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Rice production technology improvements with organic and sustainable solution in the Mekong Delta

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ABSTRACT:

Sustainable and environmentally friendly agriculture is an absolute direction in worldwide. On the other hand, recently, world's political and economic movements caused rapid price hike of necessary materials for agriculture, such as fertilizersand agrochemicals.
Rice production technology in Vietnam has been improved after the war ended in 1975, Vietnam became the third largest rice exporting country in the world. However,according to World Bank Group's report, farmers in the Mekong Delta consume excess volume of fertilizer and agrochemicals, which also increase the burden of farmers.
For realizing sustainability of rice production, technology improvements for higher productivity and higher quality are basic needs, which can also support sustainability of farmers' life. In addition to this, effective use of agricultural wastes, and reducing consumption of chemical fertilizers and pesticides also contributes to the sustainability of environment and nature.
In this study, we carried out three kinds of environmental challenges.First one wasrice cultivation experiment with new fertilizer application devicemounted on a rice transplanter. This applicator coulddeliver fertilizer to the beneath of soil during transplanting. We expected to reduce the consumption of fertilizer and also reduce the time of labor work. We tested the effectiveness of the new fertilizer applicator compared with a conventional fertilizer feeding method. However, as a result, the effect of the fertilizer applicator was effective in the maturity of rice, but it did not contribute much to the yield. Second one wasspreading chopped rice straw on the paddy field just after harvesting rice to make compost as a substitute for fertilizer. Rice straw chopping unit and chemical sprayer were mounted on a combine harvester. The chemical sprayer sprayedorganic Trichoderma chemical on the surface of harvested rice strawto accelerate composting speed. We also carried out a rice straw composting experiment and confirmed the compost completion period of six weeks. Third one was planting repellent grasses at paddy sides as a replacement of insecticides, which followedthe idea of "Integrated Pest Management (IPM)" method.

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I. INTRODUCTION

Vietnam is the third largest rice exporting country in the world.In the past, Vietnam experienced a difficult war time until 1975, and rice productivity was very low at that time, however, Vietnam successfully improved their rice production technology, and currently average rice yield is almost 6 tons per hectare and annual production volume is over 40 million tons (paddy weight).
In our previous researches [1][2], we focused on technologies and suitable conditions for increasing rice productivity and quality. We carried out rice cultivation experiments with differences of rice planting density, rice variety, volume of fertilizer, and planting method,more than 80 planting patterns in four years.
Recent years, sustainability and environmentally friendly actions are very important directions in every fields including agriculture. However, according to the World Bank Group's report, Vietnamese farmers consume excessive amounts of fertilizer, which accounts for a large portion of farmers' expenditures [3]. In addition to this, after 2020, COVID-19 pandemic and the Russian invasion to Ukraine occurred, which made a big confusion in global economy, and material prices including fertilizer and agro chemical costs soared. We have

to challenge how to reduce the cost of such chemical materials for agriculture.
In this research, we focused on how to reduce the consumption of chemical fertilizer and chemical pesticides. And we tried three kinds of challenges.
First one wasa trial of new fertilizer application device to reduce the consumption of fertilizer. We mounted the fertilizer applicator on a rice transplanter, and it can deliver the fertilizer by air pressure to the beneath of soil as side strip fertilization.
Among rice cultivation waste usage for biomass solution, rice husk discharged from rice mill plants is easy to be collected and used for several sustainable purposes already. One is making briquettes for solid fuel (Fig. 1). If rice husk volume is huge, gasified and generating electricity is also one of effective choices (Fig. 2).However, rice straw is difficult to collect when using combine harvester. Many farmers used to burn rice straw on paddy fieldsand rarely collect rice straw for commercial purposes.Then,as a second challenge, we carried out rice straw composting trial on a paddy field for the alternative of chemical fertilizers.

Fig. 1 Rice husk briquette processing example

at An Giang Plant Protection Joint Stock Company (AGPPS) rice mill plant
Source: Photos taken by the author in 2014

Fig. 2 Rice husk gasification and generating plant at Nay Pyi Taw, Myanmar

built by Yanmar Holdings Co., Ltd. in 2016
Source: photo taken by a project member of Yanmar Holdings Co., Ltd.

Third challenge was to plant repellent grasses on the paddy side. Such grasses have a function of insecticidesor reducing soil diseases,then we can expect to reduce the amount of chemical pesticides applying to paddy fields.

II. MATERIALS AND METHODS

We designed and carried out three kinds of trials for reducing consumption of artificial fertilizers and pesticides, as followings.

