PROJECT FINAL REPORT

Project Number: SW06-006

Project Title: Survey and Economic Analysis of Montana Farmers Utilizing Integrated Livestock-Cereal Grain (Ley Farming) Systems.

Principal Investigator: Chengci Chen, Central Agricultural Research Center (CARC), Montana State University, 52583 US Highway 87, Moccasin, MT 59462. Tel 406-423-5421, Fax 406-423-5422, Email cchen@montana.edu

Cooperators: Dave Buschena, Ag. Economist, Montana State University
Clain Jones, Soil Fertility Specialist, Montana State University
John Paterson, Livestock Specialist, Montana State University
Jim Krall, Agronomist, University of Wyoming
Roy Latta, Agronomist, SARDI, Australia
Jess Alger, Farmer, Stanford, MT
Jon Kvaalen, Farmer, Lambert, MT
Bob Bayles, Farmer, Boyes, MT

Funding Amount: $91,500

Summary: (100 words)
A survey of 4200 farmers and ranchers indicated 43% of farms in Montana have both livestock and crops. Annual legumes may rotate with wheat for annual cropping to replace fallow-wheat system. On-farm demonstrations were conducted at both organic and conventional farms, including legume adaptability, compatibility and rotation studies. Growing winter pea and lentil for cattle grazing on organic farms followed by winter wheat produced the highest net return. On conventional farms, growing pea for hay and lentil for green manure had greater net returns than continuous wheat, while growing lentil for grain followed by winter wheat produced the greatest net return.

Introduction:
Wheat-Fallow (W-F) cropping systems that are still commonly practiced in much of Montana and Wyoming raise concerns for the environmental and economic sustainability of these systems. Although summer fallow has generally guaranteed a successful wheat seedling establishment and relatively stable yield, the water use efficiency for W-F systems is low. Only 25% of precipitation received during the fallow period is stored in the soil profile for subsequent wheat in a tilled summer fallow system (Peterson et al., 1996). Inefficient water use during the summer fallow period could also leach nitrates and salt out of the soil profile to groundwater, causing degradation of groundwater quality and, in some cases, saline seeps (Custer, 1976). Tilled summer fallow leaves bare soil surfaces exposed for wind and water erosion, and stimulates soil organic matter degradation (Peterson and Westfall, 1990). Economically, growing winter or spring wheat after fallow does not provide great net returns (Dhuyvetter et al., 1996). Producers
facing high fuel, fertilizer, and herbicide costs are increasingly considering rotational and operational adjustments to their production systems. Therefore, there is considerable interest in identifying ecologically and economically sustainable cropping systems to replace current W-F practices (Krall et al., 1991; Krall and Schuman, 1996; Carr et al., 2005a, b).

Australian ley farming rotates legume pastures with cereal crops, mainly wheat (*Triticum aestivum* L.), and sheep and cattle graze on the legume pastures during the pasture phase of the cropping system. This system integrates livestock and cereal grain production, which has many benefits including improved soil fertility and soil structure due to biological nitrogen (N) fixation and organic matter accumulation of legume pasture, increased wheat yield, increased forage supply for sheep and cattle production, and improved pest management (Puckridge and French, 1983; Robson, 1990).

The cooperative producers in this project have been using medic (*Medicago*, spp) and clover (*Trifolium*, spp) for ley farming in Montana since the early 1990’s. Surveying and analyzing these on-farm long-term ley farming systems in Montana will provide valuable knowledge and experience about this farming system. The experiences from these producers will fill the knowledge gap of new producers and avoid many problems they might encounter in MT, WY, and ND. In this project, we surveyed producers in different geographic regions of Montana. By doing so, we learned about the current production systems in Montana, the extent that producers who are aware of ley farming and factors that have prevented them from adopting this technology. After the survey, the project team developed a plan for knowledge and technology dissemination. At the same time, newly developed annual legumes were planted in demonstration plots both on organic and conventional farms. Information generated will help Montana, Wyoming, and North Dakota producers to increase productivity and improve existing ley farming practices.

**Objectives/Performance Targets:**
This proposed project addressed the WSARE goals of enhancing the quality and productivity of soil, conserving soil and water resources, promoting crop and livestock diversification and evaluating the environmental and economic implications of adopting sustainable agricultural systems.

The specific objectives of this proposed project were:

1) Survey the current crop and livestock production systems in Montana and assess the awareness and knowledge of producers on Australian ley farming.

2) Conduct in-depth assessment on the successes and problems (agronomical and economic) of representative producers and farms practicing ley farming.

3) Demonstrate the adaptability of newly developed annual legume species, disseminate this information, and educate producers on the incorporation of these crops into their cropping systems.
Materials and Methods:

Objective 1: In 2006, the principle investigator, Chengci Chen, worked with the economist, Dave Buschena, ley farming experts Roy Latta and Jim Krall, soil fertility and livestock extension specialists, Clain Jones and John Paterson, and cooperative producers, Jess Alger and Jon Kvaalen, to design a survey questionnaire and to develop a strategy conducting the survey on Montana crop and livestock producers. During the development of survey pamphlet, the PI also contacted another cooperator, Roy Latta, in Australia and has received his inputs for the survey questionnaire. A survey pamphlet was finalized and mailed to 4200 Montana farmers and ranchers in late December, 2006.

The Montana State University Extension Service, Montana Grain Growers, and Montana Livestock Producers networks were used to develop a list of all commercial scale crop and livestock producers within the state to conduct the survey. All producers received a brief mail survey inquiring about specific components of their livestock and crop production. The goal of this survey was to evaluate the potential for ley farming systems in the state, to judge producer knowledge and interest in these systems, and to establish contacts with interested producers and county extension agents, and to obtain the information about the agricultural systems in different geographical regions of Montana. After receiving responses from the survey, a meeting was called among the researchers and collaborative growers to identify representative producers and farms.

Objective 2: After the representative producers and farms were identified, the research team interviewed the selected producers extensively in order to establish representative production practices and enterprise budgets for the ley farming operation. The production practice information included rotational patterns, planting and tillage operations, grazing dates and methods, and harvest procedures.

Ideally, if the representative producers had been consistently practicing whole farm ley-farming systems and kept good records, the researchers, as well as their assistants, would travel frequently to the producers’ farms to collect data and soil samples, and verify information collected. Economic data gathered in these interviews included crop type, yields, protein or other relevant quality measures, inputs applied, dates of operations, equipment used for each procedure, number and type of tillage passes, harvesting procedures, and the grazing AUMs realized in the ley system. The inputs applied included herbicides, fertilizer, and insecticides in non-organic farming. Unfortunately, from the interviews we found no farmer consistently practicing whole farm ley farming (see the Results section), therefore, the research team had to collect more data from research and demonstration studies (see Objective 3).

Objective 3: In the fall of 2007 and the spring of 2008, several newly developed annual legumes from MT, ND, and WY were planted at an organic farm at Stanford, MT and at the CARC near Moccasin, MT to test the adaptability of the legumes, including winter pea (*Pisum sativum* L.), winter lentil (*Lens culinaris* Medik.), rigid medic (*Medicago rigidula* L.), and birds-foot trefoil (*Lotus corniculatus* L.). Due to the concerns of conventional farmers about medic and trefoil becoming weeds on their farms, only winter pea was planted at a demonstration plot at Boyes, MT. The establishment of the legumes
was monitored. Plant samples were taken in the summer of 2008 to measure biomass accumulation and forage quality. The demonstration plots were continued at the three locations in 2009 and at CARC in 2010.

One replicated rotation study was carried out at CARC and a non-replicated on-farm rotation demonstration was conducted at the organic farm at Stanford, MT. This was not part of the proposal but deemed important especially in light of the absence of ley systems in Montana. The crop rotations at CARC were 1) fallow-winter wheat, 2) spring wheat-winter wheat, 3) spring pea-winter wheat, 4) winter pea (hay)-winter wheat, 5) winter lentil (green manure)-winter wheat, 6) winter lentil (grain)-winter wheat. The crop rotations at the organic farm were 1) oat-winter wheat, 2) winter pea (grain) –winter wheat, 3) winter pea (grazing) – winter wheat, 4) winter lentil (green manure) – winter wheat. In order to estimate the forage biomass grazed by cattle, three cages were placed in the winter pea field and biomass samples were clipped both inside and outside the cages. The difference of biomass between the inside and outside of the cages was the amount grazed by cattle.

Because no herbicide is allowed to be used to control volunteer winter lentils in organic systems, the winter wheat following lentil has to grow as a mixture with lentil volunteers. In order to test the compatibility or competition between the lentil and winter wheat, a lentil-winter wheat intercropping experiment was conducted at CARC in 2008.

Field tours and workshops were organized in the summer of 2008 at organic farm and at CARC. Producers were invited to the field tours and workshops. Clain Jones, Dave Buschena, Jim Krall, Roy Latta, and Chengci Chen gave speeches to the audience at both CARC and the organic farm on legume species, agronomic practices, fertility, and economics. In 2009 and 2010, crop tours were also organized at CARC in conjunction with the CARC field days.

After completion of field experiments and data collection, data analyses were performed for yield and economic return. Particular emphasis was placed on comparing and contrasting the operations for the ley farming or legume-wheat system relative to conventional wheat-fallow or cereal-cereal systems.

**Results and Discussion/Milestones:**

Major accomplishments and milestones are

1) Completed the survey of 4,200 Montana farmers and ranchers in 2007 with a response rate of about 15% (Fig. 1, 2, &3).
2) Survey results were presented at the 2007 Western Society of Crop Science Annual Conference.
3) Interviewed selected Montana farmers and ranchers and assessed the successes and problems in practicing ley farming.
4) Established on-farm demonstration plot as well as research plots in 2007 (Table 1).
5) At CARC, crop yields in six crop rotation systems, i.e. summer fallow-winter wheat, winter pea (hay)-winter wheat, winter lentil (green manure)-winter wheat,
spring pea (grain)-winter wheat, winter lentil (grain)-winter wheat, and spring wheat-winter wheat, were compared (Table 2).

6) On the organic farm at Stanford, MT the yields of four crop rotation systems, i.e. winter pea (grazed)-winter wheat, winter lentil (green manure)-winter wheat, winter pea (grain) –winter wheat, and oat-winter wheat, were compared (Table 4).

7) A field day/crop tour was successfully organized on June 19, 2008 at both the CARC research plot near Moccasin, MT and the organic farmer’s field at Stanford, MT. Preliminary research results were presented at the 2008 American Society of Agronomy Annual Conference.

8) The research team, including Chengci Chen, Dave Buschena, Jim Krall, and Roy Latta, met during the 2008 field day to evaluate the progress and difficulties of the project.

9) Medic seedpods were collected from Wyoming and spread to the field at CARC to test the germination and establishment in fall 2008, and winter lentil self re-establishment and seed dormancy were also evaluated in fall 2008 and spring 2009.

10) Crop tours were organized in conjunction with the CARC field day on July 9th, 2009 and June 17, 2010.

11) Economic analysis was performed in the winter of 2009.

12) Spring wheat was planted to winter lentil pasture to further test compatibility and the crop was harvested in August 2010.

13) Final report was prepared in August 2010, and two manuscripts are under preparation for journal publications.

1. Survey Results

Seven hundred and six farmers and ranchers completed and returned the survey (last one was received in June 2007). Among the 706 responses, 63 people were either retired or deceased; only 643 were valid surveys.

The farmers and ranchers who answered the survey were nearly evenly distributed across the state. The survey covered 55 out of 56 counties in Montana. The distribution chart by each county is shown in Fig. 1.

Among the 643 farmers and ranchers, 459 or 71% of them had small grain crops, 449 or 70% of them raised livestock, and 278 or 43% of them indicated they had both livestock and small grains. The farmers and ranchers under each of above categories were identified on the map in Fig.2. More detailed survey information can be seen in the PowerPoint presentation that was presented at the 2007 Western Society Crop Science Annual Conference at Las Cruces, NM (Chen et al., 2007). The most encouraging thing in this survey was that 216 or 34% of farmers and ranchers expressed interest in obtaining more information about ley farming, and 67 farmers and ranchers across Montana wanted to participate in the ley farming study.

Among the 643 farmers and ranchers, 5% of them were very familiar with ley farming, 30% were slightly familiar with ley farming, and 64% of them had never heard about ley farming. There were 10 or 1.5% who did not specify their familiarity with ley farming.
The 30 farmers and ranchers who were very familiar with ley farming were identified on the map in Fig. 3.

Fig. 1. The distribution of the 643 farmers and ranchers by counties who answered the 2006 survey in Montana.

Fig. 2. Individuals identified as livestock (green), crop (red), and livestock + crop (blue) producers in Montana.
Only two farmers actively practiced ley farming with medic, and both were organic farmers. After carefully analyzing the survey results, the research team (Chengci Chen, Dave Buschena, and Clain Jones) took a site visit with those two farmers as well as one farmer who practiced conventional farming with mixed legumes and grazing. During the site visit, we observed and received comments from the farmers about the benefits and problems of ley farming. General conclusions were

1) In central and eastern Montana, black medic germinated in May each year, thus it did not have a sufficiently long growing season to produce sufficient biomass for green manure.

2) In organic cropping systems, black medic did not leave enough biomass as green manure after grazing.

3) Fall-seeded winter pea and lentil can germinate in the fall and have an early growth in the spring. Therefore, they could produce more biomass than black medic.

4) Fall-seeded winter lentil might have self-seeding capability and can serve as an alternative ley farming legume.

5) Winter pea produced considerable amounts of biomass, and livestock had been grazing on winter peas on producers’ farms. Winter pea can be used in both organic and conventional farming systems. Winter pea mixed with wheat straw could be a good feed for livestock in the winter.

6) Due to the ley-farming systems were not consistently practiced on these farms, the effects of ley-farming on soil quality were not able to be assessed.
3. **Legume Adaptability Demonstration and Cropping System Development**

Based on the observations during the site visit, the research team decided to set up demonstration trials at three locations, i.e. the CARC (research farm at Moccasin, MT), the organic farm (Stanford, MT), and the conventional farm (Boyse, MT). Rigid medic, birds-foot trefoil, winter lentil, and winter pea were planted at CARC and the organic farm near Stanford, MT and only winter pea was planted at the conventional farm at Boyes, MT in September 2007 to test crop adaptability and potential biomass yields.

3.1. **Legume adaptability study**

Winter pea and winter lentil had very good emergence and produced very good biomass yields, while rigid medic and birds-foot trefoil had poor emergence and produced little biomass (Table 1). In the fall of 2008, medic seedpods were collected from Wyoming and spread to the soil surface at CARC, but only a few medic plants emerged in spring 2009.

Table 1. Biomass yields of different legumes from demonstration sites at CARC near Moccasin, organic farm near Stanford, and conventional farm at Boyes, MT.

<table>
<thead>
<tr>
<th>Year</th>
<th>CARC (kg ha⁻¹)</th>
<th>Organic farm (kg ha⁻¹)</th>
<th>Conv. farm (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter lentil</td>
<td>Winter pea</td>
<td>Medic</td>
</tr>
<tr>
<td>2008</td>
<td>1140</td>
<td>1233</td>
<td>226</td>
</tr>
<tr>
<td>2009</td>
<td>1204</td>
<td>1260</td>
<td>--</td>
</tr>
<tr>
<td>2010</td>
<td>1229</td>
<td>1484</td>
<td>--</td>
</tr>
</tbody>
</table>

3.2. **Crop rotation study**

At CARC, the traditional fallow-winter wheat system produced 2146 kg ha⁻¹ winter wheat grain, while the system with winter pea harvested for hay followed by winter wheat produced 2076 kg ha⁻¹ hay plus 1842 kg ha⁻¹ winter wheat grain. Winter wheat following spring wheat system produced 1244 kg ha⁻¹ spring wheat grain plus 1034 kg ha⁻¹ winter wheat grain (Table 2). Protein content of each crop is presented in Table 3.

At the organic farm, the cropping system with winter wheat following winter pea grazed by cattle produced 2727 kg ha⁻¹ hay plus 1482 kg ha⁻¹ winter wheat grain, compared to the oat-winter wheat system which produced 359 kg ha⁻¹ oat grain plus 808 kg ha⁻¹ winter wheat grain (Table 4). Winter wheat following winter lentil green manure produced 1415 kg ha⁻¹ winter wheat grain. These results indicate the advantage of WP(graz)-WW system, which produced 2727 kg ha⁻¹ pea forage for cattle grazing and, most importantly, the winter wheat yield was equivalent to that following green manure crop (Table 4). Protein contents of legumes and cereals are also presented in Table 4. The previous crops did not have much effect on the winter wheat protein contents in 2008.
Table 2. Biomass and grain yield of pea and lentil and spring wheat in 2007, and the 2008 grain yield of winter wheat following pea, lentil, and spring wheat under conventional tillage at CARC, Moccasin, MT

<table>
<thead>
<tr>
<th>Crop system</th>
<th>Biomass yield (kg ha⁻¹)</th>
<th>2007</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Grain yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2007</td>
<td></td>
<td>2008</td>
</tr>
<tr>
<td>Winter pea</td>
<td>Winter lentil</td>
<td></td>
<td>Spring wheat</td>
<td>Winter wheat</td>
</tr>
<tr>
<td>SF-WW*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP(g)-WW</td>
<td>11.21</td>
<td>2146</td>
<td>1551</td>
<td></td>
</tr>
<tr>
<td>WP(h)-WW</td>
<td>14.18</td>
<td>1351</td>
<td>1842</td>
<td>1993</td>
</tr>
<tr>
<td>WL(g)-WW</td>
<td>2076</td>
<td>1025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WL(m)-WW</td>
<td>17.82</td>
<td></td>
<td>17.82</td>
<td>19.95</td>
</tr>
<tr>
<td>SW-WW</td>
<td>14.55</td>
<td>1244</td>
<td></td>
<td>1034</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td></td>
<td></td>
<td></td>
<td>331.72</td>
</tr>
</tbody>
</table>

*SF-WW, summer fallow-winter wheat; SP(g)-WW, spring pea for grain-winter wheat; WP(h)-WW, winter pea for hay-winter wheat; WL(g)-WW, winter lentil for grain-winter wheat; winter lentil for green manure-winter wheat; SW-WW, spring wheat-winter wheat.

Table 3. Protein content of biomass and grain of pea and lentil and spring wheat in 2007, and the 2008 grain of winter wheat following pea, lentil, and spring wheat under conventional tillage at CARC near Moccasin, MT

<table>
<thead>
<tr>
<th>Crop system</th>
<th>Biomass protein (%)</th>
<th>2007</th>
<th>Grain protein (%)</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter pea</td>
<td>Winter lentil</td>
<td></td>
<td>Spring Wheat</td>
<td>Winter wheat</td>
<td></td>
</tr>
<tr>
<td>SF-WW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP(g)-WW</td>
<td>11.21</td>
<td>18.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WP(h)-WW</td>
<td>14.18</td>
<td>10.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WL(g)-WW</td>
<td></td>
<td>17.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WL(m)-WW</td>
<td>17.82</td>
<td>14.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW-WW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD 0.05</td>
<td></td>
<td></td>
<td></td>
<td>0.46</td>
<td>0.46</td>
</tr>
</tbody>
</table>

*SF-WW, summer fallow-winter wheat; SP(g)-WW, spring pea for grain-winter wheat; WP(h)-WW, winter pea for hay-winter wheat; WL(g)-WW, winter lentil for grain-winter wheat; winter lentil for green manure-winter wheat; SW-WW, spring wheat-winter wheat.
Table 4. Biomass, grain yield and protein of pea, lentil and oat in 2007, and the 2008 winter wheat yield following different crops under organic farming near Stanford, MT.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biomass (kg ha(^{-1}))</td>
<td>Grain yield (kg ha(^{-1}))</td>
</tr>
<tr>
<td></td>
<td>Winter pea</td>
<td>Winter lentil</td>
</tr>
<tr>
<td>WP (grz)-WW*</td>
<td>2727</td>
<td>-</td>
</tr>
<tr>
<td>WL(m) – WW</td>
<td>2055</td>
<td>-</td>
</tr>
<tr>
<td>WP(g) -WW</td>
<td>566</td>
<td>-</td>
</tr>
<tr>
<td>Oat - WW</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Protein (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WP (grz)-WW</td>
<td>14.0</td>
<td>-</td>
</tr>
<tr>
<td>WL(m) – WW</td>
<td>18.0</td>
<td>-</td>
</tr>
<tr>
<td>WP(g) -WW</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oat - WW</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*WP(grz)-WW, winter pea (grazing)-winter wheat; WL(m)-WW, winter lentil (manure)-winter wheat; WP(g)-WW, winter pea(grain)-winter wheat; Oat-WW, Oat-winter wheat.

3.3. Crop compatibility study

Because no herbicide is allowed to be used to control legume volunteers during the wheat phase of the rotation in organic system, winter wheat (or spring wheat) must be grown in the mixture with legume volunteers. Therefore, it is important to test the compatibility (or competition) of these legumes with wheat. A winter pea and winter lentil intercropping with winter wheat study conducted in 2007-2008 indicated that pea and lentil yield decreased greatly in the intercrops compared to their sole crops, but wheat yield did not decrease greatly in the intercrops, especially when no N was applied (Fig.4).

The wheat and pea or wheat and lentil combined yields were greater than wheat sole crop when no N was applied (Fig.5). The Land Equivalent Ratio (LER, the land use efficiency compared to sole cropping) reached 1.5 and 1.6 for lentil-wheat and pea-wheat intercropping, respectively, with no N applied (Fig.6). This indicates that pea and lentil intercropping with wheat increased the land use efficiency (LER>1), which is especially beneficial to organic farmers (without N application).

In summary,

1. Winter pea and lentil can survive the winter and adapt to the climate and soil conditions in Central Montana.
2. The total yields of intercrops were greater than sole wheat crop with 0N input, which is attractive to organic farmers.
3. Intercropping pea or lentil with wheat increased the land use efficiency when no nitrogen was applied. This result is very attractive to organic farmers. However, seed dormancy needs to be further evaluated before lentil can become a self-seeding legume for a ley-farming system.

![Wheat Grain Yield](image)

Fig. 4. Wheat yields in sole and mixed stands with 60N (67.2 kg N ha\(^{-1}\)) and 0N treatments at CARC near Moccasin, MT in 2007 crop year (2007-2008).

![Total Grain Yield of Sole and Intercrops](image)

Fig. 5. Combined grain yield of wheat with pea and lentil in the intercrops compared with the individual sole crops with 60N (67.2 kg N ha\(^{-1}\)) and without N (0N) application at CARC near Moccasin, MT in 2007 crop year (2007-2008).
Impact of Results/Outcomes:
Small grain and livestock production is important in the western region of the United States. About 43% of the farmers and ranchers in Montana have both grain and livestock productions on their farms. They are continuously seeking economically and environmentally sustainable integrated crop-livestock production systems. The newly developed winter pea and lentil cultivars have been tested and were proven to be able to adapt to the environment of central Montana. Pea production in the Moccasin area expanded from 3000 acres in 2008 to 8000 acres in 2009. The total acreage of pea reached 240,000 acres and total acreage of lentil reached 260,000 acres in Montana in 2010 (Montana Agricultural Statistics, 2010). The benefits of these legumes in the conventional and organic farming systems were demonstrated during field days and crop tours both at CARC and the organic farm. The results of this study using winter pea and lentil as hay or for grazing in wheat based cropping systems have been presented at regional and national crop science and agronomic conferences, including the 2007 Western Society of Crop Science Annual Conference in Las Cruces, NM, the 2008 American Society of Agronomy Annual Conference in Houston, TX, and the 2009 Montana Pulse Crop Day, Great Falls, MT. Several farmers have adopted winter pea and/or lentil as rotation crops on their farms either for hay, grazing or grain. In 2010, the total winter pea planted acreage was 13,000 acres in Montana (Montana Agricultural Statistics, 2010).

Economic Analysis:
In the conventional farming systems, the SP(g)-WW had the highest production costs followed by SW-WW and WP(h)-WW systems, which was mainly because the spring pea had a high seeding rate and high seed price, and nitrogen fertilizer is required for
both spring and winter wheat at SW-WW system. The greatest net return was obtained for WL(g)-WW ($832/ha), followed by SF-WW and WL(m)-WW (Table 5), which was mainly attributed to good lentil and winter wheat prices in 2007 and 2008. The legume-winter wheat system tended to produce greater net returns compared to continuous cereals (SW-WW), indicating the advantage of incorporating legumes into winter wheat rotations compared to continuous cereal mono-cropping.

Table 5. Production costs and net returns of different cropping systems at CARC near Moccasin, MT in 2007-2008.

<table>
<thead>
<tr>
<th>Cropping systems</th>
<th>07 Crop (kg ha$^{-1}$)</th>
<th>08 Crop (kg ha$^{-1}$)</th>
<th>Gross return ($\text{ha}^{-1}$)</th>
<th>¶Prod. Cost ($\text{ha}^{-1}$)</th>
<th>Net return ($\text{ha}^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-WW¶¶</td>
<td>0</td>
<td>2464a*</td>
<td>655.27c</td>
<td>381.91c</td>
<td>273.36b</td>
</tr>
<tr>
<td>SP(g)-WW</td>
<td>999</td>
<td>1751c</td>
<td>789.59b</td>
<td>636.77a</td>
<td>152.84c</td>
</tr>
<tr>
<td>SW-WW</td>
<td>1244</td>
<td>1189d</td>
<td>663.12c</td>
<td>587.34ab</td>
<td>75.80d</td>
</tr>
<tr>
<td>WL(g)-WW</td>
<td>1025</td>
<td>1843bc</td>
<td>1243.52a</td>
<td>411.06c</td>
<td>832.46a</td>
</tr>
<tr>
<td>WL(m)-WW</td>
<td>1474</td>
<td>2337a</td>
<td>624.66c</td>
<td>397.45c</td>
<td>241.05b</td>
</tr>
<tr>
<td>WP(h)-WW</td>
<td>2075</td>
<td>2068b</td>
<td>720.88bc</td>
<td>574.50b</td>
<td>146.35cd</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td></td>
<td>260</td>
<td>101.76</td>
<td>61.01</td>
</tr>
</tbody>
</table>

*Different letters following the values in the same column are significantly different according to the LSD at P<0.05 level.

¶Total cost includes fuel and oil, repairs, crop insurance, overhead costs, land taxes and miscellaneous costs. The crop price is based on September price of each crop year.

¶¶SF-WW, summer fallow-winter wheat; SP(g)-WW, spring pea (grain)-winter wheat; SW-WW, spring wheat-winter wheat; WL(g)-WW, winter lentil (grain)-winter wheat; WL(m)-WW, winter lentil (green manure)-winter wheat; WP(h)-WW, winter pea (hay)-winter wheat.
In organic systems, the WP(g)-WW had the greatest production cost because of the high seed cost in addition to the cost of using combine for grain harvest. The greatest net return was produced for the WP(grz)-WW system, because of the benefits of pea forage for cattle feed and the high winter wheat grain yield following the pea pasture (Table 6). Although winter wheat yield following lentil green manure was equivalent to that following winter pea pasture (Table 6), the nitrogen credit from the lentil green manure was less than the forage value for cattle grazing in this study, and the long-term benefits of green manure to soil quality improvement was not estimated in this study.

In summary, although the original goals (survey and analyzing historical data) of the study were not met due to an absence of true ley farming systems in Montana, the results of this study should prove extremely useful to both conventional and organic farmers interested in integrating legumes and/or livestock into their systems.

Table 6. Yield, production cost and net return of different cropping systems at the organic farm near Stanford, MT in 2007-2008.

<table>
<thead>
<tr>
<th>Cropping systems</th>
<th>07 Crop (kg ha(^{-1}))</th>
<th>08 Crop (kg ha(^{-1}))</th>
<th>Gross return ($ ha(^{-1}))</th>
<th>Prod. cost ($ ha(^{-1}))</th>
<th>Net return ($ ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat-WW*</td>
<td>359</td>
<td>808</td>
<td>671</td>
<td>276</td>
<td>395</td>
</tr>
<tr>
<td>WL(m)-WW</td>
<td>2055</td>
<td>1415</td>
<td>1061</td>
<td>242</td>
<td>819</td>
</tr>
<tr>
<td>WP(g)-WW</td>
<td>566</td>
<td>970</td>
<td>952</td>
<td>316</td>
<td>636</td>
</tr>
<tr>
<td>WP(grz)-WW</td>
<td>2727</td>
<td>1482</td>
<td>1406</td>
<td>281</td>
<td>1125</td>
</tr>
</tbody>
</table>

* Oat-WW, oat-winter wheat; WL(m)-winter wheat, winter lentil (green manure)-winter wheat; WP(g)-WW, winter pea (grain)-winter wheat; WP(grz)-WW, winter pea (grazing)-winter wheat.
¶ The production costs and crop prices are based on the actual costs and prices of the organic farmer received in 2007 and 2008.

Publications/Outreach:


Two journal publications (one on intercropping and the other on crop rotation) are in preparation.

Farmer Adoption:
Spring pea and lentil acres have increased rapidly in Montana. Winter pea and lentil productions have also increased (Montana Agricultural Statistics, 2010). Pea production in Moccasin area expanded from 3000 acres in 2008 to 8000 acres in 2009. The total acreage of pea reached 240,000 acres and total acreage of lentil reached 260,000 acres in Montana in 2010. Winter pea has been grown as the sole crop or intercropped with barley for seed or hay by a dozen of producers in the region. Several producers have livestock grazing on peas and lentils. Some farmers use winter pea and lentil as cover crop or green manure. The two collaborative producers in this project have been increasing winter pea and lentil seed for both organic and inorganic farming. The conventional farmer who collaborated in this project received 700 lbs of winter pea seed in 2007 for his demonstration plot; two years later his winter pea acres increased to 500 acres on his farm.

Areas Needing Additional Study:
1) On-farm system optimization study is needed to optimize the legume-crop-livestock system at the whole farm level.
2) Longevity or dormancy of lentil seed in the soil needs to be tested, because whether or not the lentil can establish a stand for grazing or haying after wheat depends on the longevity or dormancy of seed in the soil. Therefore, a longer rotation study is needed to test the lentil dormancy and self-establishment ability, especially in conventional farming, where lentil volunteers were killed by herbicide in wheat crop.
3) Disease pressure due to lentil volunteers needs to be tested, because in the legume-cereal-livestock system, especially in the organic system, weed control must rely on grazing and tillage. Lentil volunteers in the wheat crop might carry disease to next lentil pasture or seed crop. A longer on-farm rotation study is needed to test this hypothesis.

Literature Citations:


