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# Effects of Straw Mulching and Nitrogen Fertilization on the Growth of Direct Seeded Rice in No-tillage Rice/Vetch Cropping System

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## ABSTRACT

**No-till direct seeding cultivation of rice has major advantages such as saving of labor and cost by eliminating tillage, preparation of seed bed and transplanting procedure compared to the conventional transplanting cultivation. A field experiment was conducted to evaluate the effects of straw treatment and nitrogen levels on the rice growth in no-till direct-seeding cultivation. Rice straw, vetch straw, and the mixture of both of the straws were mulched on the surface of soil before seeding while 4 levels of nitrogen fertilizer, 0, 7, 9, and 11 kg/10a respectively, were applied at 3 split times, 3-weeks after sowing, 5-weeks after sowing and the panicle initiation stage. Mulching of vetch straw significantly reduced seedling establishment of rice which may be attributed to low oxidation-reduction potential of soil by vetch mulching treatment. Vetch straw increased the concentration of soil ammonium leading to an extension of the greenish leaf to panicle initiation stage. Agronomic nitrogen use efficiency ($AUE_N$) in heavy-mixed straw mulching plots was lower than other treatments. Grain yield and $AUE_N$ in the vetch treatment were less affected by fertilized N levels. Conclusively, it is suggested that heavy straw mulching was not efficient for rice seedling establishment and nitrogen usage.**

***Keywords*** : no-tillage, direct-seeding, nitrogen top-dressing, agronomic nitrogen use efficiency, Chinese milk vetch, mulching.

Returning of rice straw after rice cropping and/or growing of legume crop before rice cropping is known to be effective not only in maintaing the nutrient balance of cultivated paddy fields but also in improving the soil texture which, in turn, leads to increase in rice yield(Cho and Choe, 1999). In addition, legume crop harbours various natural enemies of insects and pests that the cultivation of legume crop in rice paddy fields could reduce crop damages from insect and disease (Hidaka et al, 1996). Chinese milk vetch (*Astragalus sinicus* L.), being widely grown in Korea, China and Japan for a long time, is a populargreen forage grown as an off-season crop in paddy field (Yasue, 1991). It provides not only nitrogen source to soil but also valuable organic matter for promoting and maintaining soil productivity in paddy field.

The early maturity of Chinese milk vetch (*Astragalus sinicus* L.) compared to the hairy vetch (*Visia villosa* L.) and narrowleaf vetch (*Vicia angustifolia* L.) is essential for the no-till rice-vetch cropping systems.

Partial factor productivity of applied N ($PFP_N$) has been considered as a parameter to measure nitrogen use efficiency (NUE). This is the ratio of grain yield to the applied N rate and an index for diagnosing constraints to improved NUE (Cassman et al., 1997). It reflects the agronomic efficiency (AE: yield increase due to N applied) and the balance between the initial N supply and N demand by rice plants and must be quantified for the saving of N supplying energy and environmental pollution. Several nitrogen transformation reactions are unique in flooded soils which contribute to serious losses of applied nitrogen. This experiment was conducted to evaluate the effects of straw treatment and nitrogen rates on soil texture and, eventually, to rice growth in no-till direct-seeding cultivation in rice-vetch cropping systems.

## MATERIALS AND METHODS

A field experiment was conducted on a well-drained Sirye sandy loam soil. Bulk density of soil taken from no-tillage paddy at 0-20 cm depth in autumn was 1.20 $g \cdot cm^{-3}$. Physicochemical properties of the soil were as follows : soil pH 6.4, 3.6% of organic carbon, 0.2 % of total N, and 237 ppm of available $P_2O_5$, 17.3 $cmol^+/kg$ of Ca, 2.99 $cmol^+/kg$ of K, and 4.24 $cmol^+/kg$ of Mg.

A rice cultivar, Dongjinbyeo, was direct sown on the no-tilled submerged soil surface at row spacing of 40 cm on May 30, 1997 at the seeding rate of 7.5 kg/10a. The main plot consisted of 3 kinds of straw treatments, rice only, vetch only, and mixture of rice and vetch straw (hereafter heavy-mixed mulching) and sub plots consisted of 4 levels of nitrogen fertilizers, 0, 7, 9, and 11 kg/10a, respectively. For basal application, compound fertilizer (21-18-21, N-P-K) was used, while for late application, urea was used.

Air penetration and water permeability of the soil were measured by KM-type permeability test-A and

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test-W: AF 170 for air permeability and AF173 for water permeability. Air penetration was measured by decreased amount of air volume from the cylinder to the soil by four times in 5 cm levels at 20 cm soil depth. Water permeability was determined by observing the penetrated depth for 1 day at 20 cm soil depth.

