Effect of Chinese Milk Vetch (*Astragalus sinicus* L.) as a Cover Crop on Weed Control, Growth and Yield of Wheat under Different Tillage Systems

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**Abstract**: Reduced tillage systems are gaining popularity but weed control is often a limiting factor in the adoption of such systems. Cover crops have become a viable option for sustainable agriculture because of its contribution to soil fertility and improved crop performance. However, the contribution of cover crops to weed management is not clearly defined. We compared minimum tillage (MT) and no-tillage (NT) with conventional tillage (CT) for their effects on wheat growth in an original paddy land clay soil in the presence of Chinese milk vetch as a cover crop. Cover crop biomass, weed emergence, main crop growth and yield and soil penetration resistance were examined. Chinese milk vetch was successfully established under MT and CT but not under NT, which retarded its growth resulting in a significantly large biomass of all weed species. Weed suppression was more effective when the cover crop was broadcasted than row seeded. The presence of milk vetch as a cover crop significantly suppressed weed growth under MT especially at the late stage of growth and resulted in a comparable grain yield to that under CT. Although soil penetration resistance under MT remained high throughout the period of wheat growth, milk vetch could be effectively utilized as a cover crop under MT and wheat grain yield under MT was comparable to that under CT without mulch treatment.

**Key words**: Chinese milk vetch, Minimum tillage, No-tillage, Weed Control.

The reduced tillage system is gaining popularity in recent years because it is the most economical and effective conservational practice available to control soil erosion on intensively farmed cropland. Reduced tillage saves time, fuel and labor and increases soil water infiltration. Conventional tillage has been criticized for wasting energy and for causing soil erosion and related problems of soil and water pollution. (Munawar et al.,1990). However, weed management is critical to obtaining profitable yields in reduced tillage systems, and achieving satisfactory weed control requires more intensive management. Several studies have documented that conservation tillage increased the density of perennial weeds, some annual grasses and volunteer crops (Swanton et al., 1999). Derksen et al. (1993), however, reported that the above changes were flucutational and dependent on environment, location and timing of management practices.

Removal of tillage not only eliminates an important method of weed control but also alters the environment where weeds and herbicides interact (Buhler, 1992). In order to manage weeds herbicides are widely used due to their efficiency and convenience. However, ground and surface water pollution by pesticides are a matter of concern (Hallberg, 1989).

Cover crops may enable a grower to cut costs and to decrease the amount of herbicides applied. The principle goal of using cover crops for weed control is replacing an unimaginable weed population with a manageable cover crop (Teasdale, 1996). Adversely cover crops may also compete with the crop of interest. Cover crop species vary in their suitability for certain cropping systems. Although the number of cover crops has been evaluated with different cropping systems, the establishment of main and cover crop system has not been successful under reduced tillage systems.

The success of weed control under a reduced tillage system with minimum use of herbicides depends on the local adaptability of the cover crop that could compete with weeds. A cover crop under reduced tillage becomes successful if it could suppress weeds effectively and enable the main crop to achieve comparable yields to conventional systems with minimum competition with the main crop. Improper establishment and management of the cover crop can adversely affect the yield of the main crop.

*Astragalus sinicus* (Chinese milk vetch or renge-sou), a winter-growing green manure legume, has been widely used in rice fields to fertilize the soil in Japan and China since the plant forms a symbiotic

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**Abbreviations**: CT, conventional tillage; MAP, months after planting; MT, minimum tillage; NT, no-tillage.
relationship with soil bacteria, forms root nodules and fixes nitrogen in the nodules (Murooka et al., 1993). A large amount of Chinese milk vetch is cultivated in southern China as green manure to improve soil fertility (Liu et al., 1997).

The objectives of this research were to evaluate the effect of Chinese milk vetch as a cover crop on weed control, growth and yield of wheat under minimum tillage.

**Materials and Methods**

Two field experiments were conducted in the winters of 2001/2002 and 2002/2003 at the experimental field of the Faculty of Agriculture, Gifu University on a clay loam soil (pH; 5.95, Total N; 0.175%, Total C; 1.994%, available P; 20.13mg100g⁻¹, available K; 9.87mg100g⁻¹, available Ca; 3.1mg100g⁻¹, available Mg; 2.1mg100g⁻¹).

