Effect of System of Rice Intensification（SRI）on growth and yield performance in Nam Dong district, Thua Thien Hue province, Vietnam

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The field study was conducted in Nam Dong district, Thua Thien Hue province, Vietnam during May 2019 to observe the effects of SRI method on the rice yield and eradicate the factor affecting the yield. The study was carried out to evaluate the agronomic characteristics of rice, fresh and dry matter production, soil characteristics with a focus group discussion regarding cultivation by SRI and non-SRI methods. The soil analyses using standard measurements showed quite similar soil fertility in both SRI and non-SRI methods, while rice plants showed good agronomic performances and fresh and dry matter production in SRI method. At harvesting time, the yield and yield potentials of rice were greater in SRI than that in non-SRI methods. Focus group discussion found some factors that limited SRI development in Nam Dong district.

Key words : Actual yield, Focus group discussion, Filled spikelets, SRI, Weeding.

Introduction

Rice is one of the most important cereal crops in the world, widely grown in many localities throughout the world with favorable climatic conditions（James[2], 1983；Yoshida[11], 1981）. Rice is the staple food for more than half of the population in the world（IRRI[1], 2002；Jackson *et al.*[3], 1996）. In Vietnam, rice areas under cultivation occupy 7.72 million hectares and produce more than 42 million tons of rice annually.

The System of Rice Intensification（SRI）was developed first in Madagascar based on how to improve the growing environment for rice plants by changing cultural practices（Lal *et al.*[5], 2016）. Application of SRI principles has helped farmers in that country to greatly increase their grain yields, from 2 to 8 ton. ha^{-1}（Uphoff and Randriamiharisoa[10], 2002）. With limited resources, SRI could increase yield up to 15 tons ha^{-1} on infertile soils（Stoop *et al.*[12], 2002）.

These increases were achieved not by introducing new varieties or external input but changing the management of plants, soil water, and nutrients as below：

- Transplanting young seedling, only 8−12 days old or 2.5−3.0 leaf ages.
- Planting single seedlings with sparse transplanting, carefully and quickly, in a grid pattern at least 20 × 20 cm, thereby reducing plant density as much as 80−90%.
- Water management that avoids flooding during the entire crop cycle, with no continuously standing water during the vegetative growth phase and mostly aerobic soil conditions, thereby reducing water use by 25−50%.
- Weeding by hand with a simple mechanical implement that aerates the soils.
- Use of compost to enhance soil organic matter as much as possible.

Rice production in the mountainous area of Vietnam, especially in Nam Dong district, Thua Thien Hue province meets many difficulties such as water shortages, lack of arable land and lower cultivation techniques. These difficulties lead people to have low income and face some months of food shortage each year. In order to improve food security for local people, the project on Food Security Improvement had already implemented and introduced SRI method to the local people in Nam Dong back in 2015. Besides, local people have observed rice yield increasing and gradually changed their perception of rice production by changing farming practices more innovatively. For the dissemination and replication of the SRI method, further evaluations are needed in the study sites with different households so that further recommendations can be made. Therefore, it is necessary to survey rice yield at harvesting stage and hold farmers' interviews to evaluate the effectiveness of SRI and traditional cultivation methods together with effectiveness of Farmers' Field School（FFS）method, and to

Received October 1, 2019
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propose appropriate recommendations for each region through the crop season.

Materials and Methods

1. Plant materials

At the harvesting stage of the rice, we selected 2 fields of rice grown with and without SRI cultivation methods. Rice was collected at May 3rd and May 5th, 2019 in village 1, Huong Huu and village 4, Thuong Quang communes, respectively. The varieties were PC6 in village 1 and KD 18 in village 4. These varieties are common in Nam Dong district, Thua Thien Hue province.

2. Evaluation of agronomic characteristics and yield in non-SRI and SRI fields

At the field, 10 hills for each replicate and 3 replicates per field were selected and 5 hills with an average number of stem were used to measure plant height, number of stems, number of panicles, panicle length and number of green leaves at harvesting time. After measuring fresh weight, rice plant samples were separated into leaves, stems, and panicles and dried in the ventilated oven at 80℃ until constant weight was reached. The dry weight was recorded after measuring.