Soil samples were air dried, ground and sieved by 2-mm size mesh. C/N ratio was simultaneously determined by using the dry combustion method with Sumigraph CHN analyzer (Sumigraph NC-90A). This was based on the same principle described by Nelson and Sommers(1982). Soil oxidation-reduction potential was measured by the portable ORP meter RM-12p using the surface solution of soil. Ammonium ion concentration was determined on extractable N in the soil extracts using spectrophotometer with Indophenol method.

Leaf greenness was determined by chlorophyll meter, Minolta SPAD-502, using the 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 and dried, weighed and analyzed for total nitrogen. Dry weight was determined after oven-drying for 2 days at 70℃. Tissue N content was measured by macro Kjeldahl method.

## RESULTS AND DISCUSSION

Heavy-mixed mulching reduced seedling establishment as well as oxidation-reduction potential (ORP) of soil (Fig.1 and 2) suggesting the reduction of ORP was the cause of the low seedling establishment. Although the highest concentration of soil $NH_4^+$ was observed in vetch straw mulching, heavy-mixed straw mulching reduced soil $NH_4^+$ because of the increased C/N ratio of the rice straw, indicating that the low C/N ratio increases the release of $NH_4^+$ (Fig. 3).

Leaf greenness (SPAD-value) in vetch mulching was darker than heavy-mixed straw mulching, indicating abundant vetch N was released from the vetch having a low C/N ratio (Fig. 4). Leaf area index (LAI) was lower up to the panicle initiation stage in vetch straw treatment (Fig. 5). Crop growth rate (CGR) was higher in treatments with vetch straw than the treatments without vetch straw (Fig. 6). Although the vetch straw treatment maintained high levels of the ammonium ion, the residual nitrogen was lower in the treatments. This may be ascribed to the low nitrogen absorbance by rice plants.

Soil nitrogen content was affected by straw treatments; especially high initial nitrogen content was found in heavy-mixed treatment (Table 1). An identical amount of the initial N was observed in vetch and rice straw treatment before rice cropping, but residual nitrogen was higher in rice straw treatment after rice cropping than in vetch treatment. Ammonium ions maintained high levels in vetch treatment throughout the entire growth period but nitrogen residue amounts were lower, which stemmed from the low absorbance of soil nitrogen by rice plants.

The lowest grain yield was observed in heavy mixed straw treatment which showed lower panicle numbers per area and lower ripened grain ratio. Vetch treatment decreased grain yield caused by the lower panicle numbers, in turn this was caused by less seedling establishment as discussed above. However, the vetch treatment showed a higher number of spikelets

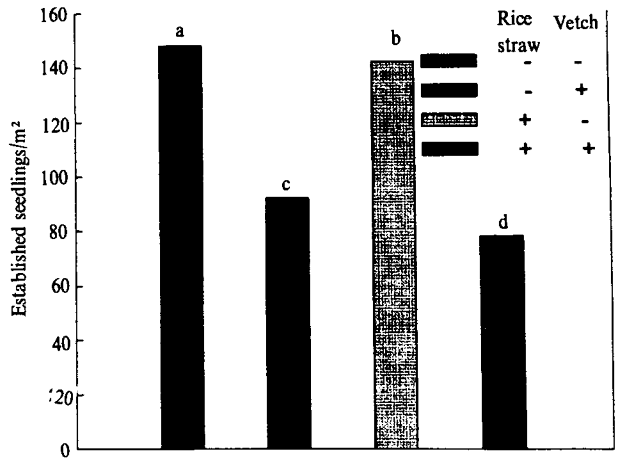


**Fig. 1. The numbers of established seedlings as affected by straw application treatments and soil depth in no-yill direct-sown rice-vetch cropping systems.**

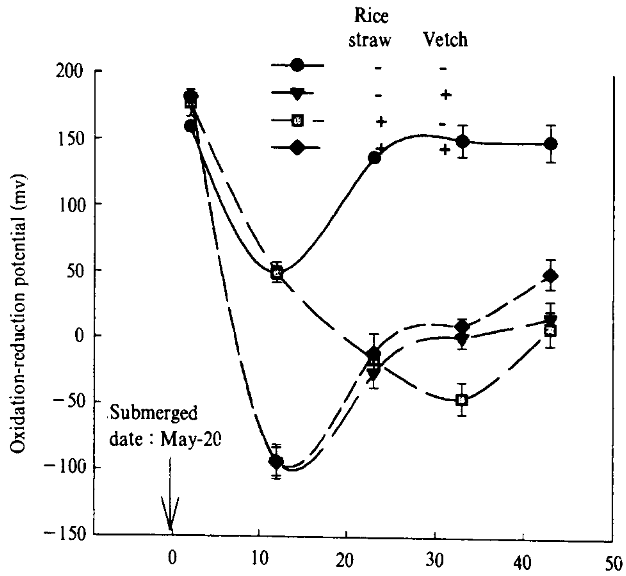


**Fig. 2. Changes of oxidation-redution potential of soil solution in paddy soil as affected by straw application treatments.**

