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Canada

Pest Management Centre - Agriculture and Agri-Food Canada

Pesticide Risk Reduction Program
Project Final Report

Project Title:	Management of annual grasses using living mulches in sweet corn
Project Code:	PRR07-040
Principal Investigator:	**Dr. Rob Nurse**
Date Submitted:	

Report must provide details and a complete summary of the results and technology transfer activities over all project years including:

- Executive summary
- Results, analysis and discussion of field trials
- Report on weather and weed pressure
- Report on measurement of pesticide risk reduction using EIQ
- Report on cumulative results of the two years of the project (in terms of pesticide risk reduction, and field trial success)
- Report on grower field tours (dates, attendance)
- Report on grower presentations (dates, locations) and others planned over the winter.
- Attach and/or reference publications resulting from the project

Please organise your report into the following sections:

Executive Summary *(1 page, suitable for web publication)*

Research trials were established at three locations in Quebec and Ontario from 2008 to 2009 to evaluate the effectiveness of several living mulches for management of annual grasses in sweet corn. The three living mulches evaluated were adzuki beans, fall rye (spring seeded), and oilseed radish. The living mulches were tested alone or in combination with an herbicide. The adzuki beans were paired with s-metolachlor (1.14 kg ai/ha) + linuron (0.55 kg ai/ha) PRE; the fall rye was paired with saflufenacil (75 g ai/ha) PRE; and the oilseed radish was paired with pendimethalin (1680 g ai/ha) PRE. A weed-free control (industry standard) was established by applying s-metolachlor/atrazine (2.88 kg ai/ha) PRE *fb* nicosulfuron (25 g ai/ha) + Agral 90 (0.2% v/v) POST. Additionally, as a comparison all of the herbicides were applied to the sweet corn without the living mulch. The management of annual grasses was evaluated by measuring the biomass of the weeds (separated by species) within each treatment plot in comparison to an untreated control. The living mulches when seeded alone and with no herbicide were effective in reducing the biomass of all weed species in this study in comparison to an untreated control, but not in comparison to the industry standard or the herbicides. When used alone adzuki bean was only effective on large crabgrass. However, when combined with an herbicide adzuki bean was the most effective living mulch tested except when proso millet was present. Spring

seeded fall rye plus the herbicide saflufenacil was not an effective treatment because saflufenacil does not provide any annual grass control. Therefore, these data would suggest that if used without an herbicide fall rye and oilseed radish would be most effective for annual grass control, and that when combined with an herbicide adzuki beans and oilseed radish are most effective. The herbicide plus living mulch combinations did help to lower the environmental impact of the weed management program in comparison to the industry standard by about 50%. Even though weed control may have been lower when living mulches were used alone yields did not differ from the industry standard, meaning that using living mulches alone may be a viable pesticide-free weed management option in sweet corn. Combination with herbicides; however, would provide the best balance between weed control and yield and the herbicides will also provide some soil residual control throughout the season. In summary, all living mulches were effective at suppressing weed biomass in sweet corn; however, for acceptable weed control an herbicide would need to be paired with adzuki beans and an herbicide that has activity on annual grasses would need to be paired with fall rye.

Results (*Please provide a synopsis of scientific results (data) obtained and technology transfer undertaken over **all** years of the project; please include any publications, fact sheets and other products generated in the course of the project, as well as raw data, as appendices at the end of the report*)

The trial was conducted at three locations (Harrow, Laval, and Ridgetown) between 2007 and 2009. The 2007 data are not presented as substantial modifications to the methods were made at the start of the 2008 growing season. In 2007 living mulches were seeded at the same time as the corn. Resultantly, there was a high degree of intra-specific competition between the corn and the living mulches producing unacceptable yields. This was rectified in 2008 by over-seeding the living mulch at the 5-leaf stage of the corn which corresponds to the end of the critical weed-free period.

The study was designed as a RCBD with four replicates (blocks) at each location. All data were subjected to an analysis of variance (ANOVA). There were 3 living mulches evaluated in this trial (Adzuki beans, spring seeded fall rye, and oilseed radish) and each was paired with an appropriate herbicide program. All living mulches and herbicides were evaluated by themselves; however, the living mulch/herbicide combinations were chosen based on the selectivity of the herbicide to the living mulch. The herbicide and living mulches were paired as follows: 1. Adzuki beans – s-metolachlor (1.14 kg ai/ha) + linuron (0.55 kg ai/ha) PRE; 2. Fall Rye – saflufenacil (75 g ai/ha) PRE; and 3. Oilseed radish – pendimethalin (1680 g ai/ha) PRE. A weed-free control was established by applying s-metolachlor/atrazine (2.88 kg ai/ha) PRE *fb* nicosulfuron (25 g ai/ha) + Agral 90 (0.2% v/v) POST. Finally, a non-treated control was also established where there was no living mulch planted and no herbicide applied.