II.-1. Fertilizer applicator trial

The first trial was effective fertilizer applying method with mechanical solution. We mounted a new fertilizer applicator on a rice transplanter (Fig. 3). This fertilizer applicator can deliver fertilizer to the beneath of soil during transplanting. We carried out several experiments with this device comparing with conventional fertilizer application on the surface of soil.

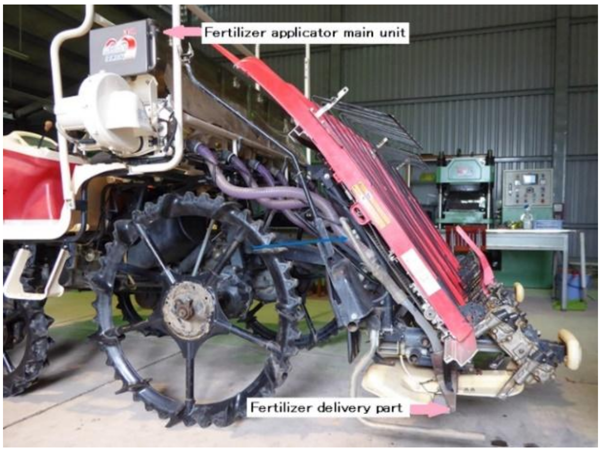

Fig. 3 Fertilizer applicator mounted on a rice transplanter
Side strip fertilization device is equipped
Source: Photo taken by the author at Can Tho City in 2019

The experiment was taken place at a paddy field of Loc Troi Group Dinh Thanh Agricultural Research Center (DTARC)located in An Giang Province in Summer-Autumn season of 2017. For this experiment, we used the rice variety "Loc Troi 5", and prepared 9 different conditions of fertilizer application. Fertilizer application method and its time schedule is shown in Table 1.

Table 1 Fertilizer application method and time schedule

Application method	1st time	2nd time	3rd time
by Fertilizer applicator	Fertilizer applicator during transplanting	none	Manual application at panicle initiation
by conventional method (manually broadcasting)	Manual application 7 days after transplanting	Manual application 18 days after transplanting	Manual application at panicle initiation

II.-2. Rice straw composting

As one of the effective usages of rice straw, we applied chopped rice straw on a paddy field just after rice harvest. And we sprayed organic *Trichoderma* chemical over the rice straw to accelerate composting. This organic *Trichoderma* chemical was developed by Can Tho University and Loc Troi Group, and named "TRICO-DHCT" [4].We prepared two special devices for the test, one was rice straw chopper mounted on the combine harvester which can chop straw at the same time of rice harvesting. Another device was chemical tank and engine driven sprayer mounted on combine harvester which could spray TRICO-DHCT over the rice straw discharged from a combine harvester on the ground (Fig. 4).

Fig. 4 Rice straw chopper and chemical sprayer mounted on combine harvester
and the leaflet of TRICO-DHCT
Source: Photo taken by the author at Can Tho City in 2015

II.-3 Repellent grass

Rice cultivation requires control work against pests and harmful nematodes. However, chemical pesticides are costly as well as having negative impact on the environment. To solve those issues, we planted repellent grass on paddy side. Since, in the Mekong Delta, rice cultivation is mostly triple cropping and no off-time, then, we cannot cultivate repellent grasses in paddy fields.

III. RESULTS

III.-1. Fertilizer applicator trial

We mounted new fertilizer applicator on a riding type transplanter (Fig. 3). The structure of the fertilizer applicator is shown in Fig. 5. Fertilizer is transferred from the top tank to the beneath of soil by air pressure.

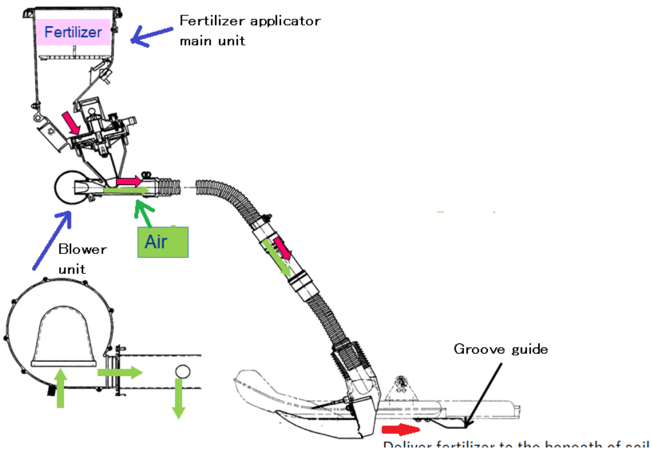

Fig. 5 Construction of Fertilizer applicator
Source: technical manual of Yanmar Holdings Co., Ltd., modified by the author

We carried out 9 different patterns of rice cultivation experiment as shown in Table 1. Transplanting density was fixed as 30 cm width × 12 cm pitch, except for plot ID BVL0 and BVL1 as 30 cm width × 19 cm pitch. The amount of fertilizer applied was different in each plot shown in Table 2.

