Evaluation of the potential of no-till seeding in organic agriculture in Quebec: Building a cover crop "crimper-roller" and farm trials

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Summary

The crimper-roller was made by Ferme Longprès ltée. during the winter. During the growing season, the following trials were done:

1) Rolling fall rye and no-till soybean seeding (three treatments compared with two control plots which were weeded);
   a. Rolling and no-till soybean seeding;
   b. Rolling twice in the same direction and no-till soybean seeding;
   c. Sowing soybean and rolling rye when soybean has developed its first trifoliate leaf;
2) Rolling annual cover crops (yellow mustard, field pea and common vetch) and no-till soybean seeding;
3) Rolling annual alfalfa after harvesting barley;
4) Rolling red clover versus shredding to control weeds after harvesting wheat.

1) Rolling fall rye and no-till soybean seeding

In spite of a poor survival of fall rye, we were able to assess that there was still a possibility of killing it with the crimper-roller at the flowering stage. However, we observed that the weed control quality of the mulch depended essentially on the homogeneity of the ground cover. Devastating weather conditions during the winter considerably reduced the survival of the fall rye which in turn allowed for the establishment of weeds (ragweed, cocklebur, forage grasses and red clover) that could not be controlled by rolling. Consequently, the trial plots were greatly contaminated which reduced soybean yields compared to the controls plots that had been weeded but were not mulched.

We observed that rolling the soybean when the first trifoliate leaf appears did not damage the plants. However, they did have a tendency to be leggy as they stretched toward the light.

2) Rolling annual cover crop (mustard, field peas and common vetch) and no-till soybean seeding

Although the emergence of mustard was rather homogenous, its growth was very slow. During rolling, the plant was too low to be rolled. Subsequently, foxtail contaminated the plots which resulted in the termination of this trial.

In the case of field peas and common vetch, biomass was quite abundant and difficult to destroy by rolling. Peas took a while to dry and soybean couldn't break through the mulch. As for vetch, it couldn't be destroyed and therefore chocked out the soybean.

3) Rolling annual alfalfa after harvesting the barley

As in previous trials, alfalfa could not be destroyed by rolling even when this rolling was done very aggressively (with additional weight).

4) Rolling red clover versus shredding to control weeds after harvesting wheat

Perennial plants cannot be destroyed by rolling. However, in this trial, we wanted to determine if weeds could be controlled so as to prevent their seeds from maturing and thereby reducing fuel use and labour. Rolling, even when done aggressively, could not control weeds such as foxtail and ragweed.

Project objectives

Evaluate the possibility of no-till seeding on mulch in organic production in Quebec using a ground cover crimper-roller.

Specific objectives

1) Building a “crimper-roller” for cover crops;
2) Evaluating the effectiveness of the equipment to terminate different species used as green manure or cover crops (annuals and perennials);
3) Evaluating no-till seeding on cover crop mulches in various crops.

The crimper-roller was built by the Dewarvrin brothers from Ferme Longprès ltée in Les Cèdres, in Quebec’s south-west. The trials were run at the farm. Their crop production is diversified: corn, soybean, and sunflower all grown on ridge planting. The main cereal crop grown for straw is wheat. Oats and barley are secondary crops, as well as vetch and grass pea grown for seed production of green manure crops.

1) Situation for the 2006 season

a) Building the crimper-roller

This implement was designed based on a model developed by the Rodale Institute (Pennsylvania, U.S.A.). We informed the Institute of our project and they assured us that we had their cooperation. We would like to point out that their technical plans are available to producers and that we passed on ours to them.

The construction went ahead in the winter of 2006 and the technical plans were available in early July. These were quickly put up on the Web sites of the Fédération d’agriculture biologique du Québec, the FABQ (organic agriculture federation of Quebec) and of the MAPAQ’s Agri-Réseau (Quebec ministry of agriculture network).

The implement consists of three sections (a 3-metre section in the middle and, on either side, a 1.5-metre section) which ensures better coverage over uneven terrain and eventually allows for added versatility for use with various crops such as, for example, vegetable crops which are usually grown on narrower seed beds. Also, the middle cylinder was designed to hold water to increase compaction over the cover crops.

Because this roller has three separate sections and has a width of six metres, it requires a counter weight on the front end of the tractor or a tractor that is sufficiently heavy (Figures 1 and 2).

Figure 1. Roller during deployment

Figure 2. Roller fully deployed

This roller is slightly different from that of the Rodale Institute (Figure 3).

Figure 1. Rodale Institute Roller

This difference rests on the following points:

- Three separate sections and greater versatility in its application;
- Middle cylinder has a diameter of 20 inches rather than 16 inches;
- Metal blades on the cylinder can be replaced more easily as they are bolted and only the fasteners are welded to the cylinder;
- End sections are pivot-mounted to follow more closely uneven terrain.

b) Changes in farm trials

Following a very rainy spring and certain logistic issues at the farm, we had to reduce the number of green manure species in our trials. As well, a poor survival rate of fall rye jeopardised this projected trial. The heterogeneity of this crop allowed for very aggressive competition from weeds such as ragweed, cocklebur, perennial grasses and red clover.

