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Effect of Chinese Milk Vetch (*Astragalus sinicus* L.) Cultivation during Winter on Rice Yield and Soil Properties

Young Son Cho* and Zhin Ryong Choe*

ABSTRACT

An experiment was carried out using pots to investigate the effects of Chinese milk vetch on the seedling establishment and growth in rice. Four irrigations with five-day intervals and three different levels of vetch straw were investigated. Significantly higher panicle numbers were obtained in vetch-treated pots. Vetch levels were non-treatment as checks, vetch with top removed, root plus shoot 7.5 ton/ha, and root plus shoot 3.0 ton/ha. The time for complete degradation of vetch straws was reduced from 10 days to 5 days as submerged time was delayed, and was affected by the amount of mulched vetch straws. As the mulched vetch amount increased, the time for a complete degradation was extended from 4 days to 12 days.

Grain yield and its components were significantly affected by irrigation time and mulched vetch amount. Effectively controlled, lowered reduction damage from the degrading vetch straw, irrigation date and vetch amount were the most important factors for the improving of seedling establishment in direct-sown rice.

Key words : Chinese milk vetch, cover crop, oxidation-reduction potential, rice, submerging time.

In sustainable crop production systems, legumes are important for the following crops due to the fixation of symbiotic N_2. Legume crops are essential for improving soil conditions and maintaining or improving crop yield. Legumes reduced disease and pest damages in rice-vetch cropping systems (Hidaka et al, 1996.). Chinese milk vetch (*Astragalus sinicus* L.) is an earlier maturing legume species than hairy vetch (*Vicia villosa* L.) and narrow leaf vetch (*Vicia angustifolia* L.). Early maturation of vetch is essential for the establishment of a new cropping system such as a no-till direct-sown rice-vetch cropping system. Chinese milk vetch has been used as a green forage crop in the paddy field and as a manure crop (Yasue and Tsutiya, 1982; Yasue, 1991) for the improvement of paddy soil in China, Japan and Korea (Wu & Arima, 1992).

Vetch provides not only fertilizer elements for crops but also organic matter for promoting and maintaining soil productivity in paddy fields. Simulation models predicting the interrelated effects of those factors provide a means for evaluating N mineralization (De Willigen & Neeteson, 1985).

The objective of this paper was to evaluate the comparative oxidation-reduction potential of vetch straws after being submerged and their subsequent effect on the growth of rice.

MATERIALS AND METHODS

Maintenance of the Chinese milk vetch population

In this pot experiment, a direct-sown rice-vetch (*Astragalus sinicus* L.) cropping system was maintained without tillage for 2 years. The vetch germinated in early September when the paddy field was drained in the ripening stage of rice. Vetch seedlings over-wintered. In spring, the over-wintered vetch plants grew steadily until mid April and then grew very rapidly until the flowering stage in late April. Dry weight was calculated from sampled plants and nitrogen (N) content (%) of vetch plants were analyzed by the macro-Kjeldahl method.

A rice cultivar, Dongjinbyeo (100 seeds/pot), was over -sown on the soil surface in 1/2,000a plastic pots on May 30, 1996. There were four water submerging dates, May 15, 20, 25, and 30, which are expressed as 15, 10, 5, and 0 days before sowing, respectively. Four levels of vetch straw treatments including no vetch(check), vetch with top removed (root), 50% vetch (root plus vetch, 1.5 ton/ha), and 100% vetch (root plus vetch, 3.0 ton/ha) were arranged in factorial design with three replications. Vetch straw was evenly mulched on the soil surface.

Vetch-mulched pots were not treated with chemical fertilizers. In order to compare unfertilized and fertilized plants, no-vetch pots were fertilized with N twice at the following levels, 0~0, 0~10, 0~20, 0~40, 0~50, 20~10, 20~40, 40~0, 40~20, and 40~40 kg/ha base, e., basal at three weeks after sowing and top-dressing at the panicle initiation stage. P and K were fertilized at 80 kg/ha and 70 kg/ha as basal at three weeks after sowing, respectively.

Soil used for the experiment was clay loam. The undisturbed no-till rice-vetch relay-cropped paddy soil core was placed into pots and maintained for two years for this experiment.

Chemical compositions of soil and vetch straw

The chemical composition of Chinese milk vetch straw and soil were : Nitrogen, 2.12%; C/N ratio, 15; P, 0.15%;

* Dept. of Agronomy, Gyeongsang Natl. Univ., Chinju 660-701, Korea.
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K, 1.47 and S, 0.38%. Soil was characterized with pH 5.1, EC 0.51, Av. P_2O_5 115 (mg/kg), Ca 6.4 ($cmol^+/kg$), K 0.48 ($cmol^+/kg$) and OM 24 (g/kg).

Characters observed in this study were seedling establishment(%) of rice three weeks after sowing; oxidation-reduction potential (Eh: mv) of flooded soil measured with ORP meter (ORP-RM12P) after being submerged; grain yield and yield components of rice; plant height at each growth stage; and leaf greenness measured with chlorophyll meter (SPAD-502).

Fresh Chinese milk vetch was dried at 70℃ for 2 days to measure the dry weight. Urea was used as fertilizer. Collection of soil solution and measurement of NH_4^+ −N concentration were made every two weeks according to Toriyama's method (Toriyama, 1988). Plant height and tiller numbers were also recorded every two weeks.

RESULTS AND DISCUSSION

Changes in oxidation-reduction potential (Eh) of soil solution

As shown in Fig. 1. oxidation-reduction potential (Eh, mv) was steeply decreased after water submerging and

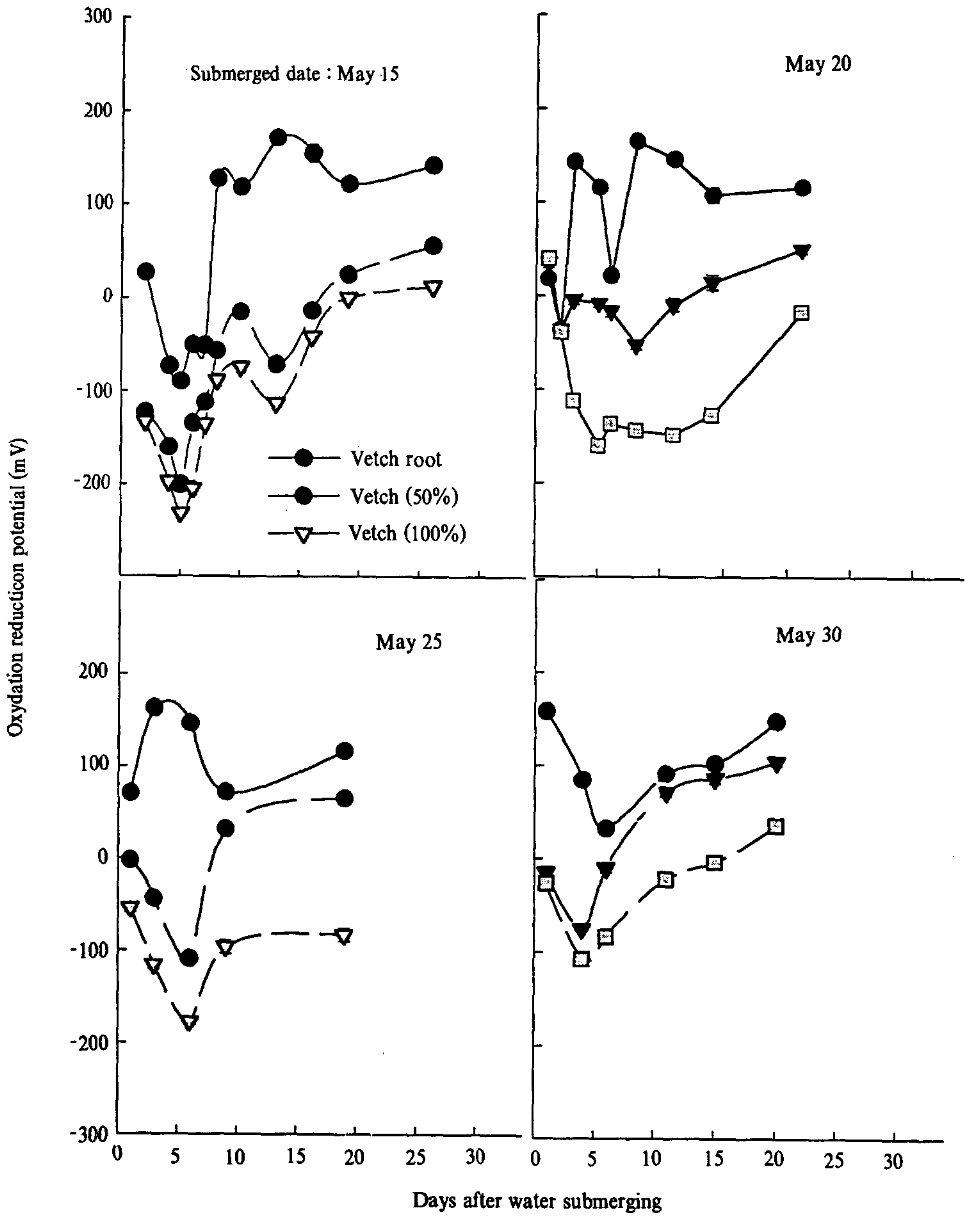

Fig. 1. Changes in oxidation-reduction potentials (mV) as affected by water submerging date and crop residue treatment.

increased slowly with the advance of the submerging period. The Eh in the high vetch level was highly reduced as compared to the half and no-vetch treatments. Low Eh value was observed before sowing in the early submerging treatment. The Eh was slowly increased one week after sowing and maintained for 15 days after water submerging. Eh was the lowest in the early submerged with high vetch level but it increased at sowing time. Eh was also low in the later submerged and small amounts of vetch treatment around sowing time. Such results indicate that the lower Eh originated from green forage with high vetch level, but Eh will increase according to the progress of vetch maturation (Fig. 1).

The rate of rice seedling establishment was highest in the early submerged condition resulting in high Eh at sowing time. Water submerging time and vetch straw quantity should be considered as important factors for the seedling establishment of rice.

The rate of seedling establishment decreased with the increased amount of vetch straw and delayed submerging time (Tables 1 and 2). Seedling establishment was correlated with Eh. Contrary to vetch treatment, established seedling rate was improved by late submerging in the no-vetch treatment. The rate of seedling establishment was also affected by temperature. The higher the temperature the higher the seedling establishment: Additionally a slightly elevated Eh value, above −100 mv, did not damage the seedling establishment (Table. 1 and Fig. 1). Therefore in this system, seeding date should be delayed until the Eh rises above −100 mv whenever possible.

Table 1. Changes in rice seedling establishment as affected by water submerging periods and amount of vetch residues.

Water submerged date	Vetch amount: Check	Top removed	50% (Shoot)	100% (Shoot)
May 15	62 d†	83 a	77 a	67 a
May 20	68 c	80 a	63 b	58 b
May 25	75 b	79 a	55 c	51 c
May 30	81 a	82 a	51 c	48 c

† Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.

Grain yield and its components

In general, early applied nitrogen affects the grain yield with an increase in panicle numbers. The early submerging time increased the panicle numbers as compared to the delayed submerging time.

The number of panicles was positively affected by the amount of vetch as well. However, the number of spikelets was not significantly related to the vetch amount and submerging time.

The percentage of ripened grain and 1,000-grain weight were not affected by the vetch amount and submerging time, either.

Grain yield and its components, except for 1,000-grain weight, were significantly affected by the amount of vetch straw. (Table 3).

These results show that late water submerging decreases grain yield but increases the speed of vetch degradation due to the high temperatures. Increased Vetch input was more positively related to grain weight than chemical fertilizer increments in the chemical fertilized pot. Similar grain yield was obtained between high vetch levels and high fertilizer levels (Tables 2 and 3).

The interaction between the vetch amount and submerging time was significant for panicle numbers per pot, spikelet numbers per panicle, and grain yield per pot (Table 3).

At the early stage there was a wide difference in plant height between no-vetch and vetch treatments. As the days progressed, the plant height differences between the treatments were not significant. A similar trend was also

Table 2. Differences of yield and its components depending on various N fertilization.

N (kg/ha) Basal…Top	Panicle number/pot	Spikelet number/panicle	Ripened grain (%)	1,000-grain weight(g)	Grain yield (g)/pot
0… 0	6d §	39e	87.4bc	24.5a	47f
0…10	8c	50c	88.5b	24.3a	82e
0…20	8c	55b	87.4bc	24.5a	94e
0…40	8c	56b	89.4b	23.7a	118d
0…50	8c	58ab	89.1b	24.1a	126d
20…10	19a	32f	86.3c	24.1a	126d
20…40	17b	46d	93.6a	23.8a	170c
40… 0	16b	47cd	89.0b	23.2a	207b
40…20	16b	52bc	89.9b	23.9a	225a
40…40	17b	60a	87.9bc	23.6a	229a

§ 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 3. Effects of amount of vetch straws on grain yield and its components of rice.

Treatment	Panicle number /pot	Spikelet bumber /panicle	Ripened grain (%)	1,000-grain weight (g)	Grain yield (g) /pot
100%, 15DBS†	26a‡	51b	93.9a	23.6a	292a
10DBS	23b	56a	93.0a	23.7a	285a
5DBS	18c	52b	82.3b	24.1a	184c
0DBS	20c	55a	93.3a	23.8a	236b
Mean	22	53	90.6	23.8	249
50%, 15DBS	23a	54b	92.4b	23.7a	267a
10DBS	23a	54b	92.4b	23.8a	267a
5DBS	17b	63a	94.4a	23.2a	242b
0DBS	18b	51b	92.4b	23.6a	193c
Mean	20	55	92.9	23.6	242
No-top, 15DBS	20a	54a	90.3c	23.9a	226a
10DBS	18a	49b	92.1b	23.6a	192b
5DBS	16b	46b	94.4a	23.4a	165c
0DBS	17ab	52a	90.8c	24.1a	193b
Mean	18	50	91.9	23.8	194
DMRT(5%) Vetch (V)	1.1	1.8	NS	NS	13.8
VxS	1.7	2.2	NS	NS	19.7
Submerged date(S)					

† Days before seeding
‡ Means by the same letter within a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.

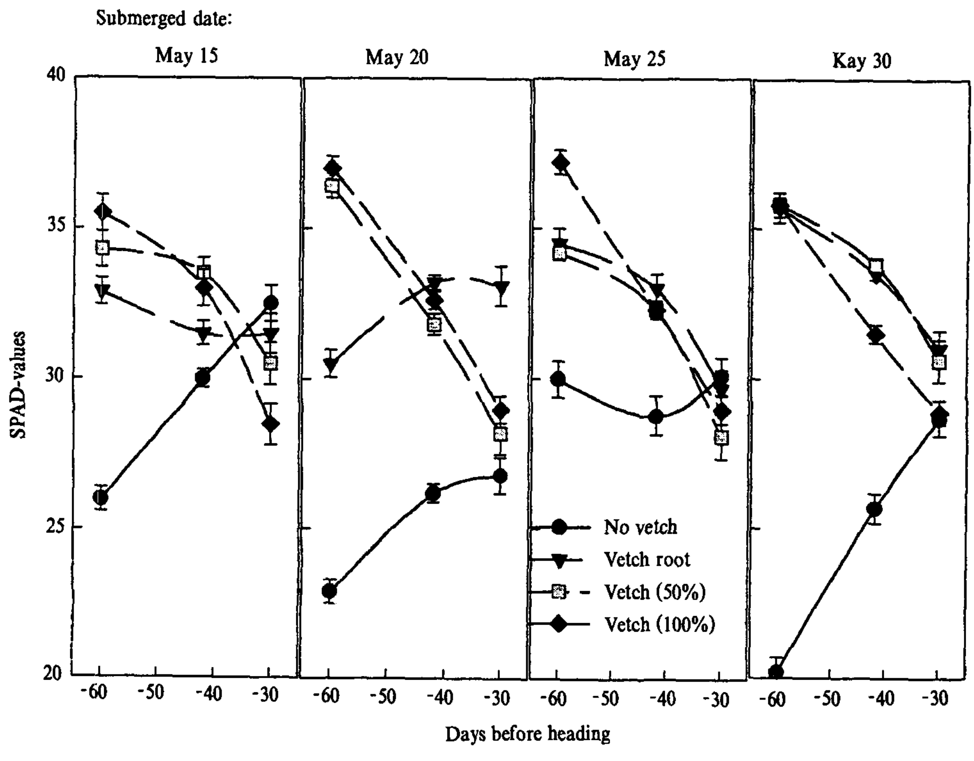

Fig. 2. Leaf greeness as affected by water submerging time and vetch straw management in pot experiment.

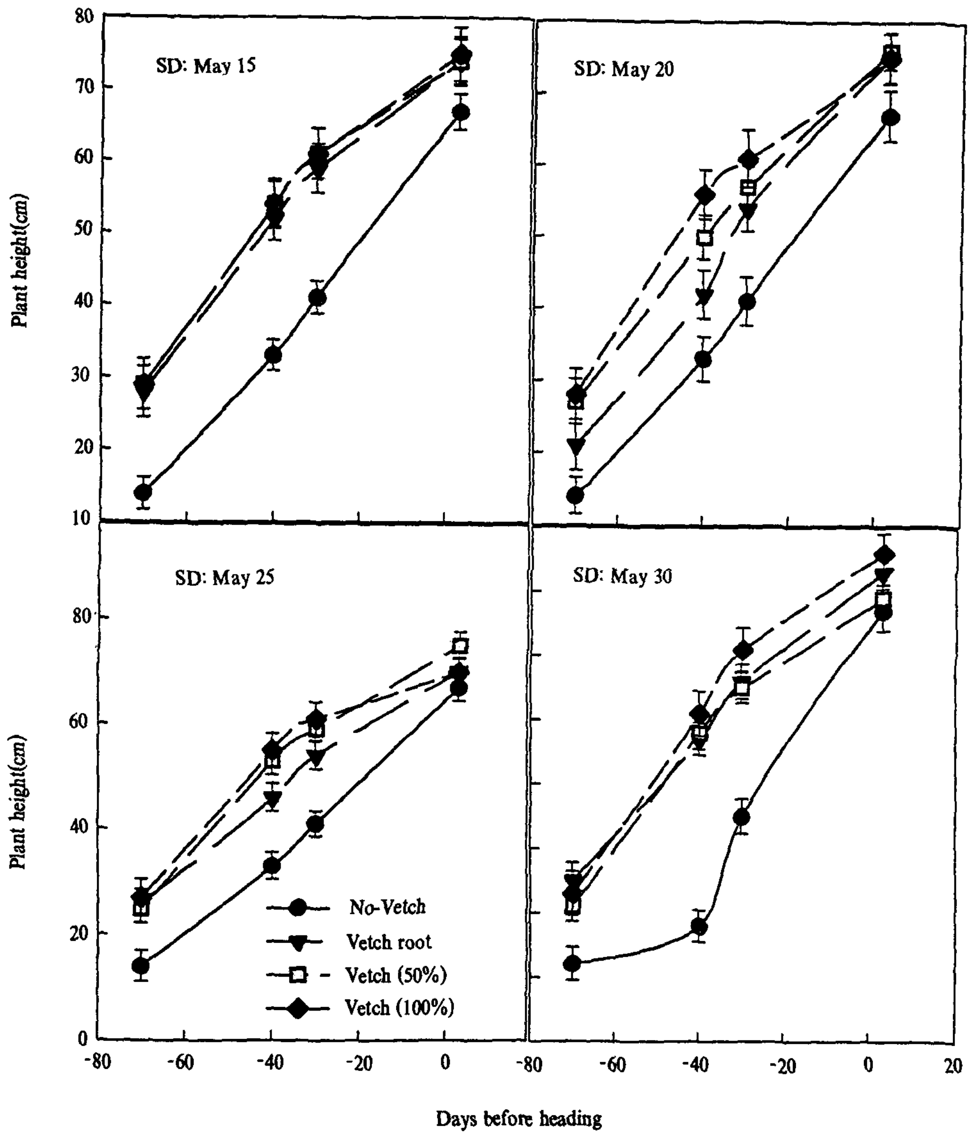

Fig. 3. Changes inf plant height as affected by submerged time (SD) and vetch straw treatments. Vertical lines represent standard errors.

observed in tiller numbers. Leaf blade greenness (SPAD -value) in vetch pots was higher than no-vetch pots until the panicle initiation stage.

Leaf greenness was closely related to vetch content in four submerging times (Fig. 2). In the no-vetch condition, leaf greenness was affected by initially delayed plant growth which slowly recovered as time passed.

Plants were taller in the high vetch treatment compared to the low vetch or no vetch treatments (Fig. 3). Plants were also taller in the early irrigated pots than in the later irrigated pots. This indicates that earlier submerging did not hampered germination of seeds and seedling establishment by the increased oxidation-reduction potential.

In conclusion, vetch forage will degrade rapidly after submerging and can provide enough nutrients for rice growth. However, high vetch treatments will decrease seed germination and seedling establishment, which might be due to significantly low redox potential.

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