Table 2 2017 experiment in An Giang, Summer – Autumn season

Plot ID	BH0	BH1	BL0	BL1	BVL0	BVL1	MBL	CL	CH
Planting density: width(cm) x pitch(cm)	30 x 12	30 x 12	30 x 12	30 x 12	30 x 19	30 x 19	30 x 12	30 x 12	30 x 12
Rice variety	Loc Troi 5								
Fertilizer volume: NPK 1st time (kg/ha)	313	313	195	195	137	137	40-40-30	60-40-30	90-60-45
Fertilizer volume: NPK 2nd time (kg/ha)	none	none	none	none	none	none	none	60-40-30	90-60-45
Fertilizer volume: 3rd time (kg/ha)	none	65	none	44	none	44	N: 20	N: 20	90-60-45
Fertilizer volume: Total (kg/ha)	313	378	195	239	137	181	130	280	585
Fertilizer applicator: beneath soil surface	yes	yes	yes	yes	yes	yes	none	none	none
Ripened rate (%)	94.71	82.20	89.14	91.84	93.73	92.22	88.45	85.67	89.56
Number of panicle / m^2	314.12	301.39	286.11	306.72	250.73	253.51	305.33	314.12	309.26
Moisture (%, wet)	17.53	19.87	25.50	24.30	25.67	23.83	23.87	23.67	25.80
Grain mass (g/m^2, wet)	820.14	860.19	737.99	887.90	745.07	669.56	905.53	765.07	875.16
Actural yield (kg/ha, wet)	608.01	703.54	564.83	601.94	626.98	667.39	701.04	662.82	-
Moisture (%, dry)	12.23	12.67	12.30	12.80	13.07	12.67	12.53	12.07	13.03
Grain mass (g/m^2, dry)	683.90	708.67	623.86	737.85	630.33	568.23	754.01	629.97	720.85
Weight of 1000 grains (g)	27.10	25.47	28.04	27.30	27.68	25.68	28.32	27.11	26.66

Each record is the average of five collected sample data. It is clear that ripened rate is rather highcommonly in the plots where we used fertilizer applicator, and fertilizer applied to the beneath of soil.We did not apply fertilizer in the plots for 2nd time where we applied fertilizer by the applicator for the 1st time (Table 1). However, yield does not show a clear correlation with the amount of fertilizer applied. We can recognize some good yield record in the plots where we applied fertilizer for 1st time by applicator and 3rd time by manual application.

III.-2. Rice straw composting to reduce fertilizer consumption

We prepared two devices on a combine harvester (Fig. 6). One was a rice straw chopper driven by the combine harvester power train. It made rice straw discharged from the combine harvester to small chopped pieces.Another device was chemical sprayer mounted on the combine harvester. We sprayed TRICO-DHCTover the chopped rice straw spreaded on the paddy field.

Fig. 6 A Rice harvesting, discharging rice straw, and spraying TRICO-DHCT
B Rice straw chopper unit, which is installed inside combine harvester
Source: photos taken by the author at An Giang experiment field in 2015

To measure the effect of TRICO-DHCT (Fig. 7), we conducted rice straw composting trial with TRICO-DHCT to produce organic fertilizer at a test field in Soc Trang Province. Three weeks after implementation in the field, composting process has progressed, however some stems and fibers remained. After six weeks from the implementation, the testing material found in black color and composting seemed to be almost completed (Fig. 8)

