Characteristics of Rice and Paddy Soil under No-Till Direct-Sown Rice-Wheat Cropping System

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ABSTRACT

No-till direct-sown rice-wheat relaying cropping system has major advantages such as labor and cost saving by eliminating tillage and preparation of seed bed and transplanting. In this system, rice sowing was done simultaneously wheat harvesting. A paddy field experiment was conducted to evaluate effects of no-till years on soil microbial changes and soil physico-chemical characteristics with rice growth and development.

Chemical fertilizers and agricultural chemicals was not applied in no-till system.

As the year in no-till direct-sown system the air permeability was increased and after water submerging soluble nitrogen was released Aerobic microbial-N was highest in May and then decreased after water irrigation. The population of aerobic soil microorganisms were steeply decreased after water submerging Soil microorganisms was decreased with the increased the soil depth.

A month was needed for the seedling establishment in a no-tillage rice-wheat cropping system. Increased cropping years improved leaf greenness and leaf area index(LAI). But stomatal conductance(Gc) was higher in conventional cultivation system than no-till system. Stomatal conductance at panicle initiation stage was increased higher in conventional condition of leaves but the difference between conventional and no-till system was increased at heading stage.

In no-till 4 years condition rice grain yield was spikelet numbers per panicle.

Ⅰ. INTRODUCTION

Korean climate is in general unfavorable for the production of winter cereals. Nevertheless, the Korean level of productivity(barley 4.2 t and wheat 3.1 t/ha in farm average) is one of the highest among Asian countries. Barley and wheat have been the most important cereals for self-sufficiency of food as well as feed in Korea. However, a drastic decrease in domestic demands for the locally produced grains due to changed dietary pattern, relative higher production cost and inferior quality compared with the foreign products(Shingh, 1991).

The productivity in experimental fields repeatedly reaches 6 to 6.5 t/ha in wheat, while the local maximum by elite farmers record 8.4 t/ha in wheat. These reports indicate a possibility of substantial increase in productivity through improved cultivars and cropping techniques(Ha et al, 1993).

For the increasing of grain yield of rice and wheat heavy application of nitrogen fertilizer contaminated surface and ground water with nitrate ions while phosphorous fertilizer contaminated surface and ground water with nitrate ions while phosphorous fertilizer was blamed for algae pollution. Frequently spray of pesticide and herbicide reduced significantly the biotic population in paddy ecosystems including insects and soil microorganisms(Lee, 1998). For the overcoming this problem, a new crop production system were developed in the world on the basis of low-input sustainable agriculture. Cover crop is essential for the no-till direct seeding rice cropping system and improving of germination ratio and established seedlings by the adaptable moisture condition by the straw mulching(Choe, 1998).

The main constraint for direct seeded rice under lowland condition is a poor seedling establishment. This is primarily due to the lack of tolerance to low O_2 stress. Another stress might be due to the anaerobic decomposition of products in the flooded soil. This situation may be improved if the residues of the previous crop or green manure incorporated in the soil is fully decomposed. High levels of crop residue can adversely affect wheat(*Triticul aestivum* L.) yield, thereby slowing adoption of conservation tillage practices that effectively control soil erosion(Paul et al, 1997).

The apparent diffusion coefficient of NH_4^+-N transferred by diffusion per unit area per unit time is proportional to the diffusion coefficient and the concentration gradient (Reddy, 1982). The apparent diffusion coefficient of NH_4^+-N is 0.216 cm^2/ day as compared with 1.33 cm^2/day for NO_3^- which suggesting NO_3^- can move about 6 times faster than NH^4_+ (Reddy, et al., 1976 ; Reddy, 1982). The transport of NH^4_+-N by ionic diffusion from the anaerobic layer to aerobic layer of the flooded soil is facilitated by high amounts of reduced Fe and Mn, lower CEC and high moisture content of the flooded soil(Reddy et al., 1976). The general movement of NH^4+-N is downward > lateral upward(Savant and DeDatta, 1980, 1982).

The objectives in this research was to observe the effect of continued cropping to the soil physical factors in rice-wheat cropping system, to observe the effect of continued cropping to the soil chemical factors in rice-wheat cropping system, to clarify the population of soil microbial changes by the seasonal changes in rice-wheat cropping system, and to evaluate the possibility of the rice growth and development under no-till rice-wheat cropping without fertilizer and agronomic chemicals.

Ⅱ. MATERIALS AND METHODS

1. Physicochemical properties of the soil

Soil samples were collected from no-till paddy field of Dansung loamy soil. This is a mid-drained soil with a slope of 7-15°. Bulk density taken in autumn, was 1.23 $g \cdot cm^{-3}$ at 0-20 cm depth.

2. Seed treatments and managements

Rice, cv. Singumobyeo, was over-sown at directly into the paddy field wheat cropping (cv. GAERUMIL) and then covered with chopped wheat straw at the same time wheat harvesting(Kim, 1992) without soil disturbance. Fertilizers or chemicals were not applicated throughout the cropping year. Soil characteristic are shown in table 1.

Four weeks after sowing, the field was irrigated, about 5cm for 5 days and then the field was drained. At panicle initiation stage for 3 days. Underground water was the field was irrigation used for irrigation.

Plant samples were collected at panicle initiation stage, full-heading stage, and harvesting time. Above-ground rice plant were harvested and partitioned into culm, leaf sheath, and panicle at full-heading stage and harvest stage.

KM-type permeability test-A and test-W were used for assuring for air(AF 170) and water permeability test(AF 173).

Soil oxidation-reduction potential was measured by using the portable ORP meter(RM-12p) with solution of soil surface.

Ammonium ion content was determined on the basis of extractable N in the soil extracts and it was measured by spectrophotometer with indophenol method.

Leaf greenness was determined by using the chlorophyll meter, Minolta SPAD-502, with fully grown uppermost leaf.

Leaf area index was measured by using the plant canopy analyzer, LI-COR LAI-2000.

Plant samples were collected at panicle initiation and heading stages of plant growth and were dried, weighed and analyzed for total nitrogen.

Dry weight was determined after oven-drying for 2 days at 70°C for constant weight. Tissue N content was measured by macro Kjeldahl method

Ⅲ. RESULTS AND DISCUSSION

Organic matter per cent was higher in longer no-tilled paddy than short no-tillage paddy. Organic matter is more accumulated in surface area than lower layer in no-till paddy field(Table 1).

Table 1. Chemical properties of the soils used for no-till direct-sown sustainable rice-wheat cropping system.

No-tillage, years	pH (1	EC : 5)	Av.P_2O_5 (mg/kg)	Ca	K (cmol$^+$/kg)	Mg	OM(%)
0	5.7	0.18	68	3.6	1.41	0.76	1.7
2	5.0	0.14	86	3.5	0.50	0.59	1.9
4	5.2	0.23	47	5.6	0.51	1.23	2.0
7	5.5	0.16	44	4.4	0.33	0.91	2.3

Soil bulk density was not affected by the tillage years. The bulk density of soil surface was increased no-till paddy.

Air permeability was influenced by no-till years and soil layers. Air permeability was increased by the increased no-till years, especially at soil surface when the surface was covered by straw of rice and wheat. Air permeability was not changed in the deep soil layer(Fig. 1).

Water penetration was a little affected by the cropping year increased but that was not significantly different between 4 and 7 years. This result indicated that no-till management is better for the root growth air permeability and water penetration increased but fourth year was critical point for the increasing air permeability and water penetration(Fig. 2.3).

Fumigated soil released much ammonium ion than non-fumigated soil, and ammonium ion was not affected by cropping years(Fig. 4.5).

1. Available Nitrogen

The measured values of soil solution as influenced by no-till years and submerged duration(Fig. 4). The levels of available nitrogen in the soil were enhanced at 20 days to 40 days after irrigation(Fig. 4).

2. Microbial Nitrogen

As shown in Fig. 5. microbial nitrogen in the soil was higher in no-till paddy than conventional cultivation paddy system.

The amount of microbial-N was highest in May and then decreased after water irrigation. The amount of microbial N was decreased as the depth of soil layer(10-20cm) increased. This results revealed that the population densities of microorganisms were higher in the soil surface, where more organic matter was accumulated.

3. Plant growth and grain yield

Seedling establishment was related to air penetration speed. Established seedlings were observed after 4 weeks from sowing. Germination was uneven and heading date was irrigated. This may be one of major hinderance of no-till direct-sown rice-wheat cropping systems.(Fig. 7).

Leaf greenness(SPAD-values) was maintained maximum as increased cropping years in no-till paddy system. SPAD-V was similar between conventional and 7 year no-till rice plant until the heading stage(Fig. 8).

Leaf area index(LAI) was the highest in 4-year no-till condition. A negative relationship was found between SPAD-value and leaf area index.

Stomatal conductance(Gc) was higher in conventional cultivation system than no-till system. At the panicle initiation stage, stomatal conductance was higher in conventional condition(Fig. 9). The main reason of the difference of stomatal conductance among the treatment was related to the difference of plant density. Dry weight of per plant was lower in no-till direct sown condition than conventional one but total amount of dry weight was influenced by tillage systems.

The highest grain yield was obtained in 4-year no-till paddy(Table 2). This was due to spikelet numbers per panicle which was significantly increased in 4-year no-till condition. In this study it was found that no tillage caused to be biologically active soil than conventional tillage. Microbial biomass N, available N, and net N mineralization rates at 0 to 10 cm tended to be higher in no tillage than conventional tillage. The available N pool as a proportion of the total N pool was higher in no tillage than conventional tillage system.

Table 2. Yield components and grain yield of rice grown under no-till sustainable rice-wheat cropping system.

Cropping years	No. of panicles/m^2	No. of spikelets/ panicle	Ripened grain (%)	1,000-grain weight (g)	Grain yield (kg/10a)
Conventional	350	69.2	90	24.0	640
No-till, 2years	338	62.8	92	25.1	600
No-till, 4years	376	69.5	93	25.3	688
No-till, 7years	400	56.6	92	26.5	618
LSD(5%)	28.8	5.78	NS	1.02	35.2

There was a trend of higher gross N transformation rates in no tillage than conventional tillage. In unfertilized soil, the ratio of gross N immobilization rates to N mineralization rates were higher in no tillage than conventional tillage. Seasonal variability was an important factor influencing magnitude of N pool and transformation rates. These results suggested that after 7 years, the overall quality of soil no-till soils was better than that of conventional tillage soils in relation to the characteristics of soil microbial biomass, available N pool, and N transformation rates.

The amount of decreased soil N was greater in conventional system and 4-year no-tillage which was corresponded with N content at before cropping. The amount of reduced N between after cropping and before cropping was the highest in soil surface(0-5cm) in all no-till plots but in conventional system was most high in 5-10cm soil depth. The amount of soil N after cropping was highest in soil surface(0-5cm) in all no-till plots but in conventional system highest at 15-20cm soil depth. These results hinted that soil surface N was enough for the rice in no-till systems because after cropping both reduced N and residue N were higher in no-tilled plot. The amount of organic N in the soil surface was enough for the rice in no-till cropping system. In this no-till direct-sown rice-vetch system, lodging was prevented because the number of panicles per plant was reduced, the diameter of root was thick and root distributed into deep soil.

The initial growth of rice plant was delayed in no-fertilized system which resulting low tiller numbers. Panicle numbers per area was recovered by increasing sowing density. Short plant height also reduced N uptake per plant but total N uptake per area was not significantly different from conventional system. This indicates that the branched roots contributed to the N uptake by the high plant density.

Table 3. Soil nitrogen per cent and difference of residual soil N between before crop (BC) and after crop(AC) as affected by no-tillage years and soil depth in no-till rice-wheat cropping system.

	Soil depth (cm)	Bulk density	BC —N (%)—	AC	BC N (kg/10a)	AC	N(kg/10a) difference (AC-BC)
Conventional system	0-5	1.14	0.14 a	0.11 a	80.4 b	64.1 c	16.2 b
	5-10	1.24	0.13 b	0.10 d	78.5 c	59.4 d	19.1 a
	10-15	1.42	0.12 c	0.10 c	85.9 a	71.0 b	14.9 c
	15-20	1.45	0.12 d	0.11 b	84.6 a	78.0 a	6.6 d
	Mean	**1.31**	**0.13**	**0.10**	**82.3**	**68.1**	**14.2**
No-till, 2 years	0-5	1.29	0.11 a	0.09 a	70.1 a	54.7 a	15.4 a
	5-10	1.53	0.07 b	0.05 c	49.4 b	41.3 b	8.1 b
	10-15	1.50	0.07 b	0.06 b	50.3 b	42.8 b	7.5 bc
	15-20	1.49	0.07 b	0.06 b	48.8 b	42.1 b	6.7 c
	Mean	**1.45**	**0.08**	**0.063**	**54.6**	**45.2**	**9.4**
No-till, 4 years	0-5	1.30	0.15 a	0.12 a	94.5 a	77.4 a	17.0 a
	5-10	1.43	0.12 b	0.10 b	83.8 b	69.5 b	14.4 b
	10-15	1.48	0.11 c	0.09 c	79.9 c	65.1 c	14.8 b
	15-20	1.52	0.10 c	0.08 d	73.2 d	62.3 d	10.9 c
	Mean	**1.43**	**0.12**	**0.10**	**82.9**	**68.6**	**14.3**
No-till, 7 years	0-5	1.35	0.11 a	0.09 a	77.0 a	62.4 a	14.6 a
	5-10	1.45	0.07 c	0.07 b	59.3 c	51.7 c	7.6 c
	10-15	1.46	0.08 b	0.07 b	59.9 c	52.6 bc	7.3 c
	15-20	1.52	0.08 b	0.07 b	63.9 b	5 3.6b	10.3 b
	Mean	**1.44**	**0.09**	**0.08**	**62.1**	**55.1**	**7.1**
DMRT(5%) (Yield)		-	0.021	0.019	2.18	2.15	2.25
Yield x Soil depth		-	0.038	0.028	4.38	5.42	3.29

For each parameters, means by the same letter within a column are not significantly different at 0.05 probability level by according to Duncan's multiple range test.

Absorbed plant N content(kg/10a) was greater in 4-and 7-year no-till rice plant than conventionally and rice plant grown in 2-year no-till system. Absorbed shoot N was lower in conventionally fertilized plot by the cool temperature at initial growth stage. The sowing method is closely related to uptake of soil N. High plant density contributed to the increasing of indigenous soil N supplying. Repeated drying and submerging also contributed to the releasing of the soil microbial N to the rice plant(Harada, 1968).

Nitrogen of leaf blade was greater in 7-year no-till rice plant In this case organic soil N was released after heading stage. Panicle N was similar inclination to the grain yield which indicated that absorbed plant N is essential for the increasing of spikelet numbers in this system. Nitrogen harvest index(NHI) was most higher in 4 years no-tilled rice plant. Absorbed N was most effectively contributed to the conventional cultivation system but gain yield was not supported AUE_N by the low panicle numbers which indicated that very lower numbers of effective tillers were acquired in conventional system than no-tillage cultivation system(Table 4).

Table 4. Nitrogen parameters in no-till sustainable rice-vetch relaying cropping system.

	Fertilized N (kg/10a)	N uptake (kg/10a)					NHI (Panicle N/ Shoot N)	AUEN (kg grain/ plant N)
		Leaf blade	Culm+ leaf sheath	Panicle	Root	Shoot		
No-till, 2Years	0	1.5 c	2.6 b	4.7 b	0.65 b	8.8 c	0.53 bc	68.2 a
No-till, 4Years	0	1.8 b	2.9 a	6.5 a	0.64 b	10.7 a	0.56 a	64.3 b
No-till, 7Years	0	2.3 a	2.6 b	6.2 a	0.77 a	10.7 a	0.54 b	58.0 c
Conven-tional	11	2.3 b	3.0 c	4.8 b	0.58 c	10.2 ab	0.47 d	62.8 b

Natural nitrogen supplies per annual were ; 0.5kg/10a (rainfall) + 1.5kg/10a (irrigation). For each parameter, means followed by the different letter (within a column) are significantly different at the 0.05 probability level according to LSD.

Seedling establishment of last year dropped rice seed is serious problem in no-till direct -sow cultivation system but rice-wheat system was recovered this problem by a little delayed wheat harvesting which cut the established rice plant of last year dropped seed at combine harvesting. But if the same cultivar was sown.

Results of this research demonstrated that no-till direct-sown rice-wheat cropping system is the best profitable double cropping system for the compensate of the amount of deficient food production at the same time it make possible the environmentally healthy and labor saved cultivation system. This system is essential for the acclimation course and duration for the stable and high rice and wheat production. Soil drying effect is the most important skill for the N absorption of the soil microorganisms(Harada, 1968) and direct sowing on drying paddy covered by the pre/cover crop. Straw mulching can protect seeds from the bird invasion and supply the adaptable moisture content for seed germination. Additionally broadcasting is essential for the improvement of indigenous nutrient uptake from the soil and prevent weeds population.

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