STUDY ON FEASIBILITY OF SYSTEM OF RICE INTENSIFICATION (SRI) IN SOUTH KOREA

ETUDE DE FAISABILITE DU SYSTEME D'INTENSIFICATION DE RIZICULTURE (SRI) EN COREE DU SUD

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ABSTRACT

An experimental study on SRI was conducted to investigate the feasibility of SRI application in Korea for irrigation water saving. Eight experimental runoff plots of 5x15 m in size were prepared and the volume of irrigation and drainage was measured during 2010 growing season with a Japonica rice variety. Irrigation water requirement of SRI and CT plots was 243.2 and 547.3 mm, respectively. SRI plots could save 55.6% of irrigation water requirement. Rice plants grew better and healthier in SRI plots than in CT plots. However, rice production from SRI plots ranged between 76 and 92% compared to CT plots because planting density in SRI was too low and the Japonica variety could not make tillers as much as Indica does. It was believed that if planting density were increased, rice production from SRI plots would be higher than that from CT plots. It was concluded that SRI could be successfully adopted in Korea and could help save irrigation requirement in paddy significantly. The research results would contribute to understand and adopt SRI in Korea.

Key Words: *System of rice intensification, Experimental runoff plots, Crop growth monitoring, Crop water requirement, South Korea.*

RESUME

Une étude d'expérimentation a été menée sur SRI pour étudier la faisabilité d'application de SRI en Corée pour économiser l'eau d'irrigation. Huit parcelles expérimentales de

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ruissellement de taille 5x15 m ont été préparées et le volume d'irrigation et de drainage a été mesuré lors de la saison de croissance en 2010 pour la variété de riz Japonica. Les besoins en eau d'irrigation des parcelles SRI et CT étaient de 243,2 et 547,3 mm respectivement. Les parcelles pourraient sauver 55,6% de l'eau d'irrigation. On a constaté une meilleure croissance du riz dans les parcelles SRI que parcelle CT. Cependant, la production du riz dans les parcelles SRI varie de 76 à 92% par rapport aux parcelles CT car la densité de plantation dans SRI était inférieure et que la variété japonica ne pouvait pas produire autant que la variété Indica. Il est cru qu'en augmentant la densité de cultivation, il est possible d'augmenter la production du riz dans les parcelles SRI que dans les parcelles CT. Il est conclu que SRI peut être adopté avec succès en Corée et il peut contribuer, de manière significative, à la conservation des besoins en eau d'irrigation du riz paddy. Les résultats de la recherche contribueront à l'adoption de SRI en Corée.

Mots clés: *Système d'intensification du riz, parcelles expérimentales de ruissellement, suivi de la croissance des cultures, besoins en eau agricole, Corée du Sud.*

1. INTRODUCTION

International Rice Research Institute (IRRI) in the Philippines has proposed eight objectives for the advancement of rice farming in underdeveloped and developing countries. These are increased land productivity (higher yield per land area), higher water productivity (more crop per drop), technology that is accessible for the poor, technology that is environmentally friendly, greater resistance to pests and diseases, tolerance of abiotic stresses such as climate change, better grain quality for consumers, and greater profitability for farmers (Uphoff et al., 2002). System of rice intensification (SRI) is one of alternatives that can satisfy these objectives. SRI has developed in Madagascar by a French missionary before 1980, adopted by developing countries from 1999 including China and Indonesia (Uphoff, 2009), and is practiced by more than 40 countries in 2010 (CIIFAD, 2010). Since then, studies on SRI has been widely conducted by many researchers (Uphoff, 1999; Wang et al., 2002; Yuan, 2002; Barrett et al., 2004; Ceesay et al., 2006; McDonald et al., 2006; Kabir and Uphoff, 2007; Satyanarayana et al., 2007; Sinha and Talati, 2007; Namara et al., 2008; Senthilkumar et al., 2008; Zhao et al., 2009). SRI has proven to be an effective rice farming method in yield increase and water saving (Zhao et al., 2010). UPhoff et al. (2002) and Stoop et al. (2002) reported that average rice production of SRI was more than twice of the conventional rice farming while the use of irrigation water in SRI was significantly lesser. Zhao et al. (2010) also reported that SRI produced 26.4% more rice than conventional culture and the water use efficiency of SRI increased by 194.9% compared to conventional culture.

There are six principles for a successful SRI application. These are to transplant young seedlings to preserve their growth potential, avoid trauma to the roots of cutting and drying of seedlings, give plants wider spacing between hills, keep paddy soil moist but not flooded, actively aerate the soil as much as possible, and enhance soil organic matter as much as possible. These SRI principles are not well understood by most of Korean administrators and researchers. Rice production system in Korea is very well established, and thus, SRI has not been yet tried in South Korea. But, Korea apprehends water shortage in the near future and the conservation of water resources is one of the most important issues. Water consumption of agricultural fields in Korea is about 48% of the nation's water supply. And about 90% of agricultural water use is consumed in paddy farming. Saving of irrigation water in paddy farming is very important in overall water resources management in Korea. SRI has a great potential in the reduction of irrigation requirement as well as increase of rice yield. Therefore, the objectives of this research was to experimentally investigate the feasibility of SRI application in Korea focused on water saving. The research results would contribute to understand and adopt SRI in Korea.

2. MATERIALS AND METHODS

2.1 Experimental Runoff Plot

Experimental plots were constructed at a university farm located at the north latitude (N) 37° 55′ 57″ and the east longitude (E) 127° 46′ 59″ (Figure 1). Eight runoff plots of 5x15 m in size were prepared in a paddy field of 1,873 m^2. Irrigation pipes and drainage channels were constructed. Each plot equipped with a flow meter for irrigation measurement, a flume for drainage measurement, and a Coshocton wheel water sampler (Bonta, 1999, 2002). An automatic raingauge was also installed near the plots to measure rainfall. Monthly average temperature, rainfall and sunshine duration around the site are shown in Table 1. Water content, organic matter content and pH of the soil before beginning of the spring farming were 18.7±1.0%, 2.5±0.03% and 6.1±0.2, respectively.

2.2 Experimental Treatment and Management

Experimental treatments were conventional (CT) and SRI cultures. SRI is subdivided into 3 transplanting spacing of 30×30, 40×40, and 50×50 cm. For conventional culture, the spacing was 30x15 cm which was the typical in the region. Each treatment was duplicated. Three to five seedlings per hill was mechanically transplanted for CT and one seedling per hill was manually transplanted for SRI (Table 2). Seedlings of 35 days old since seeding were used for both CT and SRI transplanting.

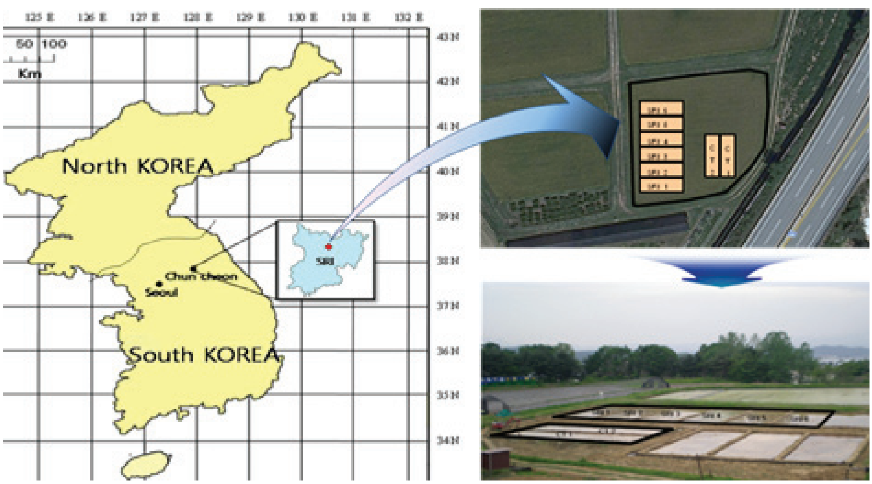

Fig. 1. Location and photos of the experimental runoff plots (Localisation des principales villes et le site des champs expérimentaux)

Table 1. Monthly average temperature, rainfall, sunshine duration, and relative humidity in 2010 (Cumul pluviométrique mensuel et heures d'ensoleillement et des moyennes mensuelles de température de l'air et l'humidité relative en 2010)

	May	June	July	August	September
Temperature (°C)	17.2	22.9	25.5	26.0	20.3
Rainfall (mm)	106.1	54.9	220.9	468.1	448.5
Sunshine duration (hr/ month)	195.0	219.8	119.0	104.4	141.5
Relative humidity (%)	63.3	67.7	77.2	82.3	79.7

Table 2. Comparison of management practices for CT and SRI (Comparaison entre les principales pratiques agronomiques pour la CT et de l'ISR)

	Age of seedling (days)	seedling per hill	Spacing of hill (cm)	Plant density per m²	Irrigation management	Weed management
CT	20-30	3 to 4	30×15	about 60 to 130	Flooding	Herbicide (1 time)
SRI	10-15	1	30×30 to 50×50	4 to 16	Intermittent wet and dry	Manual (3 times)

Irrigation management of CT followed a local rice culture guideline as shown in Table 3. For SRI, 4 to 7 day interval intermittent irrigation depending on rainfall and growth stage was practiced as suggested by SRI Homepage operated by CIIFAD (2010). For both of SRI and CT, irrigation was ended at the late ripening stage of rice. Weeding of SRI plots were conducted manually three times while herbicides were used to control weed in CT plots. Other management practices such as fertilization and disease control for both CT and SRI were the same as specified by a local guideline. Recommended fertilization for rice was 110-45-57 kg/ha as N-P2O5-K2O. A local rice variety called Odaebyeo (Oryza sativa L.) was cultivated in 2010 growing season. The summary of management practices are shown in Table 2. Crop growth monitoring was conducted with respect to plant height and number of tillers throughout the growing season according to the Research and Investigation Standard for Agricultural Science and Technology (RDA, 2003). These data were used to evaluate the effect of SRI on plant growth.

Table 3. Recommended water management for CT by a local guide (Méthode de gestion de l'eau pour les CT)

Stage	Description	Water depth (cm)
Transplanting	Shallow irrigation	2 - 3
Root development	Deep irrigation	5 - 7
Tillering	Shallow irrigation	2 - 3
End of tillering	No irrigation (5 - 10days) : 30-40 days before heading	0

Panicle Initiation/ booting	AWD(30 days before heading) : 3-day ponding and 2-day dry	2 - 4
Heading/flowering	Medium irrigation	3 - 4
Ripening	AWD (3-day ponding and 2-day dry)	2 - 3
Draining	Complete drain : 30-40 days after heading	0

*AWD : Alternating wet and dry irrigation or intermittent irrigation

2.3 Sampling and Analysis

Surface soil samples were collected and analyzed with respect to pH, water content, organic matter content, and particle size distribution according to Korean Standard (Ministry of Environment, 2009). Water samples taken from the plots and irrigation source which was a farm reservoir were analyzed with respect to BOD, COD, T-N, and T-P according to Korean Standard (Ministry of Environment, 2007) and Standard Method (APHA, 2005). ANOVA in Minitab 16 software and Tukey's test were used to analyze and compare the correlation among and the means of measured data from different treatments at the significance level of 1 and 5%.

3. RESULTS AND DISCUSSION

3.1 Soil Analysis of Study Site

Particle size analysis showed that the soil composed of sand 49.4%, silt 35.8%, and clay 14.8% and the soil texture was loam. Physicochemical analysis of the sampled soil showed that organic matter content was 2.5±0.03%, pH 6.1±0.2, and exchangeable cation Ca, Mg, and K contents were 4.6±0.2 cmol/kg, 1.7±0.3 cmol/kg, and 0.28±0.1 cmol/kg, respectively. These physicochemical properties fell in the proper range for rice cultivation in Korea as shown in Table 4.

Table 4. Physicochemical properties of the soil (Propriétés chimiques du sol expérimental)

pH	OM (%)	Exchangeable Cation (cmol/kg)		
		Ca	Mg	K
6.1± 0.2	2.5 ± 0.03	4.6± 0.2	1.7± 0.3	0.28± 0.1

Heavy metal (mg/kg)								
Al	Cr	Cu	Cd	Zn	Ni	Pb	As	Hg
720	0.9	4.4	0.2	73	26	8.7	0.03	0.1

3.2 Water Quality of Irrigation Water

Measured water quality of the farm reservoir that was used to irrigate the experimental plots was shown in Table 5. The water quality indices were within the recommended water quality in Korea and Japan except for T-N (Jung, 2006; RDA, 2008). However, T-N concentration in streams and reservoirs is generally high and T-N concentration of 2.067 mg/L measured in this study is not abnormal in Korea.

Table 5. Measured water quality of irrigation reservoir and recommended water quality for irrigation in Korea and Japan (Comparaison de la concentration dans l'irrigation en eau)

Water quality index	Recommended range		Measured quality (n=6)
	Korea	Japan	
pH	6.0 - 8.5	6.0 - 7.5	7.2 ± 0.1
BOD (mg/L)	≤ 8	≤ 8	1.6 ± 1.1
COD (mg/L)	≤ 8	≤ 6	4.9 ± 0.8
SS (mg/L)	≤ 100	≤ 100	16.1 ± 3.3
DO (mg/L)	≥ 2	≥ 5	8.4 ± 0.2
T-N (mg/L)	-	≤ 1	2.067 ± 0.1
T-P (mg/L)	-	-	0.084 ± 0.01
EC (dS/m)	-		0.109 ± 0.01

3.3 Crop Growth Monitoring

Crop growth monitoring began from seeding in April, 2010. Seedlings for SRI were raised in 200 port plastic trays. Each port was filled with a soil prepared for seedling production and seeded with one rice seed per port. For CT, seedlings were raised in plain trays. The plain trays were filled with the same soil and rice seeds were broadcasted. Length of seedlings in the plain trays ten days after seeding were taller (3.5±0.7 cm) than those (2.0±0.5 cm) in the port trays. However, as time went on, seedlings in the port trays became stronger and taller than those in the plain trays as shown in Figure 2. Seedlings in the port trays were observed to grow faster than those in the plain trays about 2 weeks after seeding as the roots developed larger in the port trays. It was thought that seedlings in the port trays might be transplanted before 20 days or preferably around 2 weeks after seeding when seedlings were about 5~7 cm tall for the best plant growth and the largest tillering.

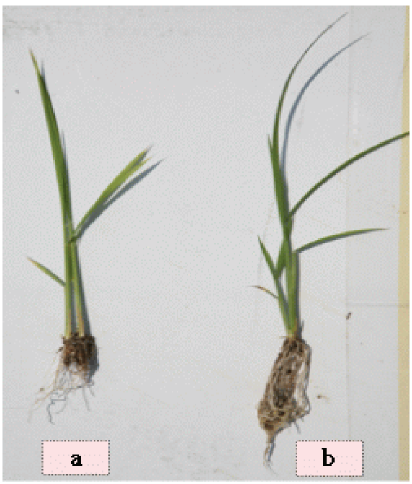

Figure 2. Seedlings in plain trays (a) for CT and port trays (b) for SRI before transplanting (Comparaison en CT et l'ensemencement de SRI)

Number of tillers per hill and plant height were periodically measured after transplanting (May 21, 2010) with respect to different experimental treatments as shown in Figures 3 and 4. It was observed the rice plants grew continuously until early August for about 75 days. And the number of tillers per hill also increased until July 16 for till about 47 DAT. The highest height and the largest number of tillers per hill were measured at the 50x50 cm spacing of SRI plots. The plant height and number of tillers per hill increased as the transplanting spacing increased as shown in Figure 3 and 4. The height of rice plant of CT, SRI 30x30, SRI 40x40, and SRI 50x50 cm was 92±1.2 cm, 94±1.9 cm, 98±2.3 cm, and 101±2.1 cm, respectively.

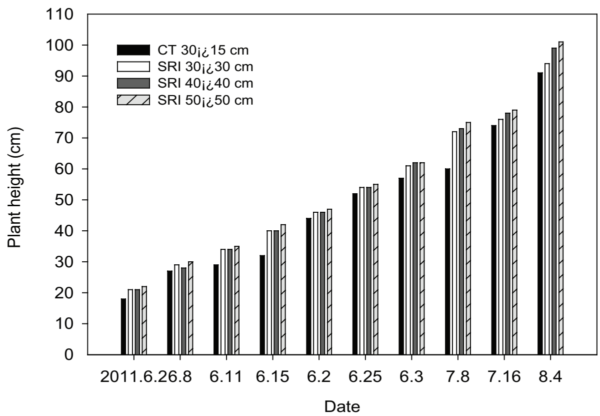

Fig. 3. Height of plant in CT and SRI plots (Hauteur de la plante dans la parcelle CT et SRI (moyenne))

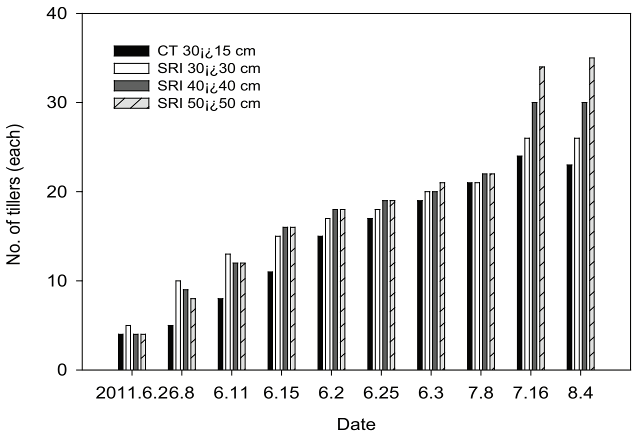

Fig. 4. Number of tillers in CT and SRI plots (Nombre de talles dans la parcelle CT et SRI (moyenne))

ANOVA was performed to analyze the differences between average plant heights and number of tillers per hill with respect to the treatments. Residual analysis showed that the plant height satisfied the normality ($p>0.05$) and homoscedasticity. And variance analysis showed that average plant heights were significantly different among different treatments at the level of 1

%. Tuchey's test also showed that the differences were significant. The number of tillers per hill in SRI plots was 1.5 times more than that in CT plots and the differences between SRI and CT were significant at the level of 1%. And the number of tillers per hill increased as the transplanting spacing increased. Therefore, it was concluded that the plant height and the number of tillers per hill in SRI plots were taller and larger than those in CT plots and thus, the rice plant grew better in SRI culture than in CT culture. These results were similar to the results of Thakur et al. (2010) and Satyanarayana(2005).

3.4 Crop Water Requirement

Average irrigation supply to the SRI and CT plots during the growing season was 547.3 mm and 243.2 mm, respectively (Figure 5). It meant that water requirement in SRI plots were 55.6% less than that in CT plots. This result was similar to that of Zhao et al. (2010) who reported the irrigation reduction of 57.2% with SRI. Irrigation water use efficiency (IWUE) of SRI increased about 88% compared to that of CT. IWUE was defined as the ratio of total irrigation amount (kg) per rice production (m^3). However, it should be noticed that the reduction rate of 55.6% might be more or less overestimated because of the small experimental plot size. It was because that as the plot size was small, the water loss through levies by lateral infiltration could be influential to the irrigation requirement. To correct this problem, further research is being carried out currently. However, it could be concluded that irrigation water requirement in SRI plots could be saved substantially and help secure water resources in future in Korea.

3.5 Grain Yield

Rice production in 2010 was relatively low compared to other years because of frequent rains and storms, and thus the lack of sunshine duration after August during the period of active reproductive growth of rice. Figure 6 shows the annual sunshine duration of 2008, 2009 and 2010. Actual transplanting density of seedling for CT plots was 1,430 hill/plot or 5,720 plant/ plot if 4 plants per hill was assumed. For SRI plots, the density was 644, 385, and 232 hills per plot or plant per plot for 30x30, 40x40, and 50x50 cm spacing, respectively, because only 1 plant per hill was transplanted (Table 6). It meant that the transplanting density of SRI culture was 45.0, 26.9, and 16.2% compared to that of CT culture.

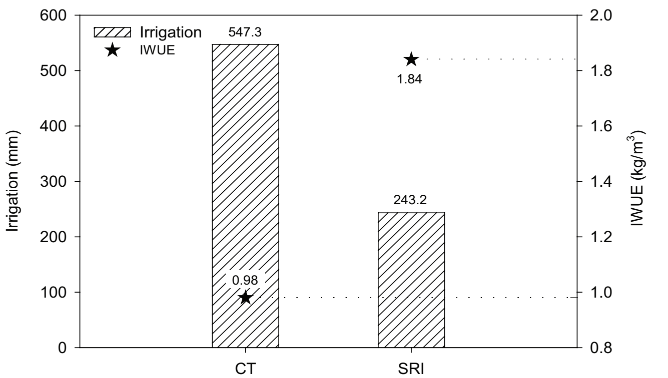

Fig. 5. Irrigation supply and irrigation water use efficiency (IWUE) of SRI and CT plots (Effet de l'ISR sur l'efficacité de l'irrigation de l'eau)

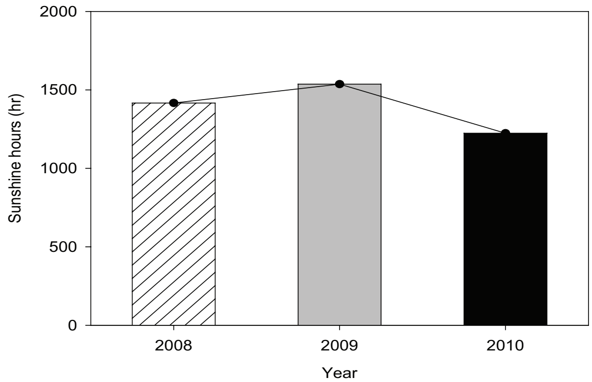

Fig. 6. Comparison of sunshine duration by year (Comparaison de la duree d'ensole illement par an)

And it was later known that Japonica rice variety did not make tillers as much as Indica variety. If SRI practiced with Indica variety, the number of tillers per hill even if 1 plant per hill was transplanted ranged between 60 to 90 or sometimes more than that. However, the largest number of tillers per hill in this experiment was 35 in the 50x50 cm SRI plots. Because of these reason, rice production from SRI plots was less than that from CT plots although the plant in SRI plots was healthier and had more tillers than in CT plots. Polished rice production from SRI plots ranged between 76 and 92% depending on the transplanting spacing, compared to CT plots (Table 6). However, rice production per hill in SRI plots were 1.8~3.9 times higher than that in CT plots. It was thought that if seedlings were transplanted 2 plants per hill in SRI plots or triangular planting explained in a report by Uphoff (2007) were adopted, the plant density would be increased and rice production from the SRI plots would be higher than that from CT plots.

Table 6. Comparison of grain yield in CT and SRI (Comparaison du rendement en grains entre le SRI et CT)

Treatment	Average yield (kg/10a)	Yield ratio To CT (%)	# of hill per plot	Yield per hill (g)
SRI (50×50 cm)	408.4	76	232	93.6
SRI (40×40 cm)	441.3	82	385	65.3
SRI (30×30 cm)	490.3	92	644	43.4
CT (30×15 cm)	535.3	100	1,430	24.3

4. CONCLUSIONS

An experimental study on SRI was conducted to investigate the feasibility of SRI application in Korea focused on irrigation water saving. Eight experimental runoff plots of 5x15 m in size were prepared at an existing paddy field. Each plots equipped with precise irrigation and drainage measuring gauges and the volume of irrigation and drainage was measured during a growing season. A Japonica rice variety was cultivated. Irrigation water requirement of SRI and CT plots was 243.2 and 547.3 mm, respectively. It meant that SRI culture could save 55.6% of irrigation water requirement. Number of tillers per hill and plant height in SRI plots were greater than and taller than those in CT plots. It meant that rice plants grew better and healthier in SRI plots than in CT plots. However, rice production from SRI plots ranged between 76 and 92% compared to CT plots because planting density in SRI was too low and the Japonica variety could not make tillers as much as Indica does. It was thought that if planting density were increased, rice production from SRI plots would be higher than that from CT plots. It was concluded that SRI could be successfully adopted in Korea and could help save irrigation requirement in paddy significantly. The research results would contribute to understand and adopt SRI in Korea.

ACKNOWLEDGEMENTS

This research was supported partly by Rural Research Institute of Korea Rural Development Corporation, the Ministry for Food, Agriculture, Forestry and Fisheries, and the Institute of Agricultural Science and Research of Kangwon National University, Korea. The authors appreciate their generous support.

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