

# Four years of herbicide trials for shrub willow biomass production systems in the Upper Peninsula of Michigan

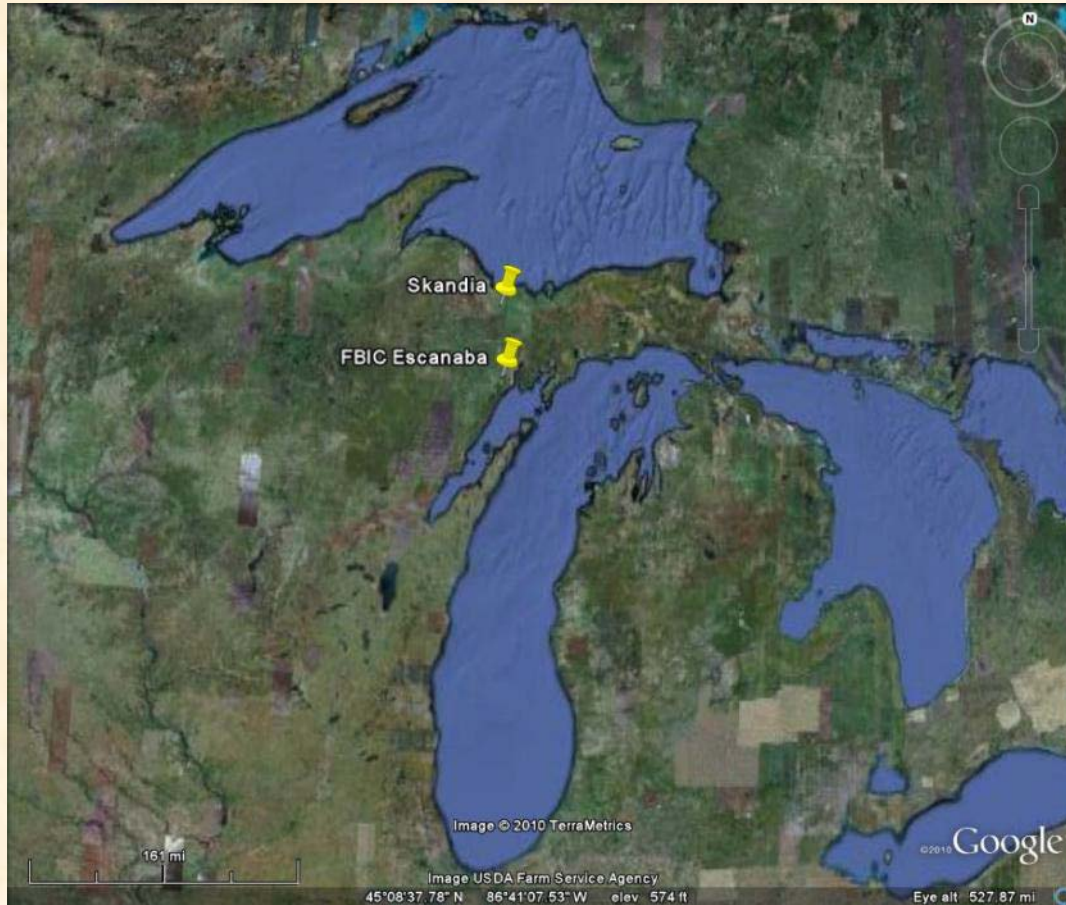
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**Table 1. Herbicide trial locations**

<i>Site Name</i>	<i>Latitude/Longitude</i>	<i>Soil Series</i>
Escanaba, MI	45°45'50"N / 87°11'30W	Onaway fine sandy loam
Skandia, MI	46°21'43"N / 87°14'48"W	Munising fine sandy loam



# The Chemicals...

<b>Table 2. Herbicides tested on newly planted willow cuttings.</b>				
<i>Common Name</i>	<i>Trade Name</i>	<i>Manufacturer</i>	<i>Mode of Action</i>	<i>Year Tested</i>
oxyfluorfen	Goal 2XL	Dow AgriSciences	Protoporphyrinogen oxidase inhibitor	2010
oxyfluorfen	Galigan 2E	Makhteshim-Agan	Protoporphyrinogen oxidase inhibitor	2010
flumioxazin	SureGuard	Valent	Protoporphyrinogen oxidase inhibitor	2009
flumioxazin	Chateau	Valent	Protoporphyrinogen oxidase inhibitor	2010
diuron	Karmex	DuPont	Photosynthesis II inhibitor	2010
simazine	Princep 4L	Syngenta	Photosynthesis II inhibitor	2010
simazine + oxyfluorfen	Princep 4L & Goal 2XL	Syngenta & Dow AgriSciences	Photosynthesis II inhibitor + Protoporphyrinogen oxidase inhibitor	2007, 2008
pendimethalin	Prowl H <sub>2</sub> O	BASF	Mitosis inhibitor	2010
imazaquin + pendimethalin	Scepter 70DG & Pendulum Aquacap	BASF	Acetolactale synthesis inhibitor + Mitosis inhibitor	2007
pendimethalin + oxyfluorfen	Prowl H <sub>2</sub> O + Goal 2XL	BASF & Dow AgroSciences	Mitosis inhibitor + Protoporphyrinogen oxidase inhibitor	2010
s-metolachlor	Dual Magnum	Syngenta	Mitosis inhibitors	2010
pendimethalin + s-metolachlor	Prowl H <sub>2</sub> O + Dual Magnum	BASF & Syngenta	Both are mitosis inhibitors	2010
norflurazon	Solicam DF	Syngenta	Carotenoid biosynthesis inhibitor	2008, 2009, 2010

# The Taxa...

**Table 3. Willow taxa tested in herbicide trials.**

<i>Taxa</i>	<i>Code</i>	<i>Year Tested</i>
<i>Salix dasyclados</i>	SV1	2007, 2010
<i>S. sachalinensis</i>	SX61	2007, 2010
<i>S. miyabeana</i>	SX67	2007
<i>S. viminalis</i> x <i>S. miyabeana</i>	Tully Champion	2008, 2009, 2010
<i>S. sachalinensis</i> x <i>S. miyabeana</i>	Sherburne	2008, 2009, 2010
<i>S. purpurea</i>	Fish Creek	2009, 2010
<i>S. miyabeana</i>	SX64	2010
<i>S. purpurea</i> x <i>S. miyabeana</i>	Millbrook	2010



- Split-plot, Randomized block
- 2, 3, or 7 taxa in sub-plots
- Herbicide treatments in main plots
- Mechanical & Untreated Controls



# The Common Design...

## U08an - Willow Herbicide Trial - 2009

Test of four levels of two pre-emergent herbicides rates on three newly planted willow clones.

Will compare growth & survival as well as weed control effectiveness.

A mechanical weeding and untreated control treatments are included.

Randomized block, split-plot design with 4 blocks and 10-tree sub-plots for each clone.

The ten Herbicide treatments are the main plot treatment and the three willow clones are the sub-plot treatment.

Main plot rows are 5-foot apart with cuttings planted 1.5-foot apart within the rows. Herbicide spray band is 48-inches wide using two 8004 nozzles

Planted 8' unrooted cuttings by hand on June 5, 2009. Treatments applied immediately after.

1xSG	M	2xSG	3xSG	1xSol	4xSG	2xSol	U	3xSol	4xSol
34	34	31	11	34	31	11	11	34	34
11	31	11	34	11	11	34	31	31	11
31	11	34	31	31	34	31	34	11	31

BLOCK 3

M	2xSG	1xSol	2xSol	4xSol	3xSol	4xSG	1xSG	3xSG	U
11	11	34	34	34	11	11	34	34	31
34	31	31	11	31	31	31	11	11	34
31	34	11	31	11	34	34	31	31	11

3xSol	1xSG	2xSol	3xSG	M	U	4xSG	2xSG	4xSol	1xSol
11	34	31	11	31	11	11	11	34	34
34	11	11	34	34	31	34	34	31	11
31	31	34	31	11	34	31	31	11	31

BLOCK 4

M	U	1xSG	2xSG	3xSG	4xSol	3xSol	4xSG	2xSol	1xSol
11	31	31	31	34	34	11	34	31	11
34	34	34	11	11	11	34	11	34	31
31	11	11	34	31	31	31	31	11	34

Herbicide Name	EPA Reg No.	Active Ingredient	% a.L.	
Sollicam DF	100-840	Norflurazon	78.8	
SureGuard	50630-120	Flumioxazin	51	
Site	LD.	Herbicide	A.L. Amount	Units / Acre
U08an	1xSG	SureGuard	4.1	ozs/acre
U08an	2xSG	SureGuard	8.2	ozs/acre
U08an	3xSG	SureGuard	12.2	ozs/acre
U08an	4xSG	SureGuard	16.3	ozs/acre
U08an	1xSol	Sollicam	3.9	lbs/acre
U08an	2xSol	Sollicam	7.9	lbs/acre
U08an	3xSol	Sollicam	11.8	lbs/acre
U08an	4xSol	Sollicam	15.7	lbs/acre

Map Name	accession #	AKA Nick Name	
34	0882-34	Fish Creek	
11	09202-011	Tully Champion	
31	0871-31	Sherburne	

1 block = 10-passes of 1x rate (1,2,3,4x's)					
1pass = 4' x 45' = 180 sqft) x 10passes x 4blocks = 7,200 sqft = .2 acres					
use 2 nozzles 8004 nozzles and 40 gal, 2.4 MPH (85' 300', 12.75' /45') JD 4200 In B-2 @ 2000rpm					
25 acres requires 10 gallons water, 1 oz or 28.4 gm of Sure Guard Product (4 oz/acre)					
25 acres requires 10 gallons water, .625 lbs of Sollicam Product (2.5 lbs / acre)					

chemical formula
Norflurazon = 4-chloro-5-(methylamino)-2-(a,a,a-trifluoro-m-lyl)-3-(2H)-pyridazinone
Flumioxazin = (z)-1-(4-fluoro-3,4-dihydro-3-oxo-4-(2-propenyl)-2H-1,4-benzoxazin-5-yl)-4,5,6,7-tetrahydro-1H-benzooxol-1,3(2H)-dione

## Methods:

1. Plant 10" hardwood cuttings in weed-free, tilled soil.
2. Apply herbicides immediately after planting.
3. Monitor & score effects @ 30, 60, and end of season.
4. Report end of season height, survival, # stems, & weed cover.
5. Comparisons here made using unweeded control as standardizing factor.



2007 Trial Design
4 blocks
3 taxa (see Table 2)
Untreated control
Mechanical weeding
Scepter <sub>0.25</sub> + Pendulum <sub>2.0</sub>
Scepter <sub>0.25</sub> + Pendulum <sub>4.0</sub>
Scepter <sub>0.50</sub> + Pendulum <sub>2.0</sub>
Scepter <sub>0.50</sub> + Pendulum <sub>4.0</sub>
Goal <sub>1.0</sub> + Princep <sub>2.6</sub>
Goal <sub>1.0</sub> + Princep <sub>5.2</sub>
Goal <sub>2.0</sub> + Princep <sub>2.6</sub>
Goal <sub>2.0</sub> + Princep <sub>5.2</sub>
<i>(subscripts are lbs a.i./acre)</i>

2008 Trial Design
4 blocks
2 taxa (see Table 2)
Untreated control
Mechanical weeding
Goal <sub>1.0</sub> + Princep <sub>2.0</sub>
Goal <sub>1.0</sub> + Princep <sub>4.0</sub>
Goal <sub>2.0</sub> + Princep <sub>2.0</sub>
Goal <sub>2.0</sub> + Princep <sub>4.0</sub>
Solicam <sub>0.6</sub>
Solicam <sub>1.2</sub>
Solicam <sub>2.4</sub>
Solicam <sub>3.6</sub>
<i>(subscripts are lbs a.i./acre)</i>

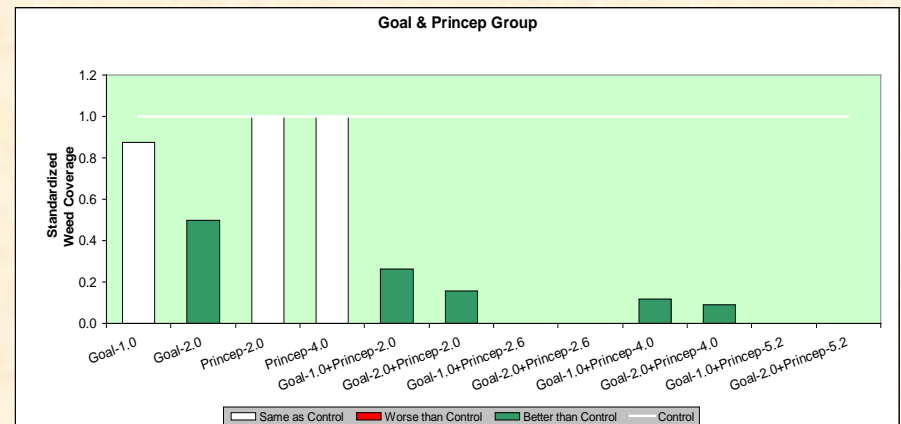
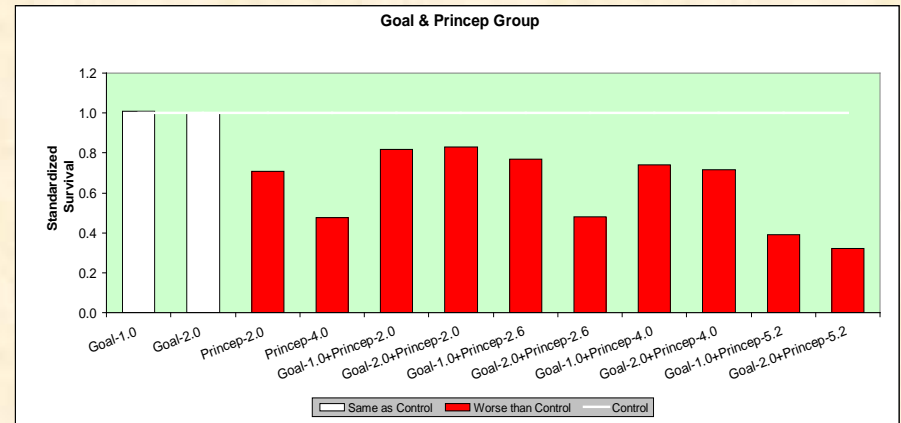
