RESEARCH ARTICLE
J. Crop Sci. Biotech. 2008 (September) 11 (3) : 193 ~ 198

Optimum Soil Incorporation Time of Chinese Milk Vetch (*Astragalus sinicus* L) for its Natural Re-seeding and Green Manuring of Rice in Gyeongnam Province, Korea

Sang-Yeol Kim*, Seong-Hwan Oh, Woon-Ha Hwang, Kyung-Jin Choi, Byeong-Gen Oh

Rice Ecology and Breeding Division, Yeongnam Agricultural Research Institute, NICS, RDA, Milyang 627-803, Korea

<Received July 30, 2008 / Accepted September 15, 2008>

Abstract

To develop a natural re-seeding technology, the optimum soil incorporation time of Chinese milk vetch (CMV) plant residues, seed persistence in soil, biomass production and subsequent rice yield were determined from 2005 to 2007 in rice with CMV green manure in southern Korea. Generally, insufficient seedling stand was regenerated with CMV incorporation to the soil at 20 and 25 days after flowering (DAF), while high regeneration of greater than 400 seedlings per m^2 was observed at 35 and 40 DAF. High re-seeding stand of CMV incorporated at 35 DAF or later was related with high seed viability and heavy seed weight. Appreciable number of CMV seeds remained 4 month after burial in soil and a good number of CMV seedlings regenerated from this seed bank at rice harvest time in the fall. Based on the relationships among re-seeding number of CMV plants, seed weight and seed viability, CMV plants should be incorporated into the soil 35 DAF (May 30) or later when CMV seeds were sufficiently matured. The natural re-seeding stand for the 3-year trials was stable ranging from 437 to 700 plants per m^2 and the biomass production was sufficient to supply nitrogen for rice growth. The use of re-seeding CMV plant can produce similar rice yield like that of rice without CMV green manure.

Key words: Chinese milk vetch, N content,, natural re-seeding, rice yield, seed persistence, soil incorporation time

Introduction

Koreans are increasingly becoming more concerned with the degradation of agricultural environment due to excessive use of chemicals. In addition, the Korean government is implementing a policy on the reduction on the use of chemical fertilizer by 40% by the year 2013. The cultivation of green manure is one of the ways to meet this requirement.

Chinese milk vetch (CMV) is a popular winter annual green manure for sustainable production in rice field of southern Korea because of its well adaptation to the winter environment (Kim et al. 2007; Lee et al. 2006; Na et al. 2007; Shim et al. 2004). The CMV maintains or enhances rice yield and improves soil fertility (Jeong et al. 1995, 1996). The cultivation area of CMV in rice fields has rapidly increased in recent years in Korea. The CMV area was only 26,326 ha in 2003 but it increased sharply to 75,388 ha in 2006, although it decreased slightly to 66,073 ha in 2007.

At present, CMV seeds were broadcasted annually in late September before rice was harvest. The Korean farmers then incorporate the surviving CMV plants into the soil when they are still relatively young, at flowering stage or when the seeds are still immature. The early incorporation of CMV plant into the soil gives no chance for the immature seeds to regenerate naturally. The practice of sowing seeds every year increases production cost in Korea because CMV seeds are entirely imported from China and additional labor input for seed sowing is needed every year. Furthermore, the practices of annual seedings sometimes result to

* **To whom correspondence should be addressed**
Sang-Yeol Kim
E-mail: kimsy3@rda.go.kr
Tel: +82-53-350-1174 / Fax: +82-55-352-3059

unstable and non-uniform seedling establishment. Farmers sometimes broadcast CMV seeds only along with the levee and they do not get inside field to sow seed uniformly. Also, farmers often sow the seeds late long after the terminal water drainage, when soil moisture is no longer sufficient and temperature is low for CMV seed germination in the fall. All these factors contribute to poor and non-uniform seedling establishment and poor winter survival rate in the annual CMV seeding practice.