Using wireframe of 1 m^2, located at 3 random places in the field, before cutting a sample for yield and yield components analysis, number of hills m^{-2} was counted. After counting the number of hills m^{-2}, rice plant were harvested for measure parameters such as number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of filled spikelets $panicle^{-1}$, thousand grain weight, theory rice yield (calculated by the number of panicles m^{-2} × number of filled spikelets $panicle^{-1}$ × weight of 1,000 grains/1,000) and actual rice yield (calculated by seed weight from 3 m^2 $field^{-1}$, and converted to the yield in area of 1 hectare).

3. Soil collection and analysis

At each field of collecting rice samples, composite soil samples were collected (0-20 cm depth) at harvesting time. Total soil samples were 4. Soil chemical properties analysis included pH of soil-1M KCl suspensions (1：5 ratio), organic carbon (C, Walkley and Black method), total nitrogen (N, Kjeldahl method), total phosphorus (P_{tot}, extraction with aqua regia, colorimetric), total potassium (Flame photometry).

4. Farmer' Field School (FFS) assessment

Focus group discussion (FGD) was used for the study. FGD had 20 participants representative for different areas at local villages, *i.e.* extension officer at commune and district levels, agriculture staff at commune, head of village, key farmers applied SRI and key farmers non-applied SRI. FGD will be used to collect deep insights of current status of FFS implementation, rice cultivation by SRI and food security.

5. Statistical analysis

All data were statistically analyzed and the differences between cultivation methods were exmined by T-test. SPSS 20.0 software was used for the data analysis.

Results

1. Soil characteristics at SRI and non SRI methods

The results in Table 1 showed that there were no significant differences in soil characteristics under SRI and non-SRI methods, except for organic matter in both villages, which was higher significantly in the SRI field than in the non-SRI field.

Acidity of soil (pH_{KCl})：The results of soil analysis in Table 1 show that the soil acidity in both cultivation methods was in the very acidic range of 3.92-4.41. This suggests that farmers should apply lime before sowing the rice, as such high soil acidity affects the nutrient solubility in the soil, and contains many toxic ions such as Al, Fe, Mn.

Organic matter (OM%)：This is an important indicator for assessing soil fertility, nutrient supply for the crop.

Table 1 Soil characteristics at harvesting time in SRI and non-SRI methods during Winter-Spring 2018-2019 season

District	Cultivation method	pH_{KCl}	OM (%)	N (%)	P_2O_5 (%)	K_2O (%)
Village 1	Non SRI	4.25	2.99	0.05	0.04	0.07
	SRI	4.41	3.75	0.06	0.05	0.07
	T-test	0.12	0.03	0.21	0.21	0.24
Village 4	Non SRI	3.92	2.38	0.04	0.04	0.0
	SRI	4.23	3.60	0.05	0.05	0.06
	T-test	0.10	0.04	0.21	0.22	0.22

In the same column, T-test values ＜ 0.05 show significant differences between non-SRI and SRI cultivation methods.

High levels of organic matter will provide favorable conditions for the growth and development of plants and microorganisms. On soils with high organic content, the nutrient content in soil and fertilizer is usually higher. The results showed that the content of OM fluctuated from 2.38% to 3.75%, which was in a moderate level. It is, therefore, necessary to enhance the addition of organic compounds to the soil through the application of organic fertilizers and/or the return of crop residues into the soil.

Total nitrogen content (N%): Nitrogen is the first essential nutrient and determines crop yield. The total nitrogen and organic matter content in the soil are sources of nitrogen for plants. In soil, nitrogen exists in two forms including inorganic and organic nitrogens, in which the amount of inorganic nitrogen is very low, accounting for 1-2% of the total nitrogen of the soil (about 1-50 ppm). In general, the N in each soil type depends on the organic matter content of the soil; the soil rich in organic matter is also rich in total nitrogen. The results indicated that the total nitrogen content in the soil was < 0.06%, suggesting that the availability of nitrogen from the soil is very low, so organic fertilizer and nitrogen fertilizer need to be applied to the soil.

