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Article

Effects on Rice Growth of System of Rice Intensification under No-till Paddy in Korea

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The objectives of this research were to investigate the system of rice intensification (SRI) on early growth, grain yield, and yield components under Chinese milk vetch residue-mulched no-tillage cropping systems at silt loam soil. The field was prepared as a split-plot design with three replications, main plots consisted of Dongjinbyeo, and Sobibyeo as a cultivar, and subplots consisted of 10×10 cm, 20×20 cm, and 30×30 cm as a planting density. Weed infestation during rice growing season was more severe in wider planting density 30×30 at 35 days after transplanting (DAT), and 20×20 cm at 95 DAT in both Sobibyeo and Dongjinbyeo. The maximum plant height was recorded in Sobibyeo compared with Dongjinbyeo, 10×10 cm and 20×20 cm planting density compared with 30×30 cm from 20 DAT until 60 DAT. Among the three planting densities, SPAD values were significantly greater in planting density of 20×20 cm both in Sobibyeo and Dongjinbyeo followed by 30×30 cm compared with closer planting density of 10×10 cm. The lowest grain yield was observed in wider planting density of 30×30 in both Sobibyeo and Dongjinbyeo due to lower number of panicle per unit area. Our findings suggest that optimum planting density for SRI in no-tillage paddy was 20×20 cm and it should be useful the systems to small-scale rice farmers in Korea as a sustainable farming system.

Key words: System of rice intensification, Rice, No-till, Chinese milk vetch, Planting density

Introduction

Rice is the dominant staple food crop throughout Asia and is an important source of carbohydrate and fiber globally. In Asia, more than 2 billion people obtain 60-70% of their calories from rice (FAO, 2004), and global demand is expected to rise by 38% above the current production within 30 years (Surridge, 2004). No doubt the Green Revolution helped many Asian countries achieve food self-sufficiency, but it also degraded the environment and threatened agricultural sustainability (Pretty, 2002). Therefore, there has been an increasing public concern about environmental quality and the long-term productivity with safe agro-ecosystems. The principle behind LEISA (Low External Input and Sustainable Agriculture) is that poor farmers, lacking capital and access to credit, need methods with which they can improve yields and income without expensive inputs and without degrading the resource base on which they depend. However, it has become increasingly clear that minimal external-input requirements are insufficient to make new technologies attractive to poor smallholder farmers (Lee and Ruben, 2000). Recently a new approach, widely known as system of rice intensification (SRI), which is a low-cost and high yielding system, might be a sustainable alternative to conventional paddy production (Batuvitage, 2002; Séguy et al. 2003). The synthesis of SRI has proceeded empirically, but the central principles for getting best results are: 1) rice field soils should be kept moist rather than continuously saturated, minimizing anaerobic conditions, as this improves root growth and supports the growth and diversity of aerobic soil organisms; 2) rice plants should be planted singly and spaced optimally widely to permit more growth of roots and canopy and to keep all leaves photosynthetically active; 3) rice seedlings should be transplanted when young, less than 15 days old with just two leaves, quickly,

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shallow and carefully, to avoid trauma to roots and to minimize transplant shock (Uphoff, 1999).

Claims have been made that with SRI methods rice yields could exceed 15-20 Mg ha^{-1} (Uphoff, 2002). In China, research by the National Hybrid Rice Research and Development Centre using the Super-1 hybrid, gave a record yield of 16 Mg ha^{-1} in trials at Mishan, 35.6% higher than the 11.8 Mg ha^{-1} achieved under conventional water-intensive methods (Yuan, 2002). However, these claims have recently been questioned in general (Dobermann et al., 2003). Sheehy et al. (2004) studied the yield potential of SRI using a theoretical model for different locations in China and Madagascar, and corroborated with field experiments in China to show that SRI has no major role in improving rice yields. Dobermann et al. (2003) reported that in intensively irrigated systems under more favourable soils, high yields can be achieved with management practices that are more cost effective than SRI. Moser and Barrett (2003) reported that it is difficult to practice SRI because it requires significant additional labour at a time of year when farmers do not have sufficient cash. A compilation of results from 11 evaluations conducted in 8 countries by a combination of universities, international agricultural research centres, NGOs, government agencies, private sector organizations, and donors, shows SRI methods, even when used incompletely or only partially, giving the following results compared with farmers' practices: 1) 52% average yield increase in tons ha^{-1} (range: 21-105%), 2) 4% average reduction in water use (range: 24-60%), 3) 25% average reduction in costs of production ha^{-1} (range: 2.2-56%), 4) 128% average increase in net income ha^{-1} (range: 59 - 412%) (Uphoff, 2007).

To address this debate and enable resource limited rice growing to raise production and incomes without relying on purchased external inputs, we conducted an on applicability of the SRI in Chinese milk vetch residue-mulched under no-till paddy in Korea. The objectives of this research were to evaluate the effects of SRI on weed occurrences, early growth and development, and grain yield and yield components.

Materials and Methods

General description of the experimental site and paddy field The experiment was conducted at Gyeongsangnamdo Agricultural Research and Extension Services (35°12' 17"N and 128°07'13"E) in Jinju, South Korea from 1 May to 14 October in 2008. The experimental soil type was silt loam (8.2% sand, 73.2% silt, and 18.6% clay) under notillage paddy. The samples were analyzed for chemical properties using the procedures as described in the soil and plant analysis (RDA, 2000). Soil pH was determined using 1:5 soil/water extract. Soil NO_3-N content was determined by Kjeldahl digestion. Soil organic matter, available phosphorus, and exchangeable cations were measured as described by RDA (2000). The chemical properties of the soil before treatments were shown in Table 1. Selected soil chemical properties in the experimental sites were 5.1 for soil pH (1:5), 30 g kg^{-1} for soil organic matter, 191 mg kg^{-1} for available phosphorus concentration, 0.25, 7.3, and 2.1 cmol$_c$ kg^{-1} for exchangeable K, Ca, and Mg concentrations, and 48 mg kg^{-1} for NH_4-N content, respectively. The total nutrients in Chinese milk vetch (3.27 Mg ha^{-1} dry weight) were 87, 18, 76, 53, 16, and 14 kg ha^{-1} for T-N, P_2O_5, K_2O, CaO, MgO, and Na_2O, respectively. In addition, the pig slurry sprayed 15 ton ha^{-1} for soil nutrient management. The total nutrients in pig slurry were 132, 5, 92, 32, 17, and 69 kg ha^{-1} for T-N, P_2O_5, K_2O, CaO, MgO, and Na_2O, respectively.

Treatments and plot design The field was conducted as a split-plot design. Main plots consisted of two Japonica type cultivars (Sobibyeo and Dongjinbyeo), and subplots consisted of three planting density (10×10 cm, 20×20 cm, and 30×30 cm). These treatments were replicated three times. The size of subplots was 3 m×5 m. Seeds soaked in water for 24 hour for pre germination then sown in seedbed for 15 days. Seedlings transplanted after 15 days on 14 June at a rate of one seedling per hill, while the plants were still in their second or third phyllochron (Stoop et al., 2002). Hand weeding was done twice during rice growing before and after tillering and weeds incorporated with simultaneous stirring up of soil. For water saving irrigation, Transplanting was performed no flooded water standing in the rice field (only moist and muddy). Then, irrigation managed to improve soil aeration by draining water from the rice field or by keeping the rice field from being continuously flooded and saturated during the vegetative growth phase. Irrigation was stopped 10 days prior to harvest.

Growth, yield and yield components Leaf greenness was determined by using the chlorophyll meter (SPAD-502, Minolta), on the fully grown uppermost leaf. Examination of plant growth and yield confined to Standard of Agricultural Research (RDA, 1995). At maturity, plants from subplots were harvested at physiological maturity to determine grain yield and straw weight, number of panicles per m^2, number of spikeletes per panicle and 1000-grain weight. Yield was adjusted to the 15% moisture content. Numbers of tiller per hill and plant height were also measured.

Statistical analyses Statistical analyses were conducted using SAS 9.1 software (SAS Institute 2002). Most of data such as rice yield, yield components, and weeds were analyzed by employing least significant difference (LSD) at a probability level of 5% for the comparison of means.

Results and Discussions

Weeds occurrences The total weed infestation during rice growth at 35 and 90 days after transplanting (DAT) was significantly higher in wider planting density of 30×30 cm (10.8 g m^{-2} for 35 DAT, and 18.4 g m^{-2} for 90 DAT) ($p<0.05$), then followed by 20×20 cm (8.5 g m^{-2} for 35 DAT, and 9.1 g m^{-2} for 90 DAT), and 10×10 cm (3.3 g m^{-2} for 35 DAT, and 4.3 g m^{-2} for 90 DAT), respectively (Table 2 and 3). At 35 DAT, the mean of weed dry mass was dominated by broadleaves (7.1 g m^{-2} for Sobibyeo, and 7.9 g m^{-2} for Dongjinbyeo) ($p<0.05$), followed by grasses (0.6 g m^{-2} for Sobibyeo, and 1.5 g m^{-2} for Dongjinbyeo), and Sedges (0.4 g m^{-2} for Sobibyeo), respectively (Table 1).

In dry season, broadleaf weeds dominated weed population considerably in SRI and provided severe competition for rice. Ahmed (1982) stated that the process of puddling results in fewer weed species, fewer weeds and a higher proportion of broadleaf weeds in the weed flora than under dry land conditions. It was contrary to Haden et al. (2000) reported that differences in dry weight observed sedges accumulating

Table 1. The chemical properties of soil before experiment.

pH	OM	Avail. P_2O_5	K	Ca	Mg	NH_4-N
(1:5)	g kg^{-1}	mg kg^{-1}	--------------	Exch. cation (cmol$_c$ kg^{-1})	--------------	mg kg^{-1}
5.1	30	191	0.25	7.3	2.1	48

Table 2. Weeds dry weight by leaf type at 35 days after transplanting for Sobibyeo, and Dongjinbyeo with different spaces.

Treatment combination		Weed dry weight (g m^{-2})			
		Grasses	Broadleaves	Sedges	Total
Clutivars	Sobibyeo	0.6	7.1	0.4	8.1
	Dongjinbyeo	1.5	7.9	0.0	9.4
	LSD ($p<0.05$)	NS	NS	NS	NS
Planting density	10×10 cm	0.8	3.3	0.0	4.0
	20×20 cm	0.2	8.5	0.7	9.3
	30×30 cm	2.2	10.8	0.0	13.0
	LSD ($p<0.05$)	NS	2.25	NS	3.16

Table 3. Weeds dry weight by leaf type at 95 days after transplanting for Sobibyeo and Dongjinbyeo with different spaces.

Treatment combination		Weed dry weight (g m^{-2})			
		Grasses	Broadleaves	Sedges	Total
Clutivars	Sobibyeo	0.0	13.0	0.0	12.3
	Dongjinbyeo	0.0	8.5	0.1	11.3
	LSD ($p<0.05$)	NS	NS	NS	NS
Planting density	10×10 cm	0.0	4.3	0.1	4.4
	20×20 cm	0.0	9.1	0.0	9.1
	30×30 cm	0.0	18.4	0.0	22.0
	LSD ($p<0.05$)	NS	6.70	NS	6.71

greater biomass than either broadleaved weeds or grasses in Indonesia. At 90 DAT, the weeds dry weights by leaf type in all planting density were similar aspect compared with 35 DAT (Table 3). During the cropping period, there is a particular duration, the critical period of competition, the presence of weeds above a certain density, critical threshold level, will cause a significant reduction in yield (Mercado, 1979).

Early growth, plant disease and insect pest There was no significant of plant height difference between 10×10 cm and 20×20 cm planting density in both Sobibyeo and Dongjinbyeo. However, closer planting density of 10×10 cm and 20×20 cm were higher than wider planting density of 30×30 cm (Fig. 1) (p<0.05). It might be due to under higher plant density, more competition among the plants induced quick growth, and also early flowering (Rao and Raju, 1987). Similarly, Yang et al. (2000) reported that under wider planting density of 25×25 cm, lesser competition for moisture, and nutrients resulted in slower growth, and more CHO assimilation per plant. It was opposite to Shrirame et al. (2000) who reported that the number of functional leaves, leaf area and total number of tillers hill^{-1} were higher in wider planting density which increased the photosynthetic rate leading to taller plant.

Among yield components, number of tillers was very important because the final yield obtained mainly the number of tillers per unit area. The data presented in Fig. 2 indicated that there was significant effect of planting density on number of tillers per plant in both Sobibyeo, and Dongjinbyeo. At 20 DAT, 30×30 cm planting density was lower tillers but it was greatly increase at 30 until 60 DAT then followed by 20×20 cm

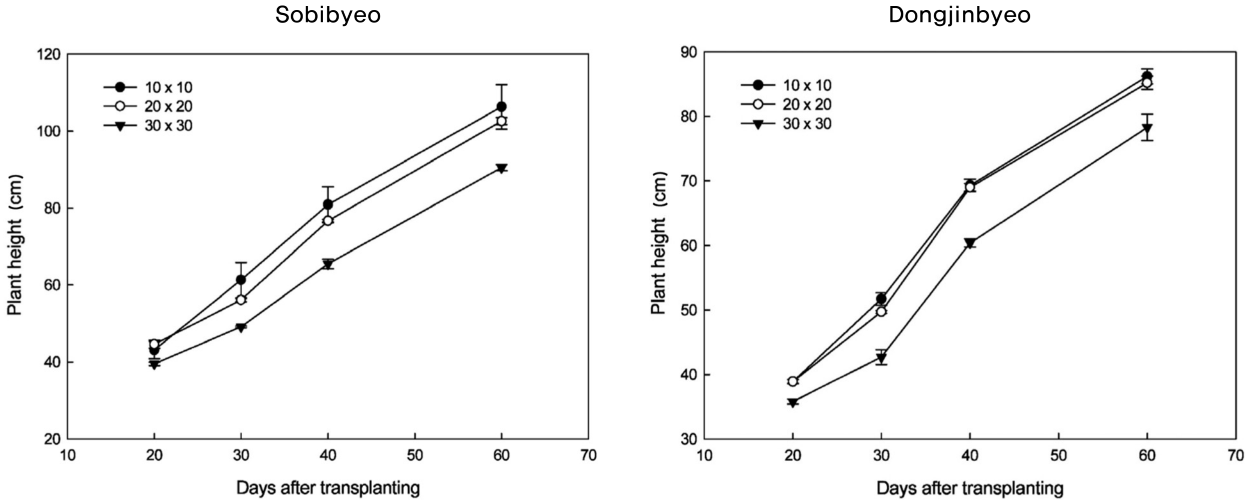

Fig. 1. Changes in plant height as affected by different spaces. Vertical bar indicates mean SE.

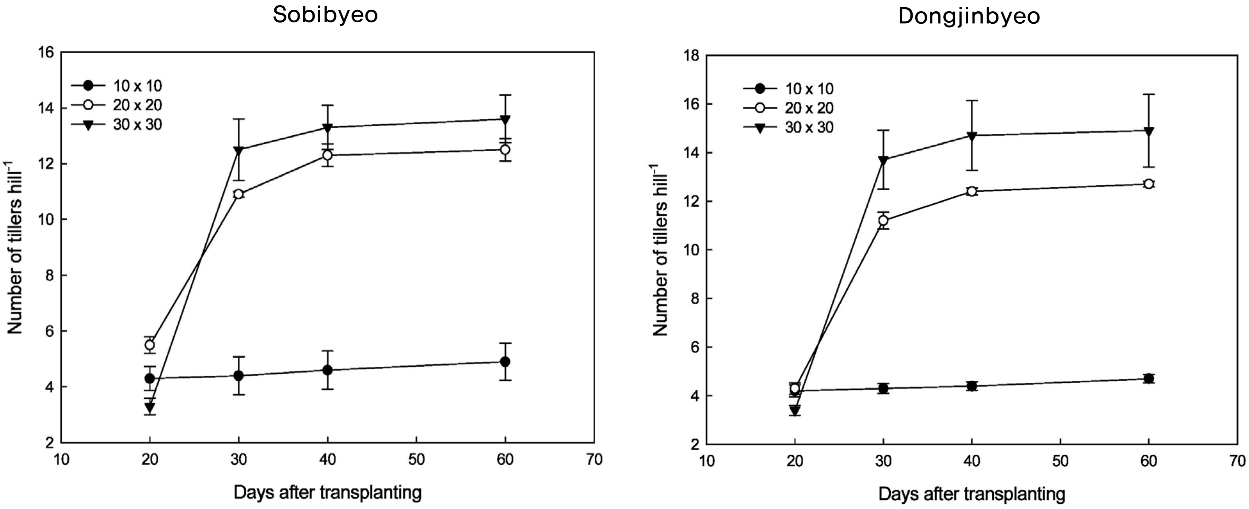

Fig. 2. Changes in tillers per plant as affected by different spaces. Vertical bar indicates mean SE.

and 10×10 cm planting density (p<0.05). Uphoff et al. (2001) reported that increased tiller density under limited irrigation might be due to maintenance of a thin film of water that will open the soil for both oxygen and nitrogen, and promote the root growth during initial stages. Among the three planting densities, SPAD value representing chlorophyll contain was significantly greater in wider planting density of 20×20 cm both Sobibyeo and Dongjinbyeo followed by 30×30 cm (p<0.05) compared with closer planting density of 10×10 cm (Fig. 3). This might be due to the reason that the younger seedlings under wider planting density recorded better root growth which facilitated increased cell division, and cell enlargement due to increased photosynthetic rate subsequently increasing leaf area index (Shrirame et al., 2000). In addition, water saving irrigation with mechanical weeding favorably influenced the soil aeration which facilitated more number of tillers and subsequently higher photosynthetic rate

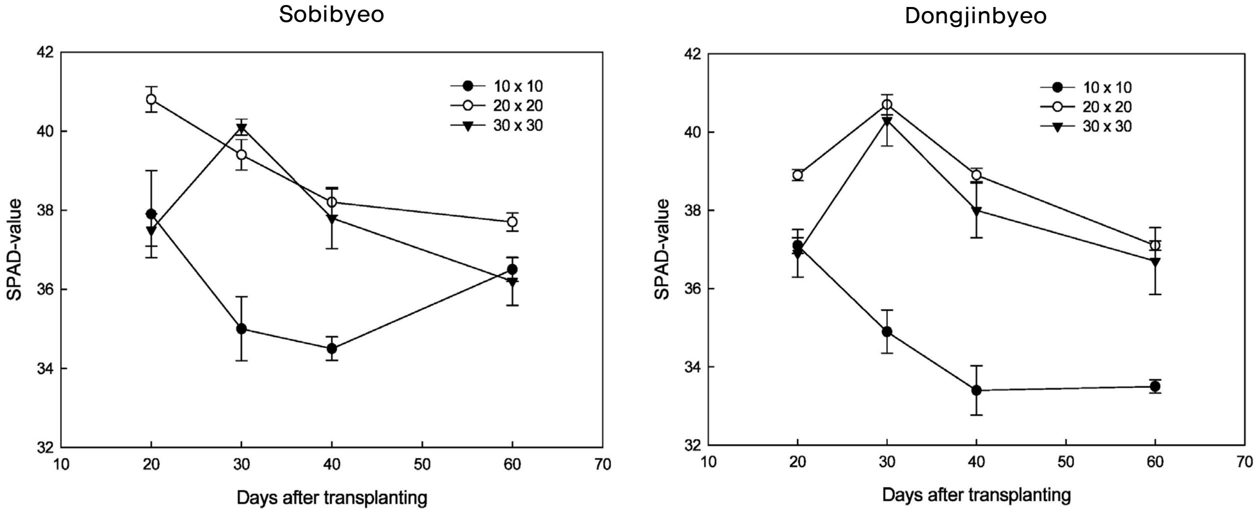

Fig. 3. Changes in SPAD value as affected by different spaces. Vertical bar indicates mean SE.

Table 4. Plant disease, and insect pest as affected by different spaces.

Treatment combination		Tremor ratio of Sheath blight	Moth	Leafhopper
		%, Spot plant height^{-1}	No. 20 plant^{-1}	No. 20 plant^{-1}
Clutivars	Sobibyeo	23.5	31.3	24.4
	Dongjinbyeo	25.1	26.0	26.2
	LSD (p<0.05)	NS	NS	NS
Planting density	10×10 cm	32.6	34.7	29.0
	20×20 cm	22.2	28.7	26.7
	30×30 cm	18.1	22.7	20.3
	LSD (p<0.05)	2.96	7.08	3.90

Table 5. The grain yield, and yield components of rice for Sobibyeo, and Dongjinbyeo with different spaces.

Treatment combination		Culm length	Panicle	Spikelets	1,000 grain weight	Ripened ratio	Grain yield
		cm	No. m^{-2}	No. panicle^{-1}	g	%	Mg ha^{-1}
Clutivars	Sobibyeo	82.3	365	125	28.3	85.7	5.11
	Dongjinbyeo	76.8	351	135	22.5	83.8	5.50
	LSD (p<0.05)	5.29	NS	NS	2.22	NS	NS
Planting density	10×10 cm	81.3	600	122	25.2	81.5	6.12
	20×20 cm	83.0	342	139	25.2	82.1	6.10
	30×30 cm	74.3	132	129	25.9	90.6	3.69
	LSD (p<0.05)	5.75	54.9	NS	NS	NS	0.584

for increased leaf area index (Thiyagarajan et al., 2002).

The tremor ratio of sheath blight, number of moth and leafhopper per 20 plants were presented in Table 4. Those of 30×30 cm planting density treatment was a significantly decreased than 20×20 cm and 10×10 cm planting density ($p<0.05$).

Grain yield and yield components Grain yield was significantly affected by different planting density (Table 5). The lowest grain yield was observed at wider planting density of 30×30 cm due to lower number of panicles per unit area ($p<0.05$). The highest grain yield was recorded in 10×10 cm and 20×20 cm planting density (6.12 Mg ha^{-1} and 6.10 Mg ha^{-1}, respectively) compared with 30×30 cm only (3.69 Mg ha^{-1}) ($p<0.05$). Also, grain yield of 5.50 Mg ha^{-1} for Dongjinbyeo was higher than 5.11 Mg ha^{-1} for Sobibyeo. There was no significant different between Sobibyeo and Dongjinbyeo in number of panicle per unit area, number of spikelets per panicle, ripened grain ratio, and harvest index. However, Sobibyeo resulted higher in 1,000-grain weight but lower in grain yield compared with Dongjinbyeo.

Conclusion

The results from this study demonstrated that systems of rice intensification with mulch-based no-till systems increased productivity by reduction of labor, seeds, water and need for agrochemicals. The maximum grain yield in the present study of SRI under no-till showed that Dongjinbyeo produced the higher grain yield (5.50 Mg ha^{-1}) compared with Sobibyeo only (5.11 Mg ha^{-1}). The planting density of 10×10 cm and 20×20 cm produced the highest grain yield (6.12 Mg ha^{-1} and 6.10 Mg ha^{-1}, respectively) compared with 30×30 cm (3.69 Mg ha^{-1}). It contrast to many SRI evaluations elsewhere which wider planting density recorded more grain yield than narrow planting density due to more space and nutrients available for the individual plant. Our findings suggest that optimum planting density for SRI in no-tillage paddy was 20×20 cm and it will expecting more 10% rice grain compared with conventional farming in Korea. This is due to under closer planting density were higher plant population per unit area. On the other hand, wider planting density was more servers of weed infestation. Our experiment was only conducted under no-tillage one growing season, and we need to be further validated in comparison with conventional tillage in different seasons and locations.

Considering the productivity and environmental and economic benefits of SRI, the constraints of rice yield increase in conventional tillage systems and the expected scarcity for irrigation water due to global warming, the systems of rice intensification are to be improved with Chinese milk vetch residue-mulched no-till paddy, and valued in introducing the systems to small-scale rice farmers in Korea as a sustainable farming system.

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