119 | 3,097 | -181 |

* *Price of selling rice = 6,700 VND/kg; price of rice pure seed = 14,500 VND/kg; urea =10,000 VND/kg; super phosphate = 4,000 VND/ha; KCl= 13,000 VND/kg; bio-organic fertilizer = 4,000 VND/kg.*

**Table 7.** Economic efficiency of the fertilizer application methods in the safety rice production towards bio-organic of OM 8017 at Chau Dien commune, Cau Ke district, Tra Vinh province in WS 2012

*Unit: 1,000 VND/ha*

| Parameters | Fertilizer treatments (kg N-$P_2O_5$-$K_2O$/ha) | | | | | |
|---|---|---|---|---|---|---|
| | ***100-60-50*** | ***80-50-50*** | ***70-50-40*** | ***70-50-40 + 0.5 t bio-fert./ha*** | ***56-40-32 + 0.5 t bio-fert./ha*** | ***42-30-24 + 1.0 t bio-fert./ha*** |
| **Grain yield (t/ha)** | 5.25 | 5.36 | 5.43 | 5.64 | 5.43 | 5.24 |
| **Gross benefit*** | **28,332** | **28,926** | **29,304** | **30,474** | **29,322** | **28,278** |
| Seed cost * | 1,740 | 1,740 | 1,740 | 1,740 | 1,740 | 1,740 |
| Fertilizer cost* | 5,086 | 4,336 | 3,866 | 5,869 | 5,095 | 6,321 |
| Pesticide cost | 4,780 | 4,142 | 4,002 | 4,002 | 4,002 | 4,002 |
| Irrigation cost | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |
| Labor cost | 8,000 | 8,000 | 8,000 | 8,200 | 8,200 | 8,300 |
| **Total cost** | **21,106** | **19,718** | **19,111** | **20,811** | **20,037** | **20,863** |
| Production price *(VND/kg rice)* | 4,023 | 3,681 | 3,522 | 3,688 | 3,690 | 3,984 |
| **Net benefit** | **7,226** | **9,208** | **10,194** | **9,664** | **9,285** | **7,415** |
| **Difference in net benefit** | **-** | **1,982** | **2,967** | **2,437** | **2,059** | **189** |

* *Price of selling rice = 5,400 VND/kg; price of rice pure seed =14,500 VND/kg; urea =10,000 VND/kg; super phosphate = 4,000 VND/ha; KCl= 13,000 VND/kg; bio-organic fertilizer = 4,000 VND/kg.*

## CONCLUSSION

Utilizing SSNM and LLC increases grain yield and improves the quality of milled rice, especially the percentage of head rice, and increases net economic benefits of rice production. The two fertilizer application methods based on the plant needs, namely (1) SSNM + LCC and additional application of bio-organic fertilizer at 0.5t/ha, and (2) applying 80% of chemical fertilizer following SSNM with additional application of bio-organic fertilizer at 0.5t/ha were selected as the most effective fertilization practices for establishing the model of sustainable rice production directed towards bio-organic and VietGAP standards of Tra Vinh province.

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## TÓM TẮT

### Nghiên cứu xây dựng phương pháp bón phân trong sản xuất lúa an toàn theo hướng hữu cơ sinh học trên các giống lúa cao sản, chất lượng cao

*Với mục tiêu xây dựng Mô hình sản xuất lúa an toàn theo hướng hữu cơ sinh học đạt tiêu chuẩn VietGAP cho tỉnh Trà Vinh, nghiên cứu đã được thực hiện trên các giống lúa cao sản chất lượng cao: OM4900, OM6976, OM5472, OM8017 và OM6600 tại 6 ruộng nông dân ở xã Châu Điền, huyện Cầu Kè, tỉnh Trà Vinh trong hai vụ ĐX2011-2012 và HT2012. Kết quả thu được cho thấy: Phương pháp bón phân theo nhu cầu cây (SSNM+LCC) có bổ sung phân hữu cơ sinh học (0,5 tấn/ha) hoặc bón 80% phân hóa học theo nhu cầu cây và bổ sung 0,5 tấn phân hữu cơ sinh học làm tăng năng suất lúa từ 170 đến 290 kg lúa/ha, nâng cao chất lượng xay chà của lúa gạo, đặc biệt tỷ lệ gạo nguyên đạt cao từ 48,4% trong vụ HT đến 55,2% trong vụ ĐX. Bên cạnh đó, hai phương pháp bón phân này còn giúp gia tăng lợi nhuận cho nông dân từ 2,06 đến 3,58 triệu đồng/ha trong 2 vụ ĐX2011-2012 và HT2012. Vì vậy, chúng được lựa chọn là phương pháp bón phân hiệu quả nhất áp dụng trong xây dựng Mô hình sản xuất lúa an toàn theo hướng hữu cơ sinh học đạt tiêu chuẩn VietGAP của tỉnh Trà Vinh.*