Data were pooled when the environment (location * year) by treatment interaction was not significant (Table 1). Otherwise the data were separated by location and year.

Weed Biomass

Weed control provided by the living mulch systems was quantitatively assessed by collecting weed biomass. The five annual grasses across all locations with the highest densities were chosen. They were large crabgrass (DIGSA), barnyardgrass (ECHCG), green foxtail (SETVI), and proso millet (PANMI).

There were weed species specific differences in biomass reductions in relation to living mulch type.

DIGSA – When living mulches were used alone there was no difference among living mulch type for biomass reduction in large crabgrass (Table 2). However, when an herbicide was combined with the living mulch the largest biomass reduction was achieved with the Adzuki bean + herbicide combination (-72%), followed by the oilseed radish (-16%) treatment. Large crabgrass biomass in the oilseed radish and fall rye treatments was not different from the biomass in the untreated control. Therefore, the best control option to control large crabgrass is the combination of an Adzuki bean living mulch and the

herbicides s-metolachlor + linuron; however, the addition of the living mulch did not add a significant benefit in comparison to the application of the herbicide alone.

ECHCG – The interaction between location and treatment was significant for barnyardgrass (Table 1). Therefore data for barnyardgrass were separated by location. At Laval the best living mulch (alone) for biomass reduction was spring seeded fall rye (Table 2). At Ridgetown spring seeded fall rye was the least effective living mulch, and the best biomass reduction was obtained using oilseed radish. Interestingly, when the living mulches were combined with an herbicide the least effective treatment at both locations was the spring-seeded fall rye and the best treatments were the adzuki bean and oilseed radish combinations. At Laval the combination of the fall rye or oilseed radish living mulches with an herbicide improved biomass reductions in comparison to the application of the herbicide alone. At Ridgetown the adzuki bean and oilseed radish combinations were better than the herbicide alone. Therefore, these data suggest that the oilseed radish plus pendimethalin treatment was the most consistent treatment for barnyardgrass biomass reduction.

SETVI – When living mulches were used alone, spring seeded fall rye and oilseed radish were best able to reduce green foxtail biomass in comparison to an untreated control. The addition of an herbicide did not improve the effectiveness of the oilseed radish; however, the effectiveness of the fall rye was reduced. The adzuki bean living mulch required an herbicide to effectively reduce green foxtail biomass.

PANMI – The best living mulches alone were fall rye and oilseed radish. The addition of the herbicide to the living mulch did not improve biomass reduction except for the adzuki bean treatment. For proso millet the living mulches on their own were the most effective treatments.

In summary, the living mulches when seeded alone and with no herbicide were effective in reducing the biomass of all weed species in this study in comparison to an untreated control. When used alone adzuki bean was only effective on large crabgrass. However, when combined with an herbicide the adzuki beans were the most effective living mulch tested except when proso millet was present. Spring seeded fall rye plus the herbicide saflufenacil was not an effective treatment because saflufenacil does not provide any annual grass control. Therefore, these data would suggest that if used without an herbicide fall rye and oilseed radish would be most effective for annual grass control, and that when combined with an herbicide adzuki beans and oilseed radish are most effective.

EIQ of herbicide selections

The EIQ values were obtained from Kovach et al (2005).

The E.I. (environmental impact) values were calculated using the equation EIQ x % a.i. x Rate.

For herbicide mixtures the E.I.'s were calculated according to the proportion of the product in the mixtures. For tank-mixes the E.I. was calculated as the sum of all components.

The environmental impact (EI) of all herbicides paired with the living mulches were lower than for the Industry standard (Table 4). The most environmentally friendly product was saflufenacil which was paired with fall rye. Unfortunately, saflufenacil does not provide any annual grass control. The E.I.'s of the herbicides for adzuki beans and oilseed radish were equivalent to each other and approximately 50% of the industry standard.

Sweet corn height and time to 50% tassel

To ensure that the living mulch treatments and herbicides tested did not cause visual reductions in corn vigour or maturity we tested sweet corn height and time to 50% tassel. For all locations there were no differences among treatments for either variable (Table 3).

Sweet Corn Yield

Sweet corn yield was measured each year. The yield was divided into two components; marketable and non-marketable based on the % kernel fill and cob diameter. There was a significant location by treatment interaction necessitating the need to separate data by location. Furthermore yields at Ridgetown needed to be separated by year (Table 3). Because the trends for the marketable and non-marketable yields did not differ statistically, the total yields (both components) are presented in this report.

Living mulch only – Across all locations the highest yields were obtained in the fall rye and oilseed radish treatments. However, at Harrow and Ridgetown (2009) the yields were lower than the weed-free control (industry standard). These results are consistent with the biomass reduction results.

Herbicide + living mulch – At Harrow and Laval there was no difference among the yields of all three living mulches. At Laval all living mulches yielded as well as the weed-free control, however, in Harrow only the fall rye treatment had a comparable yield. At Ridgetown in 2008 the highest yielding treatments were fall rye and oilseed radish and in 2009 the highest yielding treatments were adzuki beans and oilseed radish; however, both had yields lower than the weed-free control.

Interestingly, even though there was very poor weed control for the fall rye treatments, there were few negative impacts on yield.

Herbicide only – In all cases the yields for the herbicide alone treatments were equivalent to or higher than the yields obtained when the herbicide was combined with the living mulches.

Therefore these data suggest that if you are going to use an herbicide there may be no benefit to including a living mulch because any benefit in weed control does not translate into yield. However, the yields obtained when using either fall rye or oilseed radish alone without an herbicide were equivalent to the herbicide only treatments, but not necessarily the industry standard in all cases. Therefore, a living mulch only system using fall rye or oilseed radish may be a successful pesticide-free alternative.

Table 1. P-values from statistical analysis

Factor	Biomass				Height	Time to Tassel	Yield
	DIGSA	ECHCG	SETVI	PANMI			
				p-value			
Replicate	0.8894	0.7698	0.1846	0.1699	0.1316	0.1971	0.3048
Environment (E)	0.1554	0.1020	0.2145	0.1545	0.0582	0.1613	0.0666
E*treatment	0.0519	**0.0153**	0.0922	0.1455	0.0678	0.0823	**0.0003**

Table 2. Annual Grass Biomass

Treatment	Biomass (g/m^2)				
	DIGSA	ECHCG		SETVI	PANMI
	Pooled	Laval	RC	Pooled	Pooled
Living Mulch Only					
Adzuki	16.3b	64.2b	74.5b	40.0a	29.9a
Fall Rye (FR)	10.8b	18.6c	68.6b	7.9b	1.9c
Oilseed Radish (OSR)	10.5b	30.4b	2.0d	5.2b	0c
Herbicide + Living Mulch					
Herbicide (H) + Adzuki	5.9c	10.4c	0.9d	4.5b	14.0b
H + FR	38.1a	47.8b	157.9a	69.5a	13.7b
H + OSR	17.8b	16.4c	10.1d	8.9b	2.3c
Herbicide Only					
Herbicide – Adzuki	8.8c	14.6c	28.0c	8.8b	26.1b
H – FR	28.4a	95.7a	85.4b	33.5a	65.0a
H – OSR	12.7b	92.5a	31.4c	7.2b	12.1b
UTC	21.1ab	105.5a	34.3c	33.4a	12.8b

(-) minus; (+) plus; UTC – Untreated Control; RC- Ridgetown Campus; DIGSA – *Digitaria sanguinalis*; ECHCG – *Echinochloa crus-galli*; SETVI – *Setaria viridis*; SETFA – *Setaria faberi*; PANMI – *Panicum miliaceum*

Table 3. Sweet corn height, time to 50% tassel, and total yield.

Treatment	Height (cm)	Time to 50% Tassel (d)	Yield (t/ha)			
	pooled	pooled	Harrow pooled	Laval pooled	RC 2008	RC 2009
Living Mulch Only						
Adzuki	46a	56a	8.0c	3.5d	4.6d	3.0e
Fall Rye	44a	54a	14.7b	6.6abc	19.4a	13.5b
Oilseed Radish	46a	53a	16.7b	5.5bcd	19.5a	12.8b
Herbicide + Living Mulch						
Herbicide + Adzuki	46a	54a	16.4b	8.6a	9.4c	12.0bc
H + FR	46a	53a	18.7ab	7.1abc	16.2ab	5.7de
H + OSR	45a	54a	18.4b	6.1abcd	16.5ab	10.4bcd
Herbicide Only						
Herbicide – Adzuki	44a	54a	19.3ab	7.4abc	16.9ab	14.9ab
H – FR	46a	53a	22.7a	4.6cd	19.5a	7.3cde
H – OSR	45a	53a	21.0ab	6.6abc	17.7a	14.8ab
UTC	46a	56a	4.8c	3.1d	13.1bc	3.4e
WFC	44a	53a	23.0a	8.4ab	19.8a	18.5a

Table 4. The calculated environmental impact of treatments associated with each living mulch.

Herbicide	Living Mulch	EIQ	% a.i.	Rate (kg ai/ha)	EI
s-metolachlor + linuron	Adzuki beans	22 + 19.32	0.824 + 0.4	1.14 + 0.55	25.0
saflufenacil	Fall rye	12	0.7	0.075	0.63
pendimethalin	Oilseed radish	30.17	0.455	1.68	23.1
s-metolachlor/atrazine fb nicosulfuron	Industry Standard	22/22.85 fb 19.52	0.4/0.32 fb 0.75	2.88 fb 0.025	46.8

Discussion (*Please address deliverables and progress toward delivering final project outputs)*

Outputs: Scientific and extension reports, grower field demonstrations/field tours, presentations at grower and scientific meetings to promote research results

For specific discussion of results see previous section.

Field Tours –

1. Ontario Weed Tour 2007 to 2009 (Harrow and Ridgetown). Showcased trial (15 min. presentation by R. Nurse) at Harrow in 2008.
2. Harrow Research Station Open House – 2008.
3. Harrow Research Station 100th Anniversary – 2009.
4. Ridgetown Campus, University of Guelph – vegetable open house – 2007 to 2009.
5. Laval University Weed Tour days – 2007 to 2009.

Oral Presentations –

1. Mensah, R., G. Leroux, and R.E. Nurse. 2009. Utilisation de la fève adzuki (*Vigna angularis*), du radis huileux (*Raphanus sativus*) et du seigle d`automne (*Secale cereale*), combinés ou non à des doses faibles ou moyennes d`herbicides pour le contrôle des mauvaises herbes annuelles dans le maïs sucré (*Zea mays* L.). Proceedings of the 63rd Canadian Weed Science Society Meeting. (Winner of best graduate student presentation for R. Mensah).

Posters –

1. Nurse, R.E., D.E. Robinson, and G. Leroux. 2009. Living mulch systems for annual grass control in sweet corn. Ontario Fruit and Vegetable Convention. St. Catherines. Feb . 18-19.

Publications –

1. Mensah, R. 2009. Utilisation de la fève adzuki (*Vigna angularis*), du radis huileux (*Raphanus sativus*) et du seigle d`automne (*Secale cereale*), combinés ou non à des doses faibles ou moyennes d`herbicides pour le contrôle des mauvaises herbes annuelles dans le maïs sucré (*Zea mays* L.). MSc Graduate Thesis, Laval University.
2. Peer reviewed manuscript in preparation for submission to Weed Science.

Key messages pertaining to the project (*In brief paragraphs or bullets, please address the following. Note that the information provided here is intended to be used for preparation of factsheet to inform stakeholders of project.*)

- Why the project was undertaken, what issue(s) it addressed
  - The project was undertaken to develop weed management systems that would not only potentially reduce pesticide use, but also reduce soil erosion, improve soil fertility and have treatments that would be suitable for organic growers.

- Who will benefit from the project
    - The key benefactors of the information collected from the research would be Canadian sweet corn growers. The adoption of suitable treatments from the trial may reduce pesticide costs and improve environmental safety.
- The general approach taken and key collaborators involved
    - The approach was to establish the trial in two key sweet corn regions in Canada, Ontario and Quebec. Two locations in Ontario were chosen to represent different crop heat units and soil types. The trial was established as a RCBD with a full factorial of treatments present. Three potential living mulch systems were tested. Adzuki beans, which would not usually be considered, spring-seeded fall rye, and oilseed radish.
    - The key collaborators external to AAFC were the University of Guelph, Ridgetown Campus, Laval University and the Ontario Processing Vegetable Growers.
- Key findings and outcomes of the project
    - When living mulches were used for weed management in the absence of an herbicide the best options were spring-seeded fall rye and oilseed radish.
    - When living mulches were paired with an herbicide there was a benefit in terms of weed control for adzuki beans; however, overall, there were no benefits in terms of yield in comparison to the herbicide only treatments or the industry standard.
- Pesticide risk reduction results (as measured or anticipated)
    - When an herbicide program was paired with a living mulch the environmental impact (EI) of the management system could be reduced by more than 50%.
    - The living mulch systems by themselves had reduced weed control in comparison to the industry standard, but had equivalent yields and therefore, could be a pesticide-free option for growers.
- Future development opportunities
    - More research needs to be conducted investigating the optimal living mulch seeding rates and whether or not when the living mulches are paired with an herbicide if the herbicide dose may be reduced.
- Selected pictures or graphics which illustrate the work and/or outcomes of the project
- Contact information (if other than principle investigator)
    - Contact the P.I., Dr. Robert Nurse

Suggested Next Steps for implementation of results *(point form, please)*

- A manuscript is being prepared for publication in Weed Science.
- Dr. Nurse will present the research results at the 2012 Weed Science Society of America meeting.
- A final report will be provided to the Ontario Processing Vegetable Growers with a request to present the results at their annual meeting in January of 2012.