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연구보문

Effects of Rice-Winter Cover Crops Cropping Systems on the Rice Yield and Quality in No-tillage Paddy Field

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ABSTRACT: The purpose of this study was to find out optimum conditions for no-tillage rice-winter cover crops cropping system. A field research was conducted to evaluate productivity and quality of rice cultivars (Dongjinbyeo and Junambybyeo) in rice-winter cover cropping systems at Doo-ryangmyeon, Sacheon, Gyeongsangnam-do, Korea from January 2005 to October 2006. The experimental soil was Juggog series (fine silty, mesic family of Fluvaquentic Eutrudepts). The rice cultivars were experimented under some different high residue farming systems, i.e. no-tillage no treatment (NTNT), no-tillage amended with rice straw (NTRS), no-tillage amended with rye (NTR), no-tillage amended with Chinese milkvetch (NTCMV), tillage no treatment (TNT), and conventional cropping system (Control). The miss-planted rate was 8.8% in 2005 and range of 10.8% to 13.3% in 2006 at NTR, and the other treatments were carried out at miss-planted rate ranging from 1.2% to 5.0%. Tiller numbers of Junambyeo, and Dongjinbyeo in both of years were the highest in Control, and decreased nearly in NTCMV, NTR, NTRS, NTNT, and TNT in that order. The lowest grain yield was observed in TNT both cultivars due to the lower tiller numbers per area, and spikelet numbers per panicle. Also, no-tillage treatments were lower grain yield than control. On the other hand, 1,000-grain weight was lowest in control due to higher tiller numbers per area, and spikelet numbers per panicle. Ripened grain ratio was a similar aspect in all treatments. The palatability score of milled rice was lowest in control while protein content of milled rice was highest in control. The NTCMV was considered an effective sustainable farming practice for rice yield and quality.

Key Words: No-tillage, Cover crop, Paddy field, Rice yield, Rice quality

INTRODUCTION

In comparison with conventional farming, organic farming has potential benefits in promoting soil structure formation[1)], enhancing soil biodiversity[2)], alleviating environmental stress[3)], and improving food quality and safety[4)]. Because nutrient supply and pest control largely depend on organic inputs and biological processes in organic systems[5)], organic farming avoids the inputs of synthetic chemicals. It is known that tillage methods and placement of crop residues can affect physicochemical properties of soils and microbial populations and their activity in soils. Most early investigations dealt with some form of reduced tillage, such as stubble mulch, sub-tilling, or chisel plowing. No-tillage is a relatively recent practice, and its effects on changes of soil microbe have been investigated extensively. The rate of residue decomposition is slowed by a high C:N ratio (i.e. the relationship between total C concentration and total N concentration) of the residue. Mature small grain cover crops such as rye have a higher C:N ratio (~50) than legumes crops such as hairy vetch (C:N ratio > 12), and is decomposed more slowly. Mixtures of legumes and small grains are intermediate in rate of decomposition (C:N ratio > 25). Chinese milk vetch (*Astragalus sinicus* L.) is a popular green forage grown as an off-season crop in paddy field to improve rice productivity in

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China, Japan, and Korea for a long time[6]. In Japan the acreage of Chinese milk vetch was 303,766 ha in 1933, and 240,000 ha in 1960, and it has been used as green manure. After chemical fertilizer had been applied extensively, however, the acreage rapidly decreased to 4,379 ha in 1986. The rapid economic growth, and the modernization of agriculture, especially the transition in the technology of rice culture with spread of chemical fertilizer along with mechanization, caused quick decline in the culture and use of Chinese milk vetch[6]. Recently, its importance has been reassured for promoting, and maintaining soil productivity, and considered as very efficient for establishment of low-input sustainable crop production systems[6]. In these days, however, the acreage of the crop is continuously increasing. Farmers grow the vetch as green manure, rural scene, forage and honey plant. Crop residues mulched on the soil surface reduces evaporation, thereby conserving soil water[7]. Jones et al.[8] reported that mulching improved water infiltration, resulting in conservation of rainfall. The effect of vetch on rice culture varied in stage, amount, method of application, and the time of submerging after incorporation with soil[6,9]. Chinese milk vetch releases much amount of organic acids which sometimes degenerate the root growth, and absorption of nutrient, causing retardant rice growth in early rice growth stages, especially, in anaerobic condition and low temperatures conditions. Sometimes it is more serious in aerobic condition and high temperature. Straw is a reservoir of inorganic and organic plant nutrients, when recycled the soil. Crop stubbles, and roots supply 16-26 kg N ha^{-1} to the soil[10]. Successive application of rice straw increased the NH_4^+-N, available P, K^+ and Fe^{2+}contents in the submerged soil[11]. However, it should be noted that straw mulching can reduce the nitrogen supply at the beginning process due to immobilization and occasionally no increase or decrease in the supply of other nutrients[12]. The objectives of this study was to find out optimum conditions for rice productivity and quality in no-till rice-winter cover crops cropping systems.

MATERIALS AND METHODS

General description of the experimental site

A field research was treated in Sacheon, Gyeongsangnam-do, Korea from January 2005 to October 2006. The soil employed was Juggog series (fine silty mixed, mesic family of Fluvaquentic Eutrudepts). The weather data during the growing seasons are presented in Figure 1.

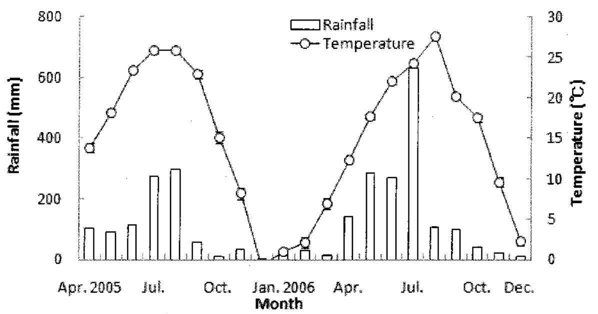

Fig. 1. Total monthly rainfall and mean temperature near the experimental site from April 2005 to December 2006.

Treatments and plot design and yield analysis

Paddy field experiments were conducted from 2005 to 2006. Main plots consisted of two rice cultivars such as Dongjinbyeo, and Junambyeo. The treatment combinations were NTRS (no-tillage amended with rice straw), NTR (no-tillage amended with rye), NTCMV (no-tillage amended with Chinese milk vetch), NTNT (no-tillage no treatment), TNT (tillage no treatment), and Control (conventional treatment). All of the treatments were replicated 3 times. Grain yield and growth of rice were determined using RDA methods[13].

Chemical properties of soil and cover crops

Soil samples were collected from the topsoil (0-15 cm depth), and chemical properties of the soil were determined by methods of soil analysis[14]. Soil samples were air dried, and sieved (<2 mm) before analysis. The chemical properties of the soil were analyzed as follows: pH (1:5 water extraction), SOM (Wakley and Black method), available P_2O_5 content (Lancaster method, UV spectrophotometer), contents of exchangeable K, Ca and Mg (1 M NH_4-acetate pH 7.0, AA, Perkin-Elmer anaylst 300, USA), and available SiO_2 content (1 M Na-acetate pH 4.0, UV spectrophotometer). The chemical properties of soil used in this experiment were shown Table 1.

The cover crops were oven-dried at 70℃ for 72 hr. and then digested using H_2SO_4 for total nitrogen and a ternary solution (HNO_3:H_2SO_4:$HClO_4$=10:1:4 with volume ratio) for the determination of P, K, Ca, Mg, and Si in rice after H_2SO_4-$HClO_4$ digestion. The nutrients of cover crops used in this experiment were shown Table 2.

RESULTS AND DISCUSSIONS

The compounds listed in Table 3, and 4 are grain yield and yield components of rice as affected by different residue management in 2005 and 2006. The miss-planted rate was 8.8% in 2005, and range of 10.8% to 13.3% in 2006 at NTR and the other treatments were carried out at miss-planted rate ranging from 1.2% to 5.0%. In 2005, SPAD values of Junambyeo were the highest in Control, and decreased in the order of NTRS, NTCMV, NTR, NTNT, and TNT but those of Dongjinbyeo were the highest in NTCMV and followed by Control, NTR, NTNT, NTRS, and TNT. In 2006, SPAD values of Junambyeo, and Dongjinbyeo were the highest in Control. Tiller numbers of Junambyeo, and Dongjinbyeo in both of years were the highest in Control, and decreased nearly in NTCMV, NTR, NTRS, NTNT, and TNT. Grain yield was significantly affected by soil tillage, and applied organic matters. The lowest grain yield was observed in TNT for both cultivars due to the lower tiller numbers per area and spikelet numbers per panicle. Also, no-tillage treatments were lower in grain yield than Control because the native soil nitrogen of the NT system has a lower mineralization rate as compared to conventional tillage system[15].

On the other hand, 1,000-grain weight was lowest in control due to higher tiller numbers per area and spikelet numbers per panicle. Ripened grain ratio was a similar aspect in all treatments. The highest grain yield was observed in Control in both of cultivars due to the higher ripened grain ratio, and tiller number.

Table 1. The chemical properties of soil used in this experiment

Plant cover*	pH	EC	SOM	Av. P_2O_5	K	Ca	Mg	Na	NH_4-N	Av. SiO_2
	1:5	dS m^{-1}	g kg^{-1}	mg kg^{-1}	---------- cmol$_c$ kg^{-1} ----------				------ mg kg^{-1} ------	
NTRS	5.7	0.20	14.4	25	0.16	5.3	2.0	0.09	5.1	164
NTR	5.6	0.16	14.3	25	0.13	4.9	1.8	0.09	1.5	176
NTCMV	5.7	0.16	14.8	25	0.15	5.4	2.0	0.09	3.5	168
NTNT	5.6	0.17	14.4	25	0.12	5.1	1.9	0.09	1.5	129
TNT	5.7	0.19	14.4	24	0.17	5.3	2.0	0.13	1.0	113
Control	6.3	0.16	22.2	24	0.29	7.1	2.1	0.12	21.3	250

* NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment, TNT ; tillage no treatment, Control ; conventional cropping systezm.

Table 2. The nutrient amount of plant cover used in this experiment

Year	Plant cover*	Dry weight	T-N	T-C	SiO_2	P_2O_5	K_2O	CaO	MgO	C:N ratio
		------------------------ kg $10a^{-1}$ ------------------------								
2005	NTRS	612	4.3	538	52.3	1.2	1.8	1.2	1.6	125
	NTR	515	5.3	491	6.0	2.3	7.8	0.7	0.4	93
	NTCMV	681	13.9	631	4.1	4.2	21.0	5.9	2.8	45
	NTNT	254	2.4	238	6.4	1.7	5.2	0.5	0.4	99
2006	NTRS	291	1.5	116	23.2	0.4	0.6	1.6	0.2	77
	NTR	379	1.8	165	4.6	1.2	7.3	0.9	0.3	92
	NTCMV	733	12.3	309	4.3	5.4	24.1	6.7	2.7	25
	NTNT	153	1.1	65	3.8	0.6	2.8	0.4	0.3	59

* NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment.

Table 3. Grain yield and yield components of rice as affected by different residue and tillage management in 2005

Cultivars	Treatment*	Miss-planted rate	SPAD values	Tiller number No. m^{-1}	No. of spikelets No. $panicle^{-1}$	Ripened grain %	1,000-grain weight g	Grain yield kg $10a^{-1}$
Junambyeo	NTRS	3.7b**	36.5a	249ab	87.8ab	97.7a	24.6a	440b
	NTR	8.8a	35.0ab	264ab	82.2ab	91.7bc	25.1a	341c
	NTCMV	3.5b	35.3ab	273ab	83.4ab	94.9ab	24.7a	394bc
	NTNT	3.7b	33.7ab	249ab	87.4ab	89.4c	24.8a	351c
	TNT	2.4c	27.0b	226b	63.3b	92.8bc	24.3a	222d
	Control	1.6d	37.2a	286a	94.2a	95.2ab	22.4b	537a
Dongjinbyeo	NTRS	3.8b	31.1	258b	67.7bc	97.2	26.4a	375b
	NTR	8.8a	31.4	272b	75.5ab	97.4	26.7a	332b
	NTCMV	2.5d	41.9	255b	71.0abc	98.4	26.0a	372b
	NTNT	3.6b	31.2	242b	51.6cd	97.1	26.4a	309b
	TNT	3.1c	24.8	209c	48.9d	96.8	24.8ab	144c
	Control	1.5e	36.4	306a	90.3a	95.0	23.1b	506a

* NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment, TNT ; tillage no treatment, Control ; conventional cropping system.
** Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.

Table 4. Grain yield and yield components of rice as affected by different residue and tillage management in 2006

Cultivars	Treatment*	Miss-planted rate	SPAD values	Tiller number No. m^{-1}	No. of spikelets No. $panicle^{-1}$	Ripened grain %	1,000-grain weight g	Grain yield kg $10a^{-1}$
Junambyeo	NTRS	4.2b**	31.5	158c	85.1ab	88.8	21.6b	215c
	NTR	10.8a	33.1	150cd	80.0ab	90.4	21.2bc	165e
	NTCMV	4.2b	32.8	202b	95.2a	89.7	23.4a	336b
	NTNT	4.2b	32.7	142cd	80.5ab	87.9	22.6ab	205d
	TNT	4.1b	31.9	124d	58.7b	78.6	19.9cd	122f
	Control	1.3c	35.2	250a	70.1ab	90.3	19.5d	424a
Dongjinbyeo	NTRS	4.2b	30.4	176c	60.4cd	81.5	22.6ab	216c
	NTR	13.3a	30.6	124e	63.9bc	91.0	23.4ab	204cd
	NTCMV	5.0b	33.2	204b	71.1b	92.3	24.0a	329b
	NTNT	5.0b	30.0	156d	54.1d	88.7	22.7ab	199d
	TNT	5.0b	27.0	78f	38.1e	91.5	22.2b	118e
	Control	1.2c	34.1	276a	86.3a	89.2	22.1b	418a

*** NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment, TNT ; tillage no treatment, Control ; conventional cropping system.**
**** Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.**

The quality and palatability score of milled rice as affected by different residue management in 2005 and 2006 were compared in Table 5 and Table 6, respectively. The palatability score of milled rice was lowest in control in 2005 and 2006. This result is likelyas to affect by high protein, and amylose content in milled rice of Control. Head rice rate of Junambyeo,and Dongjinbyeo in 2005 was the lowest in Control. The damaged rice rate of Control 1.9%, which was higher compared to that of the other treatment. The moisture of rice and milled rice quality (except damaged rice rate) of NT treatment were similar to the tillage systems. Thus, the eating taste and quality of milled rice from organic farming systems can be possibly improved by no-tillage rice-winter cover crops cropping systems. Furthermore,

Table 5. Milled rice quality and palatability score as affected by different residue management in 2005

Cultivars	Treatment*	Palatability score	Protein	Moisture	Amylose	Milled rice quality (%)				
			-------------- % --------------			Good	Chalky	Damaged	Crack	Brokens
Junambyeo	NTRS	86.7a**	5.0b	14.0	18.6b	89.9	2.1	0.7	3.8	3.4
	NTR	87.8a	5.6a	14.3	18.6b	89.4	1.8	1.0	4.7	3.1
	NTCMV	88.4a	5.3ab	14.3	18.6b	91.6	1.3	0.7	3.6	2.8
	NTNT	86.2a	5.0b	14.2	18.7ab	86.0	2.9	1.5	5.6	4.0
	TNT	84.3a	4.9b	13.9	18.6b	81.8	6.5	0.7	5.5	5.4
	Control	74.2b	5.8a	14.0	18.9a	77.5	8.2	0.9	7.3	6.2
Dongjinbyeo	NTRS	83.2ab	5.2a	13.8	18.5	87.5	1.5b	0.3b	6.9	3.8
	NTR	85.5a	5.5ab	14.3	18.6	84.6	1.8b	0.5b	8.5	4.5
	NTCMV	80.4ab	5.2ab	14.2	18.7	85.7	2.9b	0.8b	5.3	5.3
	NTNT	84.6a	5.1ab	14.2	18.7	91.5	0.8b	0.8b	3.6	3.2
	TNT	81.2ab	4.8b	14.2	18.5	86.9	3.4b	0.3b	4.5	5.0
	Control	71.0c	5.9a	13.9	18.6	80.9	8.8a	1.9a	3.5	4.9

*** NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment, TNT ; tillage no treatment, Control ; conventional cropping system.**
**** Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.**

Table 6. Milled rice quality and palatability score as affected by different residue management in 2006

Cultivars	Treatment*	Palatability score	Protein	Moisture	Amylose	Milled rice quality (%)				
			------------- % -------------			Good	Chalky	Damaged	Crack	Brokens
Junambyeo	NTRS	88.9a**	5.1ab	14.1	18.6	83.2	2.7	1.0	9.7	3.5
	NTR	86.6ab	5.4ab	14.2	18.7	81.1	3.2	0.9	11.3	3.5
	NTCMV	88.1ab	5.2ab	14.4	18.7	83.7	4.7	0.8	10.9	5.0
	NTNT	89.2a	5.0ab	14.3	18.7	83.7	2.3	1.0	10.0	2.9
	TNT	87.0ab	4.9b	13.7	18.6	84.6	2.5	0.7	8.4	3.8
	Control	84.4b	5.7a	14.2	18.9	87.4	2.5	0.3	6.7	3.1
Dongjinbyeo	NTRS	85.5b	5.6a	13.8	18.5b	76.3	3.6	0.9	12.9	6.4
	NTR	84.1bc	5.2ab	14.2	18.7b	73.7	3.0	0.7	15.0	7.6
	NTCMV	90.3a	5.3ab	14.1	18.7b	77.8	3.3	1.1	12.3	5.6
	NTNT	85.5b	5.2ab	14.3	18.8b	76.0	2.6	0.9	13.5	7.1
	TNT	84.6bc	4.7b	14.5	18.5b	86.2	0.7	0.3	9.5	3.3
	Control	83.3c	5.9a	12.9	19.1a	85.2	4.1	0.1	7.2	3.4

*** NTRS ; no-tillage amended with rice straw, NTR ; no-tillage amended with rye, NTCMV ; no-tillage amended with Chinese milk vetch, NTNT ; no-tillage no treatment, TNT ; tillage no treatment, Control ; conventional cropping system.**
**** Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.**

research is needed to improve transplanting machine method in no-tillage paddy field.

CONCLUSIONS

The lowest grain yield was observed in TNT both cultivars due to the lower tiller numbers per area, and spikelet numbers per panicle. Also, no-tillage treatments were lower grain yield than control. On the other hand, 1,000-grain weight was lowest in control due to higher tillernumbers per area,and spikelet numbers per panicle. Ripened grain ratio was a similar aspect in all treatments. The palatability score of milled rice was lowest in control while protein content of milled rice was highest in control. In a no-tillage rice-winter cover crops cropping system, the most important point is that how to maintain the cropping system longer without significant yield loss, and how to conserve soil environment as long as possible without any detrimental influence to the ecological system.

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