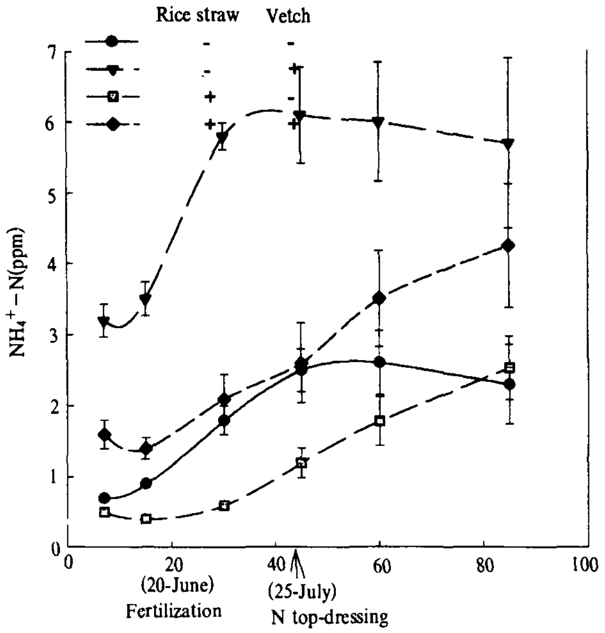


Fig. 3. Changes in soil $NH_4^+$-N content (ppm) as affected by the straw mulching and the time of rice growth. Vertyical lines represent standard errors. Fertilized N was 9kg/10a.

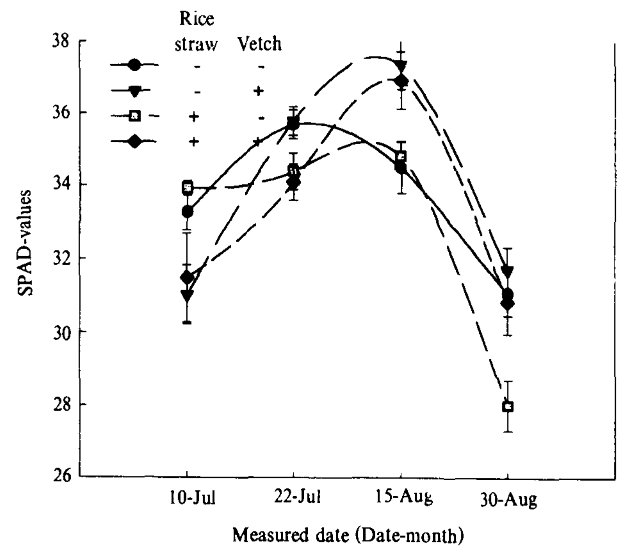


Fig. 4. Mean chlorophyll meter readings (SPAD values) of the top measuresed at fully expanded leaf stage of rice grown without fertilizer N.

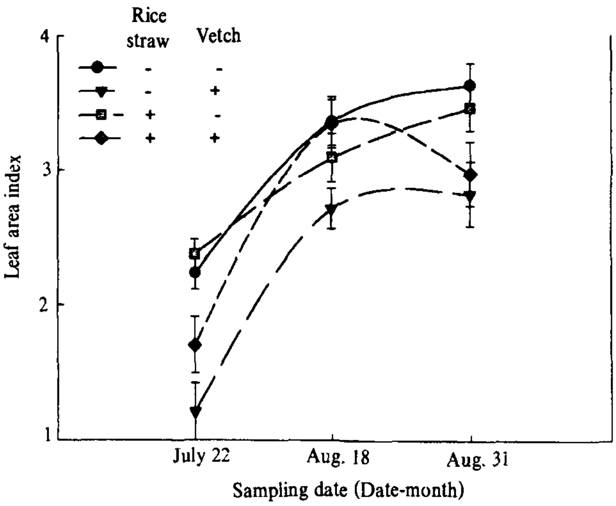


Fig. 5. Ghanges in leaf area index(LAI) of rice plant as affected by straw mulching and vetch residue management.