To overcome the problems as describe above, a natural CMV re-seeding technology has been developed in rice with CMV green manure. Natural re-seeding technology refers to continuous CMV-rice cultivation with only one-time CMV seed sowing without application of chemical fertilizer for rice growth. If CMV could be managed to reseed naturally each autumn, the annual costs of seed and planting could be minimized. In natural re-seeding, consistent seedling establishment is one of the most important factors for sufficient dry matter production for nutrient supply. For the natural re-seeding, at least 250 CMV seedling stands in the fall is required (Jeong 2002). Successful re-seedling of many green manures is influenced by soil incorporation time or grazing termination date (Carr et al. 2005a, b; Evers and Smith 2006; Kim et al. 2001), tillage methods (Chauhan et al. 2006; Kim et al. 2001) and seed persistence in soil (Mennan and Zandstra 2006; Rampton and Ching 1970).

There have been numerous studies on the effect of soil incorporation time on the CMV re-seeding stands and rice yield but the results were varied depending on the researchers. Kim et al. (2001) reported the two soil incorporation times of June 4 and May 25 in Gyeongnam Province. According to this study, high CMV regeneration was recorded in CMV soil incorporation time at June 4 but not at the May 25 treatment. Additional research on the soil incorporation time between May 25 and June 4 in Gyeongnam Province is needed since consistent seedling establishment of CMV is the most important factors for successful natural re-seeding at the initial stage. In addition, the detailed natural re-seeding mechanism of dormant CMV seeds buried in rice field soil has not been reported yet.

Therefore, to develop a natural re-seeding technology for CMV in rice with CMV green manure, this study was carried out to determine the optimum soil incorporation time of CMV plants, seed germination characteristics, seed persistence, dry matter production, and their influence on rice yield.

Materials and Methods

Seed Source

Imported CMV seeds produced from Hanam Province, China in 2004 and 2005 were purchased in September of 2005 and 2006 and used for the experiments.

Determination of the optimum soil incorporation time of CMV plant

This study was conducted on silty clay loam soil at the experimental field of the Yeongnam Agricultural Research, Milyang, Korea in from 2006 to 2007. Four CMV soil incorporation time from 25 (May 20) to 40 (June 4) DAF of CMV at 5-day interval were evaluated. The CMV seeds were sown in September 24-25, 2005 at the 50 kg/ha seeding rate before the final water drainage. The seedling counts recoded in May 10, 2006 ranged from 400 to 450 plant per m^2 and the plot size of each treatment was 340 m^2. The CMV plant was incorporated into soil with rotavator. After the soil incorporation of CMV plant, the 25-day old rice seedling of cv, Junamnbyeo was transplanted on June 8-10. The optimum natural re-seeding date was determined based on the re-seeding number of CMV plants after rice harvest in the fall (October 26-28). The CMV stand in five randomly placed 50 x 50 cm quadrats in each of the CMV soil incorporation treatments was counted.

Seed germination characteristics

To determine parameters, such as the relationship of seed maturity with CMV re-seeding stand in the fall, seed weight, seed viability and seed dormancy were also evaluated. Representative CMV seeds with pods were handpicked from each soil incorporation time and germination test were carried out in a germinator at a controlled temperature of 20±0.5℃ One hundred seeds were placed in 9-cm diameter petri dishes lined with a Whatman #1 paper disc moistened with 5 ml of deionized water. The percentage seed germination was recorded daily from 1 to 10 d after seed placement. Germination was considered as a positive when there is protrusion of the radicle through the seed coat. Each treatment contained four replicates and the experiment was repeated at least twice. For seed viability test, seed coat was clipped with sharp blade and germination test was conducted following the same procedure as mentioned above.

Seed persistence in the soil

When CMV plants were incorporated into soil in late May during land preparation for rice transplanting, either the seeds or seed with pods were buried at different soil depths in rice fields and remained there throughout the rice cropping season. To stimulate such condition, the persistence of CMV seed and seed with pod in soil was carried out. Nylon mesh bags (10 x 15 cm), each containing 100 seeds and pods, were buried separately in soil; one set at the soil surface (0 cm) and another at 5 cm depth on June 3, 2007 prior to rice transplanting on June 13. The bags were retrieved at monthly interval until October. After each recovery, in situ germination, hard seed and seed recovery were recorded and germination test was carried out with the recovered seed.