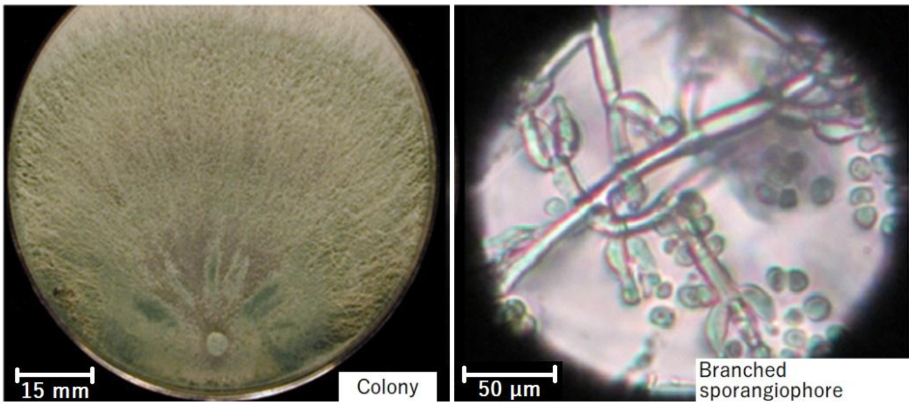

Fig. 7 Photos of *Trichoderma* colony on a petri dish (left), and
Mycelium under microscope (right)
Source: photos taken by our project member of Can Tho University in 2015

Fig. 8 Rice straw composting treatment with TRICO-DHCT in Soc Trang Province
Source: photos taken by our project member of Can Tho University in 2015

IV. DISCUSSION

We conducted repellent grass planting trials at paddy side. Instead of applying artificial pest control chemical to the paddy, our research partner, Loc Troi Group member planted insect repelling grass besides our experiment paddy fields as a supplemental solution. At first, we tried Moss Roses with purple color flower (Fig. 9), however Moss Roses blooms only one time, then we changed the grass to Arachis Pintoi with yellow color flowers (Fig. 10). Arachis Pintoi makes flowers many times and easy to maintain. However, it was difficult to measure the effectiveness.

Fig. 9 Moss Roses as repellent at test field in An Giang Province
Source: photo taken by the author in 2014

Fig. 10 Arachis Pintoi as repellent at test field in An Giang Province
Source: photo taken by the author in 2014

Recently, related to IPM method [5], planting repellent grass at paddy side is getting popular in the same An Giang Province, Vietnam. According to the head of Cultivation and Plant Protection Center of Chau Phu

District, An Giang Province, the center promote farmers to plant repellent grasses, such as Sulfur cosmos, Sunflower, Zinnia elegans, Asteraceae, Cock's comb, Crotalaria pallida, Moss Roses, and Marigold (Fig. 11). Those grasses are effective for not only repellenting insects, but some of them can also reduce nematodes and other soil diseases. This activities are supported by local government policy as well as "the Project on Sustainable Agricultural Transformation in Vietnam (VnSAT project)". They reported that they could reduce the cost of pesticides about 30 %.

Fig. 11 Sign board of promoting "Repellent grass planting at paddy side"
by Chau Phu District government, and the head of Plant Protection Center in Chau Phu
Source: VNBUSINESS web news November 2021

Planting those grasses on the paddy sidenot only has a repellent function, but also has the effect of preventing ridge collapse, and contributing to biodiversity [6] [7].

V. CONCLUSION

In our challenges to make rice cultivation activities more sustainable, one of our main goalsis how to reduce consumption of artificial chemical fertilizers and pesticides. Then, we carried out following three types of experiments or trials.

First one was to reduce fertilizer applying volume by mechanical technology. We prepared a fertilizer applicator mounted on a rice transplanter, which can deliver an exact volume of fertilizer to the beneath of soil during transplanting. We carried out rice cultivation experiment with nine different fertilizing conditions. As a result, superior maturity rateswere obtainedin plots where we applied fertilizer to the beneath of soil by the fertilizer applicator. However, yield results were not clearly correlated with applied fertilizer volume or use of the fertilizer applicator.

Second one was to produce organic compost from rice straw collected and spreaded by a combine harvester just after rice harvesting. To accelerate composting, we sprayed organic *Trichoderma* chemical named "TRICO-DHCT" over the straw. We also conducted rice straw composting trial at Soc Trang Province to measure the composting speed. As a result, we recognized that 6 weeks was the enough period for the completion of compostingusing TRICO-DHCT. As our future subject, it is necessary to quantify the effectiveness of rice straw compost in volume as an alternative to chemical fertilizers.

Third one was to plant repellent grass as a partial replacement for pesticides in paddy fields.In the Mekong Delta, rice cultivation period is generally three consecutive seasons, and we cannot plant repellent grasses inside paddy field. So, planting area of the repellent grass is limited at a paddy side.Measuring effectiveness of the repellent grasses is also important in our future researches, even there are several achievement reports by local authorities, farmers, and researchers [8].

We recognize that our sustainability challenges in this research can contribute not only to farmers' economies, but also to the environment and biodiversity in the Mekong Delta.

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