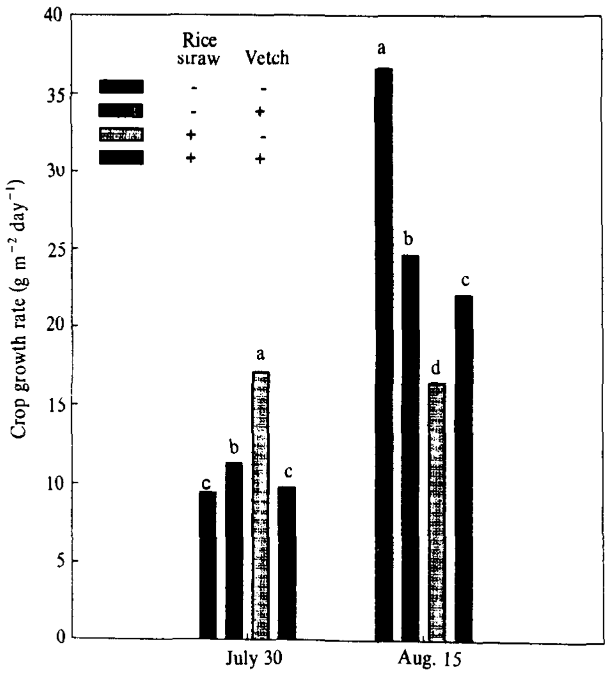


Fig. 6. difference in crop growth rate (CGR) as affected by straw managements under rice-vetch cropping system. Bars having different letter show the difference within treatment at $P<0.05$.

per panicle and heavy grains. This indicates that although straw mulching reduced the initial growth of rice plants, it promoted late growth of rice.

An increase in grain yield with increasing fertilized N levels has been reported by others but the levels of N maximized up to 15 kg/10a (Choe et al, 1998).

The harvest index (HI), expressed as the proportion of total top yield partitioned into grain, ranged from 0.42 in rice straw mulched treatment to 0.46 in heavy and mixed straw treatment. No-fertilized N and high levels of N increased HI and it varied from 0.41 to 0.47.

The values of N recovery efficiency (Nre) and

**Table 1. Nitrogen balance as affected by straw mulching and fertilized nitrogen levels under no-till direct-sown rice-vetch cropping systems.**

| Treatment | N (kg/10a) | Initial soil N Exc. | Initial soil N Organic | *Fertilized N | Plant uptake (straw+grain) | Residual soil N Exc. | Residual soil N Organic |
|---|---|---|---|---|---|---|---|
| No straw | 0 | 5.3 | 250 | 3.3 | 5.5 c | 7.5 a | 245 a |
| | 7 | | | 10.3 | 9.6 b | 7.8 a | 243 a |
| | 9 | | | 12.3 | 10.0 b | 7.8 a | 244 a |
| | 11 | | | 14.3 | 11.3 a | 7.9 a | 245 a |
| | Mean | 5.3 | 250 | 10.1 | 9.1 | 7.8 | 244 |
| Vetch | 0 | 5.4 | 260 | 3.3 | 6.1 d | 12.3 a | 260 a |
| | 7 | | | 10.3 | 7.7 c | 12.2 a | 258 a |
| | 9 | | | 12.3 | 10.2 b | 12.3 a | 257 a |
| | 11 | | | 14.3 | 11.9 a | 12.2 a | 259 a |
| | Mean | 5.4 | 260 | 10.1 | 9.0 | 12.3 | 259 |
| Rice | 0 | 5.0 | 254 | 3.3 | 5.5 c | 10.8 a | 246 a |
| | 7 | | | 10.3 | 9.3 b | 10.7 a | 248 a |
| | 9 | | | 12.3 | 10.5 a | 10.6 a | 250 a |
| | 11 | | | 14.3 | 11.0 a | 10.7 a | 247 a |
| | Mean | 5.0 | 254 | 10.1 | 9.1 | 10.7 | 248 |
| Vetch + Rice | 0 | 5.2 | 262 | 3.3 | 6.1 d | 10.9 a | 263 a |
| | 7 | | | 10.3 | 6.6 c | 10.8 a | 265 a |
| | 9 | | | 12.3 | 8.2 b | 10.5 a | 264 a |
| | 11 | | | 14.3 | 11.5 a | 10.7 a | 262 a |
| | Mean | 5.2 | 262 | 10.1 | 8.1 | 10.7 | 264 |
| LSD(5%) Vetch | | | | - | 0.64 | NS | NS |
| Vetch × Nitrogen | | | | - | 0.97 | NS | NS |

* N-input : Irrigated water (3.2ppm) + Precipitation (0.1ppm) + applied N
For each parameters, means followed by the different letter (within a column) are significantly different at the 0.05 level.

agronomic N use efficiency ($AUE_N$) were lower in heavy-mixed straw treatment than the other treatment. Partial factor productivity ($PFP_N$) was not significantly different among the treatments. The values of Nre were lower when higher levels of nitrogen was applied. Decreased Nre by increased N application in the rice straw and no-mulching treatment indicated N fertilization did not affect N uptake of rice plants. Additionally, N loss increased by increased N fertilization. The values of agronomic N use efficiency ($AUE_N$) were lowest in heavy and mixed mulching treatments, but high levels of N increased $AUE_N$. On the other hand, high levels of N fertilization did not affect the vetch treatment condition, indicating the nitrogen rate of 9kg-N/10a was appropriate for rice growth and reducing N loss. The values of partial factor productivity($PFP_N$) were decreased at high levels of fertilized nitrogen. But vetch mulching and heavy-mixed mulching treatment did not followed that trend. In the vetch treatment, 9 kg-N/10a effectively maintained $PFP_N$. All these observations indicate a greater role and effectiveness of applied fertilizer-N to rice.

Rice yields were directly related to nitrogen uptake by the crop. However, N parameters indicate 9kg-N/10a was most favorable for the rice in no-till direct-sown rice-vetch cropping systems.

Heavy straw a mixture of rice and vetch straw did not positively effect the rice growth, so rice straw can be used for other purposes. Half or slightly reduced amounts of Chinese milk vetch straw benefitted rice seedling establishment.

For the improvement of seedling establishment, oxidation-reduction potential should not be reduced more than -100 mv. Sowing time of pre-germinated seeds should be delayed until higher value redox-potential was recovered in order to escape the redox damage and toxicity from the released solutes from Chinese milk vetch. Water irrigation should be maintained until seedling establishment of rice to prevent the formation of organic matter film. Usually, the film covers the soil surface after the water is drained due to the adhesion of degraded vetch materials. To overcome the lower reduction potential, the dry sowing

**Table 2. Fertilizer-N recovery efficiency (Nre), agrnomic fertilizer-N use efficiency($AUE_N$), and partial factor productivity ($PFP_N$) and grain yield of rice grown under no-till direct sown rice-vetch cropping systems.**

| Treatments | Rice straw | Vetch | Fertilized N level | Grain yield (kg/10a$^{-1}$) | Nre (%) | *$AUE_N$ | **$PFP_N$ |
|---|---|---|---|---|---|---|---|
| No straw | | | 0 | 431 | - | - | - |
| | | | 7 | 526 | 42.4 | 31 | 78 |
| | | | 9 | 542 | 6.4 | 19 | 56 |
| | | | 11 | 560 | 2.3 | 25 | 55 |
| | | | Mean | 510 | 17.0 | 25 | 63 |
| Vetch | | | 0 | 358 | - | - | - |
| | | | 7 | 430 | 10.6 | 8 | 58 |
| | | | 9 | 538 | 13.6 | 21 | 60 |
| | | | 11 | 596 | 8.6 | 23 | 54 |
| | | | Mean | 481 | 10.9 | 17 | 57 |
| Rice | | | 0 | 437 | - | - | - |
| | | | 7 | 545 | 32.5 | 28 | 75 |
| | | | 9 | 505 | 16.5 | 24 | 60 |
| | | | 11 | 601 | 0.1 | 21 | 51 |
| | | | Mean | 522 | 16.4 | 24 | 62 |
| Vetch + Rice | | | 0 | 347 | - | - | - |
| | | | 7 | 420 | 5.3 | 10 | 60 |
| | | | 9 | 504 | 9.5 | 17 | 56 |
| | | | 11 | 626 | 4.7 | 25 | 57 |
| | | | Mean | 474 | 6.5 | 18 | 58 |
| DMRT(5%) Vetch | | | | 13.8 | 5.6 | NS | 2.7 |
| Vetch x Nitrogen | | | | 37.5 | 17.2 | 13.2 | 4.5 |

* $AUE_N$ = △ kg grain increase kg$^{-1}$ applied N,
$PFP_N$ = kg grain kg$^{-1}$ applied N.

method should be considered. But there are some problems such as birds feeding and poor seedling establishment due to sowing seeds on the vetch straw, especially in case of heavily lodged vetch. Seed should be buried in the soil using the dry sowing system but that method may consume more time and labor. Nutrient supply could be made possible by increasing seedling establishment and top-dressing N at different growth stages.

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