CMV biomass production and its influence on rice yield

For biomass production, CMV plant was harvested at May 10 using 0.25 m^2 quadrant, if the CMV biomass production was highest based on the previous experiment and the plant was dried at 70 ℃ for dry weight record. The dried plant was ground with Willy Mill and the nitrogen content of CMV plant was analyzed with 2300 Kjeltec Analyzer Unit (Foss, Sweden)

To determine the CMV plant influence on rice yield, two treatments rice-CMV cropping and rice without CMV green manure were evaluated in the naturally reseeded field in 2007. The CMV dry weight of 4,970 kg/ha was recorded at May 10. The CMV plants were incorporated into soil with rotavator on May 30. And, 25-day old Junambyeo was transplanted on June 10 and agronomic characteristics and milled rice yield were determined.

Results and Discussion

The mean monthly air temperature and precipitation recorded for the 2005-2006 and 2006-2007 seasons were shown in Fig. 1. The mean monthly temperature in October to November in 2005 was similar to the normal but its temperature in 2006 was 0.3-2.2℃ above normal. However, the mean monthly in December in 2005 was 3.5℃ below normal, while it was similar to the normal in December in 2006. In February to March 2006, the mean monthly temperature was similar to the normal but it was 0.4-2.2 ℃ above normal. Generally mean monthly temperature in 2006-2007 was higher than that in the 2005-2006.

Below normal precipitation was recorded for the months of September to April 2005-2006 and 2006-2007 except March in 2007. No precipitation was recorded in December 2005 and January 2007. The precipitation from February to March 2006 was lower than that of 2007 (42 vs. 126 mm), but it was greater in April to May 2006 than that of 2007 (234 vs. 191 mm).

Our study revealed that CMV re-seeding stand was influenced by soil incorporation time. When CMV plants were incorporated into the soil at 25 and 30 DAF, only less than 269 re-seeding stands were observed (Fig. 2). However, when CMV plants were incorporated at 35 after flowering or later, sufficient seedling of 397 to 683 plants per m^2 can be regenerated which was more than minimum natural re-seeding stand of 300-350 plant per m^2 based on winter survival rate of 80% during over-wintering period and dry matter production. However, minimum natural re-seeding stand in the fall was reported to be 250 plant per m^2 (Jeong 2002). These results suggest that for natural re-

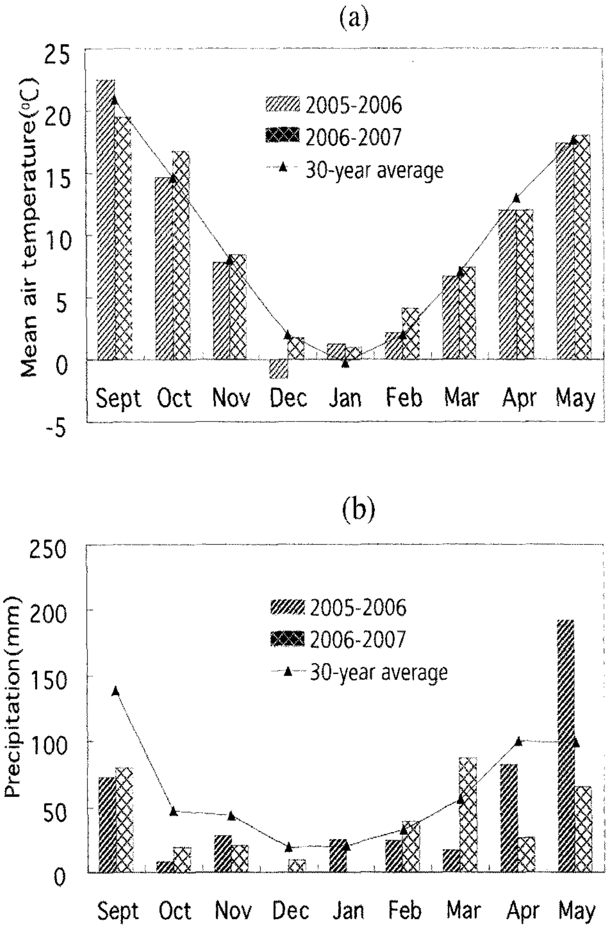

Fig. 1. Monthly mean air temperature (a) and precipitation (b) in Milyang during the growth period of Chinese milk vetch.