Before this experiment, the plots were under conventional tillage for rice for 5 years followed by one-year of no-tillage soybean. Fig. 1 shows the long-term climatic data during the two cropping seasons. These experiments were laid out in a randomized complete block design with three replicates, and each plot received the same treatment through out the period of study though no-tillage plots were excluded in 2002/2003. Plot size was 7 by 5 m.

Treatments in 2002/2003 season consisted of combinations of two tillage systems i.e., CT and MT with (T6 and T8) and without (T7 and T9) a cover crop respectively.

Wheat (*Triticum aestivum* L.) var. Norin 61gou was row seeded on November 15 and Nov 13 in the consecutive seasons at the rate of 120 kg ha⁻¹ with 20cm row spacing, and Chinese milk vetch (*Astragalus sinicus* L.) var Gifu selection was seeded either by broadcasting or row seeding (with 20cm row spacing) as shown in Table 2 at the rate of 40 kg seed ha⁻¹. The seeding depth was 1.5cm on the average. NPK (8:8:8) fertilizer was applied at the rate of 30 kg ha⁻¹ before planting in each year for all plots, and NPK (13:13:13) was broadcast onto all plots at the rate of 150 kg ha⁻¹ at Feek's growth stage 5.0 (stem erect growth stage) (Large, 1954).

Before establishing the experiments, soil samples (0-15cm) were randomly collected, composited, air-dried and crushed to pass a 2mm sieve. Representative samples were used for laboratory analysis. The samples were analyzed for pH (1:2 soil:water ratio), total N and total C using CN analyzer (Sumigraph model NC-800, Shimadzu Corporation, Japan). Available K, Ca and Mg were analyzed with a polarized Zeeman atomic absorption spectrophotometer (Hitachi Corporation, Japan). Available P was determined by colorimetry according to Murphy and Riley (1962).

Surface soil penetration resistance (PR) was measured using a soil hardness gage (Yamanaka s STD type: 30° cone tip angle, cone size 18D × 40mm) at 10 random sites in each plot. Date of measurement varied between 15th and 20th day of each month.
Chlorophyll content was determined using a chlorophyll meter model SPAD-502 (Minolta Co., Ltd., Japan). Three SPAD meter readings were taken on each fully expanded leaf (inter-venal areas) monthly. Mean plant length was also measured monthly.

Four 0.25m² quadrats were randomly placed within each plot for destructive harvests. Destructive samples were taken to determine Chinese milk vetch biomass on 15 Jan, 19 Mar, 20 May, 2002; 14 Jan, 17 Mar, 19 May, 2003. Three destructive harvests during the wheat-growing season were made to determine the weed biomass (17 Jan, 21 Mar, 22 May, 2002; 17 Jan, 19 Mar, 21 May 2003). Weeds and cover crop were identified, grouped into respective species and oven dried to a constant weight at 70°C in a forced air drier, after which they were weighed and their biomass recorded.

Wheat plants were harvested at maturity each year (Jun 15, 2002 and Jun 12, 2003) by combining 1.5m of the center 5 rows within each treatment and seed yields were adjusted to the value at 14.5% moisture. Wheat populations at grain harvest were determined by counting and recording the number of plants harvested within each plot. Spikes were threshed and sub samples were used to determine the yield components.

All data were subjected to analysis of variance and means were separated by Duncan’s multiple range test at the 5% probability level.

Results

1. Cover crop biomass and weed control

The effect of tillage on the dry biomass of Chinese milk vetch in 2001/2002 and 2002/2003 seasons is shown in Fig. 2(a) and 2(b) respectively. In 2001/2002, Chinese milk vetch stands were successfully established, but dry biomass varied with the tillage system and the season. The cover crop growth was vigorous from March (4 months after planting) under each tillage system. NT retarded Chinese milk vetch growth and a comparatively larger biomass was found on the rows than between the rows probably due to interrow cultivation. In each harvest, MT plots had a significantly larger biomass than NT plots. Dry biomass and the ground coverage of Chinese milk vetch

Table 3. Influence of tillage systems and Chinese milk vetch as a cover crop on dry biomass of each weed species in 2001/2002 and 2002/2003.

| Weed species       | Treatment | 2MAP | 4MAP | 6MAP | 2MAP | 4MAP | 6MAP |
|--------------------|-----------|------|------|------|------|------|------|
| Galium spurium     | T1        | 3.1a | 9.3a | 10.2a| T6   | 1.5a | 10.2b| 10.4a|
|                    | T2        | 8.5a | 9.8a | 11.9a| T7   | 1.6a | 10.6b| 32.6b|
|                    | T3        | 8.2a | 10.3b| 16.3b| T8   | 4.9b | 5.9a | 12.3a|
|                    | T4        | 21.4b| 23.0c| 31.8d| T9   | 5.8c | 11.2b| 48.8c|
|                    | T5        | 11.2b| 22.3c| 26.2c|      |      |      |      |
| Cerastium glomeratum| T1       | 0.4a | 2.1a | 6.7a | T6   | 1.3a | 8.8b | 11.1a|
|                    | T2       | 5.0a | 4.1a | 7.4a | T7   | 1.3a | 10.7c| 22.6b|
|                    | T3       | 0.6a | 2.5a | 16.5b| T8   | 3.7b | 5.6a | 14.2a|
|                    | T4       | 23.3b| 62.0b| 29.6c| T9   | 5.6c | 9.8b | 31.3c|
|                    | T5       | 21.3b| 65.4b| 40.6d|      |      |      |      |
| Alopecurus aequalis | T1       | 0.5a | 4.4a | 9.4a | T6   | 2.1a | 6.9b | 11.3a|
|                    | T2       | 0.4a | 4.0a | 8.8a | T7   | 2.1a | 8.7c | 14.4b|
|                    | T3       | 1.2a | 4.6a | 5.3a | T8   | 2.9b | 5.1a | 12.3a|
|                    | T4       | 5.4ab| 30.1b| 12.7a| T9   | 2.7b | 7.2b | 17.6c|
|                    | T5       | 9.5b | 33.4c| 13.8a|      |      |      |      |
| others             | T1       | 7.5a | 9.6a | 15.2a| T6   | 3.7a | 8.6a | 12.6a|
|                    | T2       | 9.5ab| 10.2a| 15.6a| T7   | 5.4b | 7.7a | 14.4b|
|                    | T3       | 10.2b| 16.5b| 21.2b| T8   | 7.2c | 11.2b| 12.9a|
|                    | T4       | 13.2c| 22.3c| 21.3b| T9   | 9.0d | 13.6c| 13.6ab|
|                    | T5       | 12.1c| 18.2b| 23.0b|      |      |      |      |

1 Values in each column followed by the same letter are not significantly different according to the Duncan’s (p<0.05) test. MAP, Months after planting.
were significantly affected by the seeding method. Broadcasting resulted in a significantly high biomass per unit area irrespective of the type of tillage.

In 2002/2003, no significant difference was found between the dry biomass of Chinese milk vetch at the first harvest (14 Jan). However, the biomass was significantly higher under CT compared to MT at the second and third harvests. The type of tillage did not affect the growth of Chinese milk vetch at an early stage.

2. Weed control

Table 3 shows the effect of tillage and the cover crop on the dry biomass of the most abundant weed species in 2001/2002 and 2002/2003. False cleavers (Galium spurium) was the dominant weed species in both seasons. In 2001/2002, biomass of all the species concerned was significantly smaller in CT plots (T1) and larger in NT plots (T4, T5) in each harvest. At 2MAP, the difference in weed biomass between CT and MT plots (T2, T3) was not significant in the dominant weed species observed (Table 3). False cleaver biomass was significantly high in the NT (T4, T5) plots irrespective of the method of establishment of the cover crop at 2MAP and 4MAP. At 6MAP, the weed biomass was larger in the plot T4 than in the plot T5. In the early stage of growth (2MAP and 4MAP) T2 plots did not significantly different from that in the T1 plots but at 6MAP in 2002/2003 the differences were significant. Weed biomass was sensitive to the method of establishment of the cover crop at later stages of growth under MT.

Sticky chickweed (Cerastium glomeratum Thuill.) and short-awned foxtail (Alopecurus aequalis Sobol.) responded to the given treatments almost in the same manner except at a late stage of growth. The weed biomass showed no differences between CT and MT plots at any stage of growth. As a whole, other minor species showed mixed responses but NT plots had a significantly larger weed biomass than the other plots and the CT plots the smallest weed biomass (Table 3).

In 2002/2003, although the presence of Chinese milk vetch did not affect the weed dry biomass under CT (T6, T7) at the first harvest, the differences became more apparent at the later stages of growth. Under MT (T8, T9) weed dry biomass was significantly affected by the presence of cover crop except in A. aequalis at 2MAP. Other weed species showed mixed responses to the presence of cover crop.

In both seasons, tillage effect on total weed biomass was significant at each sampling. In 2001/2002, seeding method had no significant effect on the total weed biomass. In 2002/2003, the effect of tillage, and cover crop, and their interactions were significant (Table 4).

3. Wheat growth

Table 5 shows the influence of different tillage systems on the seedling emergence, plant length and SPAD value. No significant differences among treatments were observed in seedling emergence in both seasons. In 2001/2002, plant length at the heading stage was not significantly influenced by the treatments and that at the ripening stage was not significantly influenced by the treatments except T1. The SPAD value clearly responded to the given tillage treatments at the heading stage but no difference with the treatment was observed at the ripening stage. In 2002/2003, none of the treatments affected the either plant length or SPAD value at the heading stage and ripening stage.

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**Table 4. Influence of tillage systems and Chinese milk vetch as a cover crop on total weed dry biomass.**

| Season* | Treatment | Total weed dry biomass |
|---------|-----------|------------------------|
|         |           | 2MAP | 4MAP | 6MAP |
| 2001/2002 | T1        | 11.5a | 25.4a | 41.4a |
|           | T2        | 24.6b | 37.6b | 49.1ab |
|           | T3        | 10.1a | 25.1a | 44.0a |
|           | T4        | 38.4c | 115.2c | 85.9c |
|           | T5        | 26.4b | 134.5d | 61.8b |

**Level of significance**

| Tillage (T) | 0.01   | 0.01   | 0.01   |
| Seeding (S)  | 0.01   | NS²  | NS²  |
| T X S       | NS²  | 0.01   | NS²  |

**2002/2003**

|          | T6      | 8.7a  | 25.9b | 45.4a |
|          | T7      | 10.3b | 30.1d | 83.9c |
|          | T8      | 18.7c | 16.7a | 51.7b |
|          | T9      | 22.9d | 28.3c | 111.3d |

**Level of significance**

| Tillage (T) | 0.01   | 0.01   | 0.01   |
| Cover crop (C) | 0.01   | 0.01   | 0.01   |
| T X C       | 0.01   | 0.01   | 0.01   |

*Values in each column followed by the same letter are not significantly different according to Duncan’s (p<0.05) test. MAP, Months after planting.

²Not significant at 0.01 probability level.

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**Table 5. Influence of different tillage systems and Chinese milk vetch as a cover crop on seedling emergence, plant length and SPAD value of wheat.**

| Season  | Treatment | Emergence | Plant length (cm) | SPAD value |
|---------|-----------|-----------|-------------------|------------|
|         |           | Headling  | Ripening          | Headling   | Ripening |
| 2001/2002 | T1     | 59.6a¹ | 28.3b | 79.6b | 30.0c | 28.3a |
|          | T2     | 51.1a  | 25.4b | 73.2a | 25.3b | 21.1a |
|          | T3     | 48.3a  | 28.2b | 74.0b | 26.3b | 25.3a |
|          | T4     | 46.4a  | 27.9b | 66.4b | 20.1a | 19.6a |
|          | T5     | 48.4a  | 23.3a | 63.1a | 20.2a | 18.3a |
| 2002/2003 | T6     | 59.0a  | 36.3a | 83.6a | 33.6a | 28.4a |
|          | T7     | 57.7a  | 37.5a | 83.3a | 31.2a | 26.9a |
|          | T8     | 57.2a  | 35.8a | 83.2a | 31.6a | 27.4a |
|          | T9     | 55.1a  | 35.2a | 82.8a | 30.1a | 26.5a |

¹Values within columns followed by the same letter are not significantly different according to the Duncan’s (p<0.05) test.
4. Wheat yield and yield components

Altering tillage systems and seeding methods of cover crop significantly affected the variables measured in relation to yield and yield components of wheat (Table 6). In 2001/2002, the number of heads per unit area and that of kernels per head were highest in the T1 but were not significantly different from that in the T2 plot. No significant differences were found among T3, T4 and T5 plots. Kernel weight was significantly high in the T1 but seeding method did not affect kernel weight either under MT or NT. Harvest index (HI) did not respond to the given treatments.

Grain yield was significantly high in the T1 than in other treatments concerned. A significantly high grain yield was recorded when the cover crop was broadcasted (T2 and T4) than row seeded (T3 and T5).

In 2002/2003, the number of heads per unit area, in the T8 (MT with cover crop) did not significantly differ from that in the T6 (CT with cover crop), but it was significantly low in the T9 (MT without cover crop). The highest and the lowest numbers of kernels were observed in the T6 and T8 plots respectively. No differences were observed in the mean single kernel weight among all treatments except T8. The number of kernels per head and HI was not affected by the treatments in this season. Grain yield was significantly high in the T6 but that in the T8 did not significantly differ from that in the T7 (CT without cover crop).

Interaction effects of tillage method and cover crop were significant on grain yield and the number of heads per unit area in both seasons.

5. Soil penetration resistance (PR)

PR differed due to the given tillage systems and monthly changes were shown in Fig. 3 (a) and 3 (b).

Table 6. Grain yield, yield components and harvest index (HI) of wheat as affected by tillage method and Chinese milk vetch as a cover crop.

| Season | Treatment | No of heads m⁻² | No of kernels head⁻¹ | Kernel weight (mg) | HI | Grain yield gm⁻² |
|--------|-----------|-----------------|---------------------|-------------------|----|-----------------|
| 2001/2002 | T1        | 344.6b          | 39.3b               | 25.9c             | 0.54 | 308.6c          |
|         | T2        | 340.6b          | 37.8b               | 26.6b             | 0.55 | 291.8c          |
|         | T3        | 166.6a          | 28.6a               | 22.4b             | 0.54 | 100.2b          |
|         | T4        | 169.6a          | 30.1a               | 20.8a             | 0.54 | 91.3b           |
|         | T5        | 133.3a          | 26.6a               | 20.8a             | 0.55 | 70.1a           |

Level of significance:
- Tillage (T):
  - 0.01
- Seeding (S):
  - 0.01
- T x S:
  - 0.01

Within seasons, values followed by the same letter in each column are not significantly different according to Duncan’s (p < 0.05) test.

Fig. 3. Soil penetration resistance as affected by tillage and Chinese milk vetch as a cover crop in 2001/2002 (a) and 2002/2003 (b).
for respective seasons. The mean PR values under CT (T1, T6 and T7) were remained below 45Kpa throughout the period of study. In 2001/2002, PR was greater under NT (T4, T5), which was always above 95Kpa. Mean PR values under MT conditions were between 55 (T2) and 84Kpa (T3) in 2001/2002 and 70 (T8) and 110Kpa (T9) in 2002/2003 seasons. PR levels in MT remained comparatively high in the second season most probably due to the low rainfall between December and February.

Discussion

In this study the potential of Chinese milk vetch as a cover crop for wheat was evaluated under different tillage systems. The results showed that this crop combination has a definite potential for controlling weeds without adversely affecting wheat yield under MT conditions. Previous studies on Chinese milk vetch are limited. Nakano and Hirai (2000) evaluated rice - Chinese milk vetch rotation system under two different tillage systems i.e., no-tillage (NT) and sod seeded tillage and observed poor growth and establishment of milk vetch under NT. Nakano (1999) examined the effect of various green manure crops including Chinese milk vetch on Rice yield and yield components under no-tillage cultivation and concluded that the number of tillers, number of grains per head, the percentage of ripened grains and grain yield of rice were markedly higher in the presence of milk vetch and crimson clover than on bare ground.

NT, which represents an alternative to CT, resulted in the lowest wheat yield in this experiment. Although NT systems has gained in popularity in recent years due to its economical and conservational aspects, contradictory results were reported for the effect on crop yield compared with CT. Barzegar et al. (2003) reported that no-tillage, reduced tillage and stubble retention systems resulted in equivalent or even higher crop yield compared with conventional tillage over a wide range of environmental conditions. However, O’Sullivan and Ball (1982) reported a decline in crop yield under the NT system in the first few years of crop production. Hemmat and Eskandari (2004) observed the highest wheat yield in the wheat-chickpea rotation under MT and reduced tillage (MT and NT) conditions. In their study, wheat and chickpea yields were 14% to 27% higher than those under CT conditions respectively. In the present study, high soil compaction seems to have reduced grain yield under NT conditions. Taboda et al. (1998) pointed out that the grain yield decrease are caused by shallow compaction, an idea which is based on the higher penetration resistance often found in zero tilled top soils in relation to similar conventionally tilled ones. There are many reports showing that the soil structure and the environment under NT may require a longer period to reach a steady condition (Mrabet, 2000).

In this study, MT plus cover crop resulted in grain yield that is comparable to CT. Ghuman and Sur (2001) examined the effect of tillage and residue management on soil properties and yields of rain fed maize and wheat and pointed out that MT plus residue is a promising soil management practice to improve and sustain higher yields compared to CT. They further stated that this practice improved soil quality by increasing organic carbon, aggregation and infiltration rate and soil water retention as well as decreasing bulk density near the soil surface.

Tillage method significantly affected soil PR, and NT resulted in comparatively higher PR values throughout the period of study. Isaq et al. (2002) also pointed out that deep tillage to a depth of 1-1.5m with higher fertilization reduced PR compared with other tillage systems. Unger and Jones (1998) reported higher PR values in the NT conditions than in stubble mulch tillage conditions.

In the present study, comparatively higher wheat yields were achieved when Chinese milk vetch was established by broadcast seeding. Edwards (1998) compared two spring seeding methods to establish cover crops in relay with winter cereals and found that Italian ryegrass and red clover provided 5.5% more ground coverage by drill seeding than by broadcast seeding.

To our knowledge this is the first attempt to evaluate Chinese milk vetch as a cover crop for wheat. Although many legumes have been evaluated as cover crops for different main crops, the establishment cover crop - main crop system has not been successful. Enache and Ilnicki (1990) found that corn silage and grain yields under NT with living mulch [living mulch is a cover crop that remains alive for part or all of the cropping season. Species are typically perennial but may be self-seeding annuals (Teasdale, 1996)] treatments were comparable to or higher than those obtained under the conventional tillage without mulch treatment. Abdin et al. (2000) reported that the ability of interrow tillage plus cover crops to suppress the development of weeds was affected by the level of weed infestation, the growing conditions and location. The cover crops provide additional weed control but the interrow tillage or some herbicide application may still be necessary. Ngouajio et al. (2003) observed the effect of cover crop and management system on weed populations in lettuce cultivation and concluded that cover crops could be used in intensive vegetable cropping systems to improve weed management, soil fertility and crop yield. Cover crops are compatible with both organic farming and conventional farming systems.

In the present study, the presence of Chinese milk vetch significantly reduced the wheat grain yield in 2001/2002, but, it increased the yield in 2002/2003. Less water evaporation and accumulation of organic
matter on the soil surface in 2001/2002 may have caused this difference. However, the primary concern of cover crop systems is the extent of competition between the primary crop and the cover crop. Martin et al. (1999) observed delayed development and yield reduction in corn when it was grown with a living mulch and concluded that cool temperate climates may limit the use of living mulches for cool season crops.

Conclusion

Based on the results obtained in the present study, we conclude that MT wheat accompanied with Chinese milk vetch has the potential to reach the same yields as conventional tillage under given conditions. High soil penetration resistance caused significant low yield under NT conditions. The adoption of suitable tillage system should be determined carefully considering the local soil structure and other environmental factors. Chinese milk vetch can be used as a cover crop in wheat cultivation with no significant yield reduction. Although there are still many management aspects to be investigated, the wheat-Chinese milk vetch system could leave less opportunity for weed invasion, requires less tillage and results in yield comparable to the conventional cultivation system.

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