Total phosphorus (P_2O_5%): This is a very essential element for the plant. It has nutritional implications and helps especially to overcome some toxic elements of the soil. The total phosphorus content of the soil ranged from 0.04-0.05% in both cultivation methods and villages. Total phosphorus content in soils was poor, so it will be necessary to increase the phosphorus fertilization to supplement phosphorus into the soil.

Total potassium content (K_2O%): The results show that the total potassium content in the soil is very poor, so the potassium supply for rice in the study sites was almost non-existent. Increasing organic fertilizer, and returning by-products into the soil are very important.

2. Rice plant performances at harvesting time

The characteristics of rice plant at harvesting time at the survey sites are shown in Table 2.

The number of hills m^{-2} was ranged from 25-42 and 32-42 in village 1 and 4 respectively. The number of hills tended to be higher under non-SRI than that in SRI methods.

Rice plant height was ranging from 96-105.4 cm in village 1 and 75.1-84.2 cm in village 4. Plant height depends on genetic characteristics and cultivation method. In both villages, rice plant height under SRI method was higher and showed better lodging resistance than that under non-SRI methods.

In village 1 and 4, some farmers were very skeptical about the sparse transplanting and the potential of young seedling development, especially in village 4. Thus, they had just reduced the rate of transplanting to 32 hills with SRI methods compared to their non-SRI field with 42 hills m^{-2}. By contrast, in village 1, farmers who followed the SRI protocols using sparse transplanting could get a higher number of effective tillers than that in non-SRI. The numbers of effective tillers were 7.7 and 7.1 tillers in village 1 and 4, respectively. The numbers of effective tillers were significantly higher in SRI than in non-SRI in both villages.

Panicle length in SRI method tended to be longer significantly than that in the non-SRI method. Panicle was longest at SRI method in village 1 with 25.0 cm, significantly longer compared with non-SRI method. Longer panicle contributed to higher number of spikelets, resulting in higher actual grain yield. Panicle was longest at SRI method in village 1 with 25.0 cm.

The number of green leaves at harvesting time reflects the photosynthesis ability of rice, especially after heading. Whith higher number of green leaves, larger photosynthesis products were obtained. Results indi-

Table 2 Plant performance of rice at the study sites during Winter-Spring 2018-2019 season

Sites	Cultivation methods	Number of hills (m^{-2})	Plant height (cm)	Number of tillers ($hill^{-1}$)	Number of effective tillers ($hill^{-1}$)	Panicle length (cm)	Number of green leaves ($plant^{-1}$)
Village 1	Non-SRI	42 ± 2.0	96.6 ± 2.4	5.9 ± 1.1	4.2 ± 0.9	21.7 ± 1.3	2.0 ± 0.4
	SRI	25 ± 2.0	105.4 ± 3.2	9.9 ± 1.2	7.7 ± 1.1	25.0 ± 1.9	2.4 ± 0.5
	T-test	0.016	0.016	0.015	0.002	0.086	0.020
Village 4	Non-SRI	42 ± 3.0	75.1 ± 3.0	5.9 ± 1.3	4.5 ± 1.1	19.3 ± 1.2	2.0 ± 0.5
	SRI	32 ± 3.0	84.2 ± 2.8	9.1 ± 1.5	7.1 ± 1.4	22.4 ± 2.0	2.0 ± 0.5
	T-test	0.023	0.005	0.009	0.012	0.000	0.742

In the same column, T-test values < 0.05 show significant differences between non-SRI and SRI cultivation methods.

cated that the green leaves were significant higher in SRI field than in non-SRI field. Number of green leaves in village 1 was 2.4 and 2.0 leaves under SRI and non SRI. In village 4, there was no significant difference in green leaves in either cultivational method.