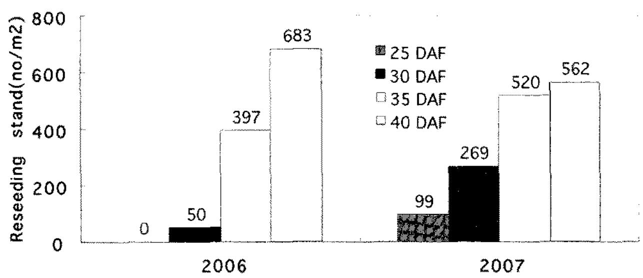

Fig. 2. Natural re-seeding stand of Chinese milk vetch plant after rice harvest as influenced by CMV incorporation time into the soil before rice transplanting in spring. CMV flowering time was April 20 (CMV 30% flowering)

Table 1. Germination and viability of Chinese milk vetch seeds as influenced by seed collection time.

Seed collection time (DAF)	Germination (%)		Hard seed (%)		Seed viability (%)		1,000 seed weight (g)	
	2006	2007	2006	2007	2006	2007	2006	2007
25	15	6	52c	81b	54c	83b	1.94c	2.25c
30	12	7	82b	92a	85b	97a	2.59b	2.74b
35	8	3	92a	95a	95a	98a	2.92a	3.06a
40	7	4	93a	95a	98a	98a	3.09a	3.08a

Means with the same letter in columns are not statistically different at $\alpha = 0.05\%$ probability

seeding, CMV plants should be incorporated into the soil when CMV seeds are already matured as indicated by the black color of the pods. Our result was consistent with the previous report by Kim et al. (2001) but not agreed with Jeong (2002). This discrepancy could be explained by the higher growing day-degree in Jeonbuk Province than that in Milyang (data not shown).

To further investigate high seedling regeneration at 35 DAF or later, seed germination characteristics and viability at four seed collection times from 25 to 40 DAF were evaluated. Freshly harvested CMV seeds are strongly dormant because of their hard seed coats and not due to their immature embryo development. This is evidenced by 6% germination of the intact seeds while viability of seeds with seed coat clipped harvested at 35 and 40 DAF ranged from 95 to 98 %, respectively (Table 1). Similar results on germination and dormancy patterns of CMV seeds were reported by Na et al. (2007) and Shim and Kang (2004). Percentage of hard seed percentage was low at 25 DAF with 52-81%, but it was increased to 92 to 95% at 40 DAF. Imrie (1992) reported that hard seed percentage was depended on physiological maturity, a combination of high temperature and humidity and period of wet and drying. The highly dormant CMV seed at 35 and 40 DAF is an ecologically adaptive mechanism of CMV seeds in rice field because the seed dormancy is broken gradually in the soil during rice cropping period from June to September and the seeds finally emerge after the final water drainage in fall. High re-seeding rates of CMV incorporated at 35 DAF or later are also related with heavy 1,000 seed weight. The 1,000 seed weights collected at 35 and 40 DAF ranging from 2.92 to 3.09 g are heavier than those of 25 to 30 DAF. The high hard seed dormancy, high seed viability and heavy seed weight at 35 and 40 DAF contributed to high seeding regeneration in the fall, while that of 25 to 30 DAF showed significantly lower seed viability and lighter seed weight. It indicated low maturity levels leaded to poor re-seeding stand as shown in Fig 2. These results on higher CMV seed germination due to increase in physiological seed maturity was consistent with the previous report (Cho and Choe 1999).