The changes from the initial project are as follows (Table1):

Table 1. Changes relative to the initial project

Factor	**Initial project**	**Trials done in 2006**	**Additions in 2006**
Annual species	6	3 (mustard, peas, common vetch)	Annual alfalfa[2)]
Bi-annual species	Fall rye and hairy vetch	Fall rye (hairy vetch did not survive the winter)	Red clover, perennial species[2)]
Rolling dates	2 flowering stages in cover crop	Same as for the 3 annual species[1)]	
Number of runs	1 or 2 runs	2 runs were done over fall rye	

Notes:

1) We passed only once with the roller as green manure crops were not high enough at the time of the initial run.
2) These trials were suggested by the farmers in order to test the implement in other conditions and to reach new objectives.

Other unfortunate events limited the results from the 2006 trials and jeopardised the trials planned for the 2007 season.

- Biomass samples of green manure crops were lost. They were stored in a machinery garage where doors were left opened, and heavy winds lifted the bags between the concrete structure and the tarp roof thereby exposing the paper bags to inclement weather. We thought they had been blown away and were lost, and it was only at the end of the season that they were recovered, but were unfortunately found to be unusable.

- Because of the low survival rate of fall rye, ragweed invaded the fall rye field. Consequently, we kept only a small area for the trials so as not to increase the weed population. In the trials done to evaluate soybean yields drilled on rye residue, of the two replicates of the three treatments, only one plot per treatment survived, which limited the findings.

- In the spring, we also drilled three species of green manure, replicated twice (sweet clover and hairy vetch) in barley for trials in 2007. We had also planned to drill fall rye in this field at the end of the summer. Because the green manure had a good biomass, thanks to the spring rainfall, we decided that we could mow it after harvesting the barley. Crushing was done too close to the surface or at a critical growth stage, which damaged the regrowth, so much so that these plots were abandoned. It was then too late to seed bi-annual varieties. Only one fall rye plot was drilled at the beginning of September. Establishment was generally uniform and the tillering phase was reached before a serious frost which is a winter survival factor. We hope that this trial will not be nullified by a winter warm spell.

- These setbacks in 2006 were disturbing and at the end of this progress report we suggest alternatives for the 2007 season.

2) Results of the 2006 season

Below is a list of the different plants that where rolled during the 2006 season:

- Fall rye followed by no-till soybean seeded every 30 inches; three treatments replicated twice;
- Field peas;
- Yellow mustard;
- Common vetch (annual);
- Annual alfalfa;
- Red clover (perennial).

The trials with mustard and legumes were replicated twice, sometimes on soils with different textures.

2.1 Fall rye followed by no till soybean seeded every 30 inches

Methodology

This trial was carried out in a fall rye field with a soil texture going from silt loam to a clay loam. Unfortunately, the rye did not survive the winter. A warm spell at the end of 2005, followed by rainfall and finally ice formation considerably reduced the rye population. This uneven establishment favoured red clover, perennial forage grasses of the *agrotis* (bent grass) variety and red fescue, as well as dicotyledonous weeds such as the very competitive ragweed and cocklebur.

Three treatments were compared:

- Rolling followed by no-till soybean seeded every 30 inches (RS);
- No-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT);
- Two rollings of rye in the same direction followed by no-till soybean seeded every 30 inches (2R);
- To evaluate soybean yields and soybean aphid population, we took two control fields close to the rye field: one which had red clover between the soybean rows until it was weeded (SRc) and another without an intercrop but weeded (S).

The test plots were six-metre strips (width of the roller and seeder: 8 rows) on the length of the field, which was about a 100 metres. The treatments were replicated twice, at two different areas in the field (Figure 4).

Figure 4. Layout of the test plots in the fall rye field

Wooded area

2R2	FR not rolled	2R1	FR not rolled	S+RT2	RS2	S+RT1	RS1	FR not rolled

Stream

The Src control plot (soybean with red clover between rows) was on the left of the rye field and the second S control plot was on the other side of the stream, on the right side of the field.

Table 2 summarises the dates of the field operations. No fertiliser was applied on rye or on soybean.

Table 2. Field operations for the 2006 season

Operation	Date	Comments
Seeding of fall rye	Beginning of Sept. 2005	110 kg/ha
Rolling of rye and seeding soybean in all 3 treatments	June 2	Auriga variety
Late rolling	June 26	First trifoliate leaf in soybean
Yield evaluation	September 22	
Threshing of soybean samples	October 26	

Fall rye biomass

Before the initial rolling (June 2), rye biomass was sampled by taking 10 samples representative of the diversified population. The biomass sampling was done on a linear metre. The samples were air-dried in a machinery garage during several weeks. A tissue analysis was done on the head, the stem and the whole plant by the Agri-direct laboratory.

Whereas the initial rolling was followed by soybean seeding, the later rolling was done on June 26 after soybean had developed its first trifoliate leaf, about three weeks after seeding. Before this later rolling, we had again sampled the rye biomass three days after rolling (the rest of the rye field was not rolled) by taking ten new samples on a linear metre. The drying process was similar to that of the first rolling.

Evaluation of soil coverage by rye mulch

On July 1, we evaluated the soil coverage by the mulch by using a knotted cord, an implement that is commonly used to estimate the percentage of crop residue, which is an indicator for soil conservation. The cord had 45 knots and the distance between knots was on average 14 cm. The cord was 6.30 metres long, overlapping the eight soybean rows. We collected five readings per treatment and replicate. We considered three evaluation parameters: FR (rye as vegetative mulch), FH (rye which was poorly crushed and hence slightly raised) and weeds. As these parameters are evaluated on a percentage basis, the difference between their sum and 100% corresponds to the area of uncovered soil or of the crop.

Evaluation of soybean plants

On August 8, we evaluated the soybean plants in the three treatments and the two controls. We uprooted eight plants per treatment and the evaluation was based on the following parameters:

- Number of trifoliate leaves;
- Number of pods in two categories: 5 mm to 2 cm; > 2 cm;
- Height starting from the crown (<50 cm, 50 cm and > 50 cm).

Evaluation of soybean aphid

In order to determine if mulch could be helpful in controlling the soybean aphid, we counted the number of aphids on three upper leaves of soybean plant. This was done ten times per treatment and in both controls plots. The scouting period lasted four weeks, from August 15 to September 7. However during this period, we scouted only three times as the aphid population was rather small.

Evaluation of soybean yields and of weed and fall rye mulch biomass

We evaluated yields manually on September 22 by taking three samples of a linear metre per treatment, as well as from both control plots. We collected the weeds in the inter-row to the right of the soybean row harvested to determine yields. The same was done for the rye mulch. Grain samples were fan-dried and the other samples were air-dried in a machinery garage at the Centre de recherche des grains, or CEROM (grain research centre) in St-Bruno de Montarville. Threshing was done on October 26. The seeds were again air-dried for eight days in a heated room. To estimate yield and biomass per hectare, we considered the following parameters:

Average weight (kg) per treatment/meter * 134 soybean rows/ 100m * 100m = kg-ha

Results

1) Fall rye biomass before first rolling

As mentioned previously, the fall rye suffered from rain and ice during the winter. An uneven plant population allowed for the establishment of weeds, ragweed, red clover, cocklebur, perennial grasses and other secondary species (Figures 5 to 7). Consequently the rye biomass was very variable.

Figure 5. Heterogeneous plant population of fall rye (biomass rather low)

Figure 6. Heterogeneous plant population in fall rye (biomass rather high)

Figure 7. Presence of red clover in fall rye

We collected 10 samples on June 2 (five days before rolling and seeding soybean) when the soybean was at the first flowering stage: Often there wasn't any rye. The biomass of samples ranged from 6.07 to 11 tonnes^{-ha}, with an average of 7.8 tonnes^{-ha} (dry matter). It should be noted that although the fall rye biomass was significant, the efficiency of the mulch in controlling weeds depends less on the total biomass and rather on the heterogeneous distribution of the biomass within the field.

The results of the leaf analysis are given in Table 3. The spike has most of the concentration of N, P, and Mg as well as minors elements Zn and Mn.

Table 3. Results of fall rye leaf analysis at the time of first rolling

Parameter	Stem (%) and ppm	Spike(%) and ppm	Whole plant (%) and ppm
N total	1.6	3.3	2.4
P	0.45	0.54	0.48
Mg	0.08	0.15	0.11
Ca	0.22	0.23	0.3
K	2.54	1.53	2.22
Zn	30.8 ppm	42.9 ppm	24.2 ppm
Cu	9.81 ppm	5.49 ppm	8.02 ppm
Mn	<21.6 ppm	32.0 ppm	<21.9 ppm
Fe	88.8 ppm	56.6 ppm	96.2 ppm
B	3.4 ppm	4.9 ppm	5.7 ppm

Note: Certain results will differ from averages as different individuals were used to analyze whole plant parameters whole plant was different from those used for the spike and stem analysis.

2) Fall rye biomass at the time of late rolling when soybean has developed first trifoliate leaf

Rolling was done on June 26, three weeks after the soybean was seeded. From a visual standpoint the soybean did not appear to have suffered from this rolling. Sampling of the rye biomass from the rest of the field that was not rolled was done on June 29. Unfortunately, as mentioned previously in the *Situation for the 2006 season* section, we lost these samples, but we were able to do tissue sampling (Table 4).

Table 4. Results of fall rye foliar analysis at the time of late rolling

Parameter	Stem (%) and ppm	Spike (%) and ppm	Whole plant (%) and ppm
N total	1.6	1.6	1.1
P	0.19	0.38	0.32
Mg	0.05	0.11	0.09
Ca	0.18	0.08	0.12
K	1.20	0.65	1.10
Zn	18.0 ppm	36.7 ppm	34.5 ppm
Cu	1.89 ppm	6.75 ppm	1.76 ppm
Mn	<21.1 ppm	<20.8 ppm	<20.5 ppm
Fe	36.6 ppm	96.8 ppm	54.1 ppm
B	2.5 ppm	3.8 ppm	2.3 ppm

Note: Certain results will differ from averages as different individuals were used to analyze whole plant parameters whole plant was different from those used for the spike and stem analysis.

The results indicate that for the stem, nitrogen content did not change but the content of the other elements lessened with large variations in Zn and Cu. For the spike, the content for all other elements was diminished, particularly for Ca and K; however the level of Cu and Fe increased. For the whole plant, aside from an increase in Zn content, the other elements diminished, particularly K, Ca, Cu, and B.

3) Evaluation of soil coverage by fall rye mulch

On July 1, we took five readings per treatment and per replicate, for a total of 10 readings per treatment. Table 5 presents these results.

Table 5. Evaluation of soil coverage by fall rye mulch

Treatment[1)]	**FR**[2)] **(%)**	**RA**[2)] **(%)**	**WE** [2)] **(%)**	**Soil and soybean**[2)]
2R	39	5	21	35
RS	28	6	35	31
S+RT	27	6	30	37
Average	31	6	29	34
Number of knots in soybean inter-rows[3)]	1.55	0.3	1.45	

Notes:

1) Three treatments were compared: rolling followed by no-till soybean seeded every 30 inches (RS); no-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT); 2 rollings of the rye in the same direction followed by no-till soybean seeded every 30 inches (2R).
2) FR = fall rye; RA = rye above the soil (inefficient rolling); WE = weeds; Soil and soybean = difference between 100% and sum of all 3 preceding factors.
3) Results of (5 knots per inter-row * percentage of related parameter).

On average, the soil coverage by rye mulch is rather scanty and demonstrates the heterogeneousness of plant population. The treatments are not noticeably different. If inter-row distance is 75 cm, there will be about 5 knots between the two soybean rows. If we consider the average sum of FR an RA (Table 5), 37% of the area would be covered by the rye mulch, which is barely 2 knots (1.85) out of a total of five in the inter-rows. This situation leaves considerable space for weeds to grow.

However, several observations can be made after analyzing data individually (Table 6):

- When the area covered with rye is greater than 50%, the weed area is rather low;
- When the area covered with rye is low or non-existent, the weed area is rather high (Figure 8);
- When the area covered with rye ranges from 20 to 50%, the weed area can be more or less pronounced, the relationship is not clear.

Table 6. Evaluation of soil coverage by rye mulch (FR + RA) and weeds regardless of treatments (15 readings out of 30)

Area of the rye mulch	**FR (%)**	**WE (%)**	**Treatment**
Mulch >50%	58	5	2R
	62	7	RS
	66	4	S+RT
	71	6	2R
	76	13	2R
Scanty mulch	0	66	S+RT
	10	59	RS
	19	76	RS
	22	75	RS
	27	37	RS
Mulch between 20-50%	22	75	RS
	27	44	S+RT
	32	61	S+RT
	34	17	2R
	38	13	2R

Figure 8. Scanty mulch

4) Evaluation of soybean plants in all 3 treatments and both control plots

The results of the evaluation of soybean plants are presented in Table 7. The soybean plants in the control plots are significantly different as compared to those in the treatment using vegetative mulch. Double rolling (2R) seems to have favoured soybeans. During yield evaluation, this treatment showed greater rye biomass and reduced weed biomass as compared to the other treatments with vegetative mulch.

Table 7. Evaluation of soybean plants depending on treatments

Treatment[1)]	Height (number of plants < 50 cm; 50 cm or >50 cm)	Average number of trifoliate leaves per plant	Number of seed pods < 2 cm	Number of seed pods > 2 cm
RS	4 < 3 to 50 cm 1>	7.4	5	5.9
S+RT	2< 6 to 50 cm	7	2	7
2R	3> 4 to 50 cm 1>	9	3.6	10.8
S	8>	13.6	10	11
SRc	8>	11.9	8.8	9.1

Notes:

1) Three treatments were compared:
   - Rolling followed by no-till soybean seeded every 30 inches (RS);
   - No-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT);
   - Two rollings in the same direction (2R).

   Two control plots: S= weeded soybean; SRc = soybean with red clover in the inter-row until weeding.

5) Soybean aphid

Generally, biodiversity favours the natural control of crop pests by way of beneficial insects. The rye mulch applied in the soybean field adds biodiversity therefore increasing the action of soybean aphids' natural predators, in particular the ground beetle which benefits from a vegetative ground cover. In the spring, we noted the presence of ladybugs on the red clover, a natural predator of aphids (Figure 9).

Figure 9. Ladybugs on red clover in the spring

We scouted the soybean aphid from August 15 (soybean phenological R5 stage) to September 7 during 3 visits. At the beginning of August, the presence of aphids was rather rare whereas generally the peak is in August during the soybean phenological stages R4 to R5 (RAP, No 7, June 26, 2000). This observation was the same in all soybean production zones in Quebec (Terre de Chez Nous, 2006). Table 8 details this situation.

Table 8. Presence of soybean aphids in all 3 treatments with mulch and both controls

Date/Treatment[1)]	**Total/Average number of soybean aphids: 3 upper leaves/plant and 10plants/treatment**				
	RS	S+RT	2R	S	SRc
August 15	9/0.9	13/1,3	16/1.6	93/9.3	35/3.5
August 24	84/8.4	73/7.3	105/10.5	159/15.9	44/4.4
September 7	109/10.9	148/14.8	318/31.8	159/15.9	132/4.4
Average	202/6.7	234/7.8	439/14.6	404/13.4	132/4.4

Notes:

1) Three treatments were compared:
- Rolling followed by no-till soybean seeded every 30 inches (RS);
- No-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT);
- Two rollings in the same direction (2R).

Two control plots: S= weeded soybean; SRc = soybean with red clover in the inter-row until weeding.

The scouting method recommended by the Réseau d'avertissements phytosanitaires, or RAP (phytosanitary advisory network) states a threshold of 250 aphids/plant on average, above which the scouting must become more intensive. The strategy consists in not reaching a level of infestation of 1,000 aphids/plant before the soybean R6 stage (RAP, 2006). We did not reach this critical level.

Our results are much less than 250 aphids/plant on average, a situation which was similar in all soybean cultural zones in Quebec (Terre de Chez Nous, 2006).

During the scouting period, the presence of aphids in soybean was very variable from one plant to the next. Unless the contamination level is very high, the distribution of pest insects was very heterogeneous. However, the number of aphids slowly increased during the 4 weeks of scouting. Only the SRc treatment had a rather constant contamination level. The treatments using mulch didn't seem to differ from the controls. Worth noting is the fact that our scouting period was very short and that during strong infestation, the results could indicate different trends among the treatments.

6) Soybean yields and evaluation of weed and fall rye mulch biomass

Figure 10 shows no-till soybean sowing over rye mulch (sowing done before rolling when soybean has developed first trifoliate leaf).

Figure 10. No-till soybean sowing over rye (treatment S+RT)

Results are compiled in Table 9.

Table 9. Soybean yields and evaluation of weeds and fall rye mulch

Treatment[1)]	**RS**	**S+RT**	**2R**	**S**	**SRc**
Soybean yield (kg^{-ha})	992	1286	1514	4395	3511
Weeds (kg^{-ha})	2760	5119	1018	1983	1286
Mulch(kg^{-ha})	1461	710	1595		

Notes:

1) Three treatments were compared:
   - Rolling followed by no-till soybean seeded every 30 inches (RS);
   - No-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT);
   - Two rollings in the same direction (2R).

   Two control plots: S= weeded soybean; SRc = soybean with red clover in the inter-row until weeding.

The production of soybean on fall rye mulch does not contend with that of the control plots that were weeded. It should be noted that we observed the presence of vetch in the control plots (S and SRc), but less in the S plot (soybean without red clover).

From these results, we can observe a trend in which weed biomass is smaller when rye biomass is greater in soybean inter-rows for 2 treatments (RS and 2R). However the relation between soybean yields and weed biomass is not linear and is unrelated to the way in which the crop was grown (mulch vs. weeding). This relation is quite complex and depends on several factors. For example, the biomass of a plant like ragweed or cocklebur, a dominant species in the soybean field, can be very high as demonstrated by sample 1 taken from SRc and sample 2 from S (Table 10; Figure 11).

Figure 11. Cockebur plant

Table 10. Distinctiveness of certain weed samples (W)

Treatment[1)]	Weed biomass (g)	Soybean Yield (g)	Comment
SRc (control with clover)			
Sample			
1	245	183	Large ragweed plant
2	0	303	
3	44	301	Very few weeds
S (control without clover)			
1	0	344	
2	378	287	One large cockebur plant
3	65	352	
S+RT			
1	323	109	
2	254	81	
3	213	97	
RS			
1	284	84	Ragweed dominates
2	173	52	Ragweed dominates
3	163	87	Red clover significant
2R			
1	90.2	123	Ragweed and cockebur
2	79	115	Ragweed dominates
3	59.8	100	Ragweed dominates

Notes:

1) Three treatments were compared:
- Rolling followed by no-till soybean seeded every 30 inches (RS);
- No-till soybean seeded every 30 inches and rolling of the rye when soybean has developed first trifoliate leaf (S+RT);
- Two rollings in the same direction (2R).

Two control plots: S= weeded soybean; SRc = soybean with red clover in the inter-row until weeding.

7) Effectiveness of crimper-roller and no-till seeding on fall rye mulch

The 2006 results of no-till soybean seeding on fall rye mulch were certainly disappointing for several reasons, some of which have been previously mentioned:

- A poor winter survival rate in fall rye, a growing concern for the south-east region of Quebec.

- This poor survival allowed for a greater tillering, which in turn allowed for a large biomass whose distribution was heterogeneous, which contributed to a large variability of soil coverage by the mulch.

- Also, in the areas with little or no rye, weeds (ragweed, cockebur, perennial grasses, and red clover, species which are very invasive) developed quickly and were already in a very advanced stage at the time of rolling.

- Furthermore, towards the end of the season, a herd of forty beef cattle broke through a fence and overran most of the plots with mulch, trampling the soybean plants and eating the upper portion of the plants.

The results clearly show that there are limitations to seeding no-till soybean on fall rye mulch: a poor rye survival rate and a heterogeneous biomass.

It is absolutely necessary to obtain not only sufficient mulch biomass, but also that this biomass be the most homogeneous possible throughout the field. To achieve this, good quality seeds are required, as well as an appropriate seeding rate, a suitable seed bed. Furthermore, seeds must be sowed using a seeder instead of being simply scattered. In addition, the seeding date is very important for rye survival as this crop must have reached the tillering stage (4-5 leaf) before a killing frost.

With regards to the efficiency of the crimper-roller for rolling rye, we found it quite acceptable. When the rye was not flattened on the ground, the stems which were raised were only 4 to 5 cm from the ground (Table 5). We did not notice any regrowth from young rye tillers, which is often the case when no-till soybean is seeded after the silage during the bolting or heading stages

The late rolling of fall rye after sowing soybean can be an option as long as the rye hasn't reached the pollination stage which is ideal, if it is to be killed by rolling. Rolling when soybean has developed its first trifoliate leaf did not seem to affect the plant. Another interesting fact when using rye is that the straw doesn't break down quickly, so that the mulch is still present during harvesting.

A potentially negative aspect to consider is the viability of the seed which may form in spite of rolling. This could happen if rolling is done too early. In this case, the shoots from the secondary tillers could go to seed. In our trial, we sampled some rye heads randomly. Very few seeds were formed and when they were, they were very small.

In conclusion, we found out in August that another organic producer had built another type of roller and that he had done trials sowing corn and soybean on fall rye mulch. During a farm visit, we observed promising and interesting results.

2.2 Rolling annual cover crops followed by no-till soybean seeding trial

Species, their biomass and their content in plant nutrients

The species used were yellow mustard and two annual legumes: field peas and common vetch.

During the rolling of fall rye on June 7, the plants of the 3 species were not high enough to do an effective rolling even though the mustard had begun flowering. We then waited for a late rolling on June 26. The mustard was not that much higher, but the field peas and the vetch had begun flowering. As mentioned at the beginning of this Report, the biomass samples were lost. We can however mention that the mustard biomass was rather low, the field pea biomass was rather large, and the ground coverage was rather heterogeneous (Figures 12 to 14). As for the common vetch, biomass was large and soil coverage homogeneous. However, the plants had a tendency to collapse on the ground.

Figure 12. Yellow mustard and field peas

Figure 13. Common vetch

Figure 14. Hairy vetch that did not survive the winter

However, we were able to perform chemical analyses of these cover crops at 2 different phenological stages (Tables 11 to 13). In the case of no-till on mulch, the cover crop should not break down easily. In this line of thought, total nitrogen content, or better yet C/N ratio, are indicators of the rate at which various species break down. Tables 11 to 13 show that at the beginning of June, the difference in nitrogen content of cover crops was not significant (table 11). But, towards the end of June, the differences between the legumes were dependant on soil quality. This data is useful when selecting plants best suited to soil type.

Table 11. Chemical analyses of annual cover crops (June 2): Fertile section of field

Parameter	Peas (%)	Mustard (%)	Common vetch (%)	Grass pea (%)[1)]
N total	5.7	4.1	5.1	5.4
P	0.62	0.6	0.68	0.63
MG	0.26	0.24	0.24	0.22
Ca	1.1.5	2.14	1.49	0.77
K	4.05	3.08	3.29	4.03
Zn	44 ppm	36.8 ppm	37.8 ppm	49.8 pmm
Cu	13.5	9.05 ppm	13.3 ppm	13.8 pmm
Mn	<21.4 ppm	35.3 pmm	<22.3 ppm	<21.2 pmm
Fe	188 ppm	2600 pmm	722 ppm	141 pmm
B	21.7 ppm	24.5 pmm	23.3 pmm	17.2 pmm

Note:
1) Grass peas were not rolled but we wanted to compare their chemical quality to that of hairy vetch as plant growth habit in these two species is identical and grass pea could be another option as a ground cover.

Table 12. Chemical Analyses of annual legume cover crops (June 26): Poor section of the field

Parameter	Peas (%)	Common vetch (%)
N total	2.4	3.7
P	0.32	0.48
MG	0.21	0.34
Ca	0.77	1.22
K	1.62	2.96
Zn	25.2 ppm	91.3 ppm
Cu	7.57 ppm	9.05 ppm
Mn	< 22.4 ppm	< 21.6 ppm
Fe	202 ppm	176 ppm
B	24.7 ppm	25.1 pmm

Table 13. Chemical Analyses of the annual legume cover crops (June 26): Fertile section of the field

Parameter	Peas (%)	Common Vetch (%)
N total	4.2	5.4
P	0.47	0.57
MG	0.25	0.32
Ca	0.97	1.63
K	2.47	2.85
Zn	34.5 ppm	46.9 ppm
Cu	11 ppm	12.8 ppm
Mn	< 22.3 ppm	< 21.0 ppm
Fe	114 ppm	134 ppm
B	21.7 ppm	32.0 pmm

Effectiveness of crimper-roller for annual cover crops

- Rolling of mustard could not really be done as the stems were too short.

- The very dense biomass of common vetch and field peas did not allow the roller to reach each stem. The thickness of the mat to be crushed acted as a barrier and reduced the contact of crimpers on the stems of the plants. This occurred even though the roller was filled with water. Additionally, vetch had a tendency to fall over due to its weight and hence hold humidity close to the ground which can cause mildew, a detrimental condition for young soybean plants. Field peas also have this tendency.

- Late rolling of field peas is more efficient than with common vetch. The pea stem is bigger and the species does not spread as much as hairy vetch.

- Rolling of peas and vetch would probably be more efficient if the species were mixed with a high-stemmed cereal which would act as a support.

- Spreading plants such as common vetch and field peas limit the growth of soybean by blocking the sunlight (especially common vetch). The soybean ultimately becomes leggy looking for light, and then dies back.

2.3 Rolling annual alfalfa after harvesting barley trial

This trial was suggested by Ferme Longprès to evaluate the possibility of achieving other objectives with the crimper-roller.

The cereal crops of the farm are seeded with legumes. In this instance naked barley had annual alfalfa as a companion or "nurse" crop. Usually when alfalfa is well developed as was the case this season when moisture was not a limiting factor, the green manure is shredded a few weeks after harvesting the cereal to generate regrowth in alfalfa and prevent weed seeds from maturing.

Therefore, the purpose of this trial was to determine whether rolling could control weeds and hence replace shredding, which in turn would reduce work time as well as fuel consumption (Figure 15).

Figure 15. Rolling annual alfalfa

- Naked barley was harvested July 25.
- On August 15, alfalfa had reached approximately 30 to 40 cm in height.
- On August 17, we rolled four strips based on the following treatments:
  - B1: 6-metre width rolled with the tractor in front (normal position);
  - B2: 6-metre width rolled with the tractor behind. The position of the roller blades is reversed and the effect should be more aggressive;
  - B3: 3-metre width for rolling with both 1.5-metre side sections raised in order to increase the weight during rolling, the tractor at the front;
  - B4: 3-metre width as above but, with the tractor at the rear.

We should point out that the roller weighs about 1,400 kg and that we added water to the cylinder, about 800 litres, for a total mass of 2,500 kg.

The biomass of the alfalfa in the trial zones was evaluated by taking four samples from a quadrant measuring 21 cm * 51 cm (0.107 m^2) (Table 14). The sample could have contained straw and weeds.

Table 14. Average alfalfa biomass not shredded on August 24.

Sample	Biomass (g/quadrant)
1	48
2	30
3	26
4	28
Average	33
Kg^{-ha}	**3,084**

- Generally, rolling crimped the alfalfa stem in two places. The height of the alfalfa was about 35 to 50 cm in the non-rolled control plot whereas in the rolled trials, it was on average approximately 25 to 30 cm. In the more aggressive treatment, we noticed a greater flattening of the alfalfa.

- Generally the rolled plants had a lower stance as rolling caused the plant to bend. On September 7, (2 weeks after rolling) the difference in height had lessened.

- Subsequently, the rest of the field was shredded, leaving a control strip which was not rolled.

- On September 27, we re-evaluated the alfalfa biomass from the rolled treatments and the one from the non-shredded control plot (2 samples/quadrant/treatment) (Table 15). We should point out that the sample was cut at a height that was higher than on the sampling operations conducted on August 24 to ensure that we were sampling alfalfa only.

Table 15. Average rolled alfalfa biomass and control plot on September 22

Rolling treatment	Alfalfa biomass (kg^{-ha})
B1	1,626
B2	1,449
B3	1,542
B4	1,551
Average of rolled treatments	1,542
Non-shredded control	1,911

Table 16 illustrates the difference between non-rolled, non-shredded biomass and regrowth biomass after shredding.

Table 16. Average non-shredded, non-rolled alfalfa biomass and regrowth biomass after shredding on October 17

Sample	**Biomass (g/quadrant)**	
	Non-rolled, non-shredded alfalfa	**Alfalfa regrowth after shredding**
1	24	3
2	19	6
3	17	10
Average	20	6.3
Kg^{-ha}	1,869	589

- As compared to the non-rolled control plot it would seem that rolling decreased the biomass, probably due to the stress to the plant (Table 15), a difference of 24%. Regrowth seems to account for about 31% of total biomass (Table 16). However the number of samples was not sufficient to identify any significant difference.

- Rolling did not destroy the alfalfa which was the case with common vetch.

- According to the literature, the effectiveness of rolling annual or biannual plants is greatest when done during flowering. Our trials seem to indicate that rolling is more effective in cereals than in legumes.

2.4 Rolling red clover after harvesting wheat trial

This trial was also suggested by Ferme Longprès. In this instance, the objective was to compare the effects of rolling and shredding on weeds (especially ragweed and the *setaria* species) and the biomass of red clover. If rolling could prevent weed seeds from maturing while still maintaining adequate red clover biomass, the savings in work time and fuel consumption would be advantageous compared to shredding. Rolling can be done at a speed of 15 km^{-h} at low throttle speed (1,200 rpm engine speed) whereas shredding is done at 9 km^{-h} at high throttle speed (2,200 rpm engine speed) so as to maintain the efficiency of the rotating shredder.

Figure 16. Rolling red clover and weed bands after wheat has been harvested

The trials were done in the wheat field which had red clover as a companion crop. Following the wheat harvest, the field was shredded, with the exception of 2 strips of 6 metres used for the rolling trials.

- On August 17, rolling was done as follows:

- Strip 1: rolled with the tractor in front;
- Strip 2: rolled with the tractor behind (more aggressive effect).

- At the time of rolling, red clover was about 40 cm high. Although rolling allowed red clover and weed stems to be crushed, the total biomass seemed to act as a barrier, thereby reducing the impact of the roller on the whole of the plant population.

- Vegetative residue due to shredding covered the clover.

- We followed up on the plants that had been crushed (clover, foxtail, ragweed and milkweed) and observed that with time, certain plants partially wilted but very slowly.

- On September 7 (4 weeks after rolling) we saw less shredded residue, as clover regrowth had gone through the mulch.

- On October 17, after collecting 4 samples from a quadrant of 21 cm * 51 cm (0.107 m2) (Table 17), we evaluated the clover biomass in strip 1 and in the control field which had been shredded. We also took samples from the residue on the soil which represented the shredded biomass (clover and weeds) or the wilted clover leaves and weeds in the rolled plot.

Table 17. Average red clover biomass (shredded vs. rolling) on October 17

Sample	**Biomass (g/quadrant)**	
	Red clover	**Shredded clover**
1	10	6
2	6	7
3	8	8
4	7	6
Average	7.75	6.75
Kg^{-ha}	**724**	**631**

- The biomass of rolled red clover is approximately 15% higher than that of shredded clover, which represents the regrowth that occurred after shredding.

- However, the sample collected from residue on the soil seemed higher in biomass (about 65%) in the rolled plot than in the one which was shredded. The wheat stubble was flattened to the ground by rolling and clover leaves were decomposing. As in the case of annual alfalfa, the shredded biomass and the subsequent regrowth produced a total biomass higher than rolled biomass.

- Although the rolled plots had much more weeds, the shredded section did not control all weeds (ragweed and the *setaria* species).

Partial conclusion

Despite the disappointing trial results of no-till soybean seeding on rye mulch, we believe this technique exhibits some potential as the effectiveness of rolling rye has already been demonstrated.

For other plants, the effectiveness of rolling was insufficient. For mustard, the plant was too short. For legumes, (peas, common vetch, annual alfalfa), the effectiveness was deficient and as a consequence, soybean could not take off properly as it was chocked off by legumes.

Part of the problem may very well be that the diameter of the roller is too large (20 inches) whereas the Rodale Institute uses 16 inches. With a smaller diameter, the blades should be less tall and as a consequence the number of hits on the stem should be greater, which in turn could increase the effectiveness of rolling operations.

The half-day demonstration organized by Ferme Longprès took place on July 4 and was attended by approximately 55 people (farmers, advisors, researchers and students).

Another member of the SPGBQ, Noël Robert, built another type of roller which he used on fall rye before sowing soybean and corn (Figure 17). With soybean, the crop was well established every 30 inches; however ragweed developed between the rows but did not choke off the soybean (Figure 18). In the case of the corn, the plant seemed to have suffered from the allelopathic effect of the rye. We must therefore be vigilant with this crop. In this case, we should perhaps roll the rye at least 2 weeks before sowing the corn.

Figure 17. Mr. Robert's roller

Figure 18. No-till soybean on fall rye mulch (Mr. Robert)

Suggested trials for 2007

- Repeating the trial of no-till soybean on rye mulch – the plot for this trial has been chosen in an area of the Ferme Longprès that has greater potential for snow coverage, which should improve winter survival rate in rye.

- The roller prototype has been made available to all farmers who wish to perform trials on their farm, provided they cover the costs of transporting the implement. Modifications can be made to the end unit (1.5 m) so as to make it usable for use on small vegetable plots.

- Mr. Noël Robert, a farmer who performed an independent trial in 2006, is interested in going forward with further trials. We should plan them at the beginning of 2007.

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