3. Fresh and dry matter production at harvesting time

Dry matter of rice plants was significantly affected by cultivation methods and variety. The results in Table 3 indicated that the fresh and dry matter production in SRI tended to be higher in SRI than that in non-SRI in both villages but there was a significant difference in fresh and dry matter production between non-SRI and SRI methods at village 1.

The highest dry matter production got 42.95 g $hill^{-1}$ followed by 28.22 g $hill^{-1}$ in village 4. The higher fresh and dry matter production might be potential to higher grain yield of rice in village 1 than village 4 under both cultivation methods.

4. Yield and yield components of rice

Yield and yield components of rice are presented in Table 5 and 6. Cultivation methods had a significant effect on grain yield components, such as number of panicles m^{-2}, number of spikelets $panicle^{-1}$ and number of filled spikelets $panicle^{-1}$.

The results in Table 4 indicated that rice tillering ability has a positive relationship with the number of panicles m^{-2} in both cultivation methods. The number of panicles m^{-2} in SRI method was higher than that in the non-SRI method. In village 1, the number of panicles m^{-2} in SRI method reached 278 panicles m^{-2}, significantly higher than that in the non-SRI method.

In village 4, however, the number of panicle m^{-2} under

Table 3 Fresh and dry matter production of rice at the study sites during Winter-Spring 2018-2019 season

Sites	Cultivation methods	Fresh weight (g $hill^{-1}$)	Dry weight (g $hill^{-1}$)
	Non-SRI	57.17 ± 8.61	20.27 ± 2.32
Village 1	SRI	98.12 ± 7.72	42.95 ± 5.14
	T-test	0.021	0.004
	Non-SRI	31.20 ± 7.24	18.89 ± 3.40
Village 4	SRI	46.45 ± 5.92	28.22 ± 4.22
	T-test	0.062	0.070

In the same column, T-test values < 0.05 show significant differences between non-SRI and SRI cultivation methods.

Table 4 Yield components of rice at the study sites in Winter-Spring 2018-2019 season

Sites	Cultivation methods	No. of panicle m^{-2}	No. of spikelets $panicle^{-1}$	No. of filled spikelets $panicle^{-1}$	Ripening percentage (%)	1,000 grains weight (g)
	Non-SRI	267 ± 9	96 ± 7	77 ± 4	80 ± 4	25.07 ± 0.02
Village 1	SRI	278 ± 10	125 ± 3	107 ± 2	86 ± 1	25.26 ± 0.08
	T-test	0.356	0.035	0.014	0.147	0.056
	Non-SRI	261 ± 4	85 ± 6	69 ± 8	81 ± 4	22.32 ± 0.12
Village 4	SRI	249 ± 7	95 ± 5	77 ± 2	82 ± 2	22.79 ± 0.04
	T-test	0.194	0.262	0.308	0.807	0.013

In the same column, T-test values < 0.05 show significant differences between non-SRI and SRI cultivation methods.

Table 5 Theoretical and actual yields of rice in Winter-Spring 2018-2019 season

Sites	Cultivation methods	Theoretical yield (tons ha^{-1})	Actual yield (tons ha^{-1})
	Non-SRI	5.16 ± 0.13	4.09 ± 0.16
Village 1	SRI	7.51 ± 0.22	5.71 ± 0.44
	T-test	0.005	0.011
	Non-SRI	4.03 ± 0.42	2.97 ± 0.06
Village 4	SRI	4.39 ± 0.15	3.30 ± 0.20
	T-test	0.367	0.091

In the same column, T-test values < 0.05 show significant differences between non-SRI and SRI cultivation methods.

Table 6 Rice production in the survey sites

Content	Village 1	Village 4
SRI cultivation areas (m^2)	500–750	300–400
Quantity of seed (kg / 500 m^2)	< 1	< 1
Fertilizer application	100 kg / 500 m^2 of compost	None
Bokashi foliar fertilizer application	Application : 100%	Application : 10%
Percentage of weeding number		
1 time	20%	0%
2 times	80%	90%
More than 2 times	0%	10%
Use of pesticides	Only when insects and diseases appeared	None
Rice yield		
< 4 ton. ha^{-1}	10%	50%
4–4.5 ton ha^{-1}	80%	50%
4.5–5 ton ha^{-1}	10%	0%

SRI method was 249 panicles m^{-2}, lower than in the non-SRI method.

Longer panicle could explain higher number of spikelet $panicle^{-1}$. The number of spikelets of both cultivation methods ranged from 96–125 and 85–95 in village 1 and village 4, respectively. Higher number of spikelets contributed to higher number of filled spikelets $panicle^{-1}$. In village 1, rice plant in SRI methods was 107 and significantly different from non-SRI method (77 filled spikelets). In village 4, although the higher number of filled spikelets was observed in SRI method, there was no significant difference with non-SRI method.

Ripening percentage (%) is an important component involved in productivity and economic efficiency. The results in Table 4 indicated that there was no significant difference between SRI and non-SRI methods on this parameter. Ripening percentage tended to be high and ranged from 80–84% in village 1 and 81–82% in village 4.

Thousand grain weight is one of the yield components and it depends on varietal genetic characteristics. Thousand grain weight ranged from 25.07–25.26 g in village 1 and 22.32–22.79 g in village 4. However, there was no significant difference between SRI and non-SRI methods in village 1.

Theoretical yield and actual yield of rice plants are shown in Table 5 and Fig. 1. The results indicated that theoretical yield of rice is determined by the number of panicles, number of filled spikelets $panicle^{-1}$ and thousand grain weight. If the rice plant was well taken care of, the yield components were better, resulting in a yield increase. Theoretical yield ranged from 4.03–7.51 ton ha^{-1}.

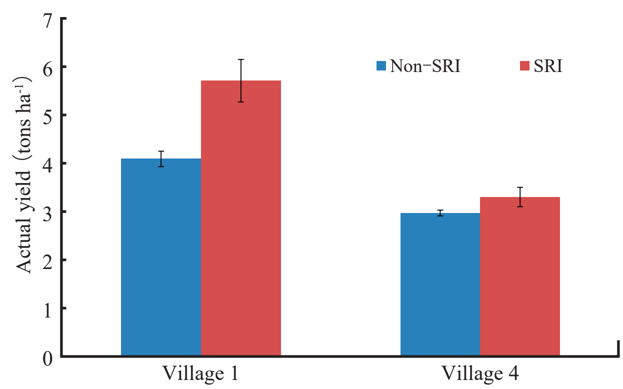

Fig. 1 Yield of rice in SRI and non-SRI methods during Winter-Spring 2018-2019 season

The highest theoretical yield was observed in village 1 with SRI method. SRI methods increased yield as compared with non-SRI method in both villages, but there was a significant difference in village 1. The highest grain yield was 5.71 ton ha^{-1} and the lowest grain yield was 2.95 ton ha^{-1}. Compared with the non-SRI method, rice grain yield increased 39.6% and 11.1% in village 1 and village 4, respectively.

5. Rice production situation in the survey sites

The survey results (Table 6) indicated that SRI cultivation area is still limited, especially in village 4, where the farmers had only used 300–400 ㎡ for SRI cultivation, while farmers used 500–750 ㎡ for SRI cultivation in village 1. The differences in cultivation area come from the limiting of irrigated field. Although the farmers understand the benefits from SRI cultivation method, they do not want to expand production because of higher labor cost.

Farmers have recently changed the cultivation method from direct sowing to transplanting recently. They use less than 1 kg of rice seeds instead of 5-6 kg of seeds for direct sowing in a field of 500 m^2.

In village 1, farmers applied compost and bokashi fertilizer two times for rice at active tillering and panicle initiation stages, which explain that why rice grain yield in SRI method was higher than that in non-SRI method as compared with village 4.

Weeding by hand created a good environment for rice root growth and development. All interviewed farmers answered that they performed weeding according to the recommended 1-2 times, and one particular household conducted weeding in 3 times.

Rice grain yield was different between village 1 and village 4, reflecting the variation of abilities and cultivation techniques.

Discussion

The increase of grain yield with SRI methods could have resulted from the farmers' cultivation abilities, sampling fields, applying SRI method or using compost and foliar fertilizer. However, this could not explain the differences observed. Soil analyses using standard measurements showed quite similar soil fertility in both the SRI and non-SRI fields (Table 1). Soil analysis using standard measurement methods shows similar soil fertility in both SRI and non-SRI fields, except for OM content. OM contents fluctuated from 2.38% to 3.75% and it was higher in SRI than that in non-SRI fields. From the FGD results, we got the information that farmers applied compost to SRI fields, with the amount of 50 kg of compost into the soil of 500 m^2, they did not apply in village 4. This means that the success of SRI does not depend primarily on compost use.

The conventional method is characterized by the transplanting of three or more seedings per hill. Planting with high density is thought to provide farmers assurance that if one plant dies, others still grow. In contrast, SRI recommends single and sparse transplanting because of many advantages. San-oh *et al.*[8] (2004) indicated that a single plant had a greater number of roots compared with more plants per hill. A single plant could increase tillering ability in rice and its shows better tillering than a larger number of plants per hill (Joelibarison[4], 1994). Young seedlings had a longer time to adapt to field conditions. Therefore, plant height and tiller number produced were larger in the SRI method. Moreover, single seedling with wider spacing in SRI method reduces competition between plants which can significantly increase the growth of individual rice plant under the SRI method (Thakur *et al.*[9], 2010). Well-developed root systems and increased tillering ability with sparse transplanting could contribute to higher grain yield at harvest time.

Root growth and higher tillering ability were greater in SRI plants than in conventional rice plants. These lead to the total fresh and dry matter production being larger in SRI method than that in non-SRI method. The highest dry matter production, 42.95 g $hill^{-1}$ was obtained followed by 28.22 g $hill^{-1}$ in village 4. The larger fresh and dry matter production might be potential to higher grain yield of rice in village 1 than village 4 with both cultivation methods. However, there was no significant difference between fresh and dry matter production in SRI and non-SRI methods in village 4.

SRI is a method for increasing the yield of rice by changing the management of plants, soil, water, and nutrients by reducing external inputs. It has been raising yields by 32% to 100% and sometimes more, with reduced requirements for water, seeds, fertilizer and crop protection (Sato and Uphoff[7], 2007). Omwenga *et al.*[5], (2014) monitored yield parameters like the number of tillers, panicles and panicle length during the growth period of the crop to determine the effect of system of rice intensification. In this study, the grain yield tended to be higher in SRI than that in non-SRI methods. The grain yield increased 39.6% and 11.1% in village 1 and village 4, respectively. The yield increment could not be explained by changes in the application methods of SRI.

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ベトナム国トゥアティエンフエ州における水稲の生育収量に及ぼす SRI 農法の影響

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ベトナム国トゥアティエンフエ州ナムドン郡において，2019年 5 月に SRI 農法が水稲の生育収量に及ぼす影響を現地調査するとともに，収量に影響する要因を明らかにすることを目的とした．水稲の農業形質，バイオマス生産，土壌特性を SRI 農法と慣行栽培で比較するとともにフォーカス・グループ・ディスカッションにより農家インタビューを行った．標準的な土壌分析による土壌の肥沃度に SRI 農法と慣行農法で相違は見られなかった．しかし，水稲の生育特性，物質生産特性は慣行栽培に比べ，SRI 農法で優る傾向にあった．収穫期における収量と収量構成要素は慣行栽培に比べ SRI 農法で高くなった．フォーカス・グループ・ディスカッションにより，ナムドン郡における SRI の普及を制限している要因を明らかにした．

Received October 1, 2019

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