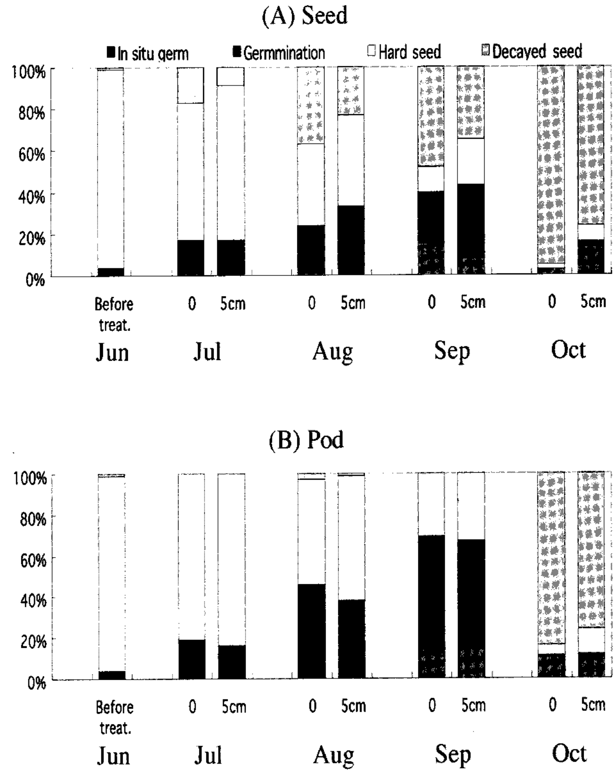

Fig. 3. Change in percentage of hard seed, germination and seed persistence in Chinese milk vetch seed buried in the rice field as (A) seed and (B) pod at 0 and 5cm soil depth.

Freshly harvested CMV seeds were strongly dormant due to hard seed coat but the dormancy was gradually broken with time. The percentage of hard seed was high with 95% in June, but it decreased to 12 to 22% in seed and 31 to 33% in seeds with pod after four months of being buried. The seed recovery rate was only 52 to 65% in the seed, while nearly 100% recovery was recorded in the seeds with pod after four months burial in the soil in both 0 and 5 cm depths in September (Fig. 3). The recovered seed germination rate was 25 to 35% in seed and 55 to 61% in seeds with pod. This indicated that dormant CMV seed buried in the soil during land preparation became nondormant after rice cropping period. And, the appreciable numbers of remaining seeds were regenerated in the September or October, when the rice field was drained for rice harvest in the fall. Our result confirmed that CMV plant could regenerate naturally from the natural soil seed bank during previous cover crop periods due to breakage of seed dormancy in the fall. The seed viability was lost faster in the seed than in seeds with pods, regardless of depth of placements in the soil. However, after final water drainage, seed recovery rate was sharply declined to less than

Table 2. Seedling stand, dry matter production and NPK yield in natural re-seeding rice with CMV green manures.

Year	Seedling stand (plant/ m²)	Dry matter (kg/ha)	Content (kg/ha) ※		
			N	P	K
2005	437	3,470	101	23	43
2006	565	4,380	130	29	55
2007	700	4,970	158	33	62

※ N 2.9~3.2, P 0.67, K 1.25

Table 3. Rice growth and yield in natural re-seeding rice with CMV green manures in 2007.

Cropping pattern	$N-P_2O_5-K_2O$ (kg/ha)	Spikelet (no/m²)	Ripened grain (%)	1,000 brown rice weight (g)	Milled rice (kg/ha)
Rice with CMV green manure	0-0-0	31,184	80.8*	24.1*	5,140
Rice without CMV green manure	90-45-57	30,869	83.4*	23.0*	4,880

※ significant at 5% probability. The amount soil incorporation of CMV dry matter was 4,970kg/ha

20% in both seed and seed with pods, indicating that CMV seeds did not persistent long in soil.

A high CMV natural re-seeding stand 437 to 700 plants per m2 were recorded during the 3-year trials when soil incorporation was made on May 30 (Table 2). The seedling stand was increased after the 3-year trials. It can be explained by the accumulation of mature seed production in the natural reseeded plot. This CMV stand produced more than 3,470 kg dry matter per ha and 101 to 158 kg N ha^{-1} can provide more than the recommendation rate of 90 kg of nitrogen per ha and similar amount to the 57 kg of potassium per ha for rice production. This indicates that natural re-seeding of CMV stand is stable and can supply sufficient N for rice growth. The greater CMV N content in 2007 was associated with greater dry matter accumulation.

Rice yield in 2007 was not statistically different between rice with and without CMV, even 11% increase in rice with CMV compared with rice without CMV (Table 3). The increase in rice yield was contributed by increased panicle spiketlet number per m2 and heavier grain weight in rice with CMV green manure. This suggests that the CMV residues are sufficient to supply NPK nutrient in rice production without application of additional chemical fertilizer. Similar increase in rice yield was reported in only 24 ton CMV fresh weight per ha treated plot (Jeong et al. 1995).

Acknowledgements

The author would like to express sincere thanks to Dr. Edwin P. Ramos, post-doctoral fellow of Plant Environment Division, Yeongnam Agricultural Research Institute for the critical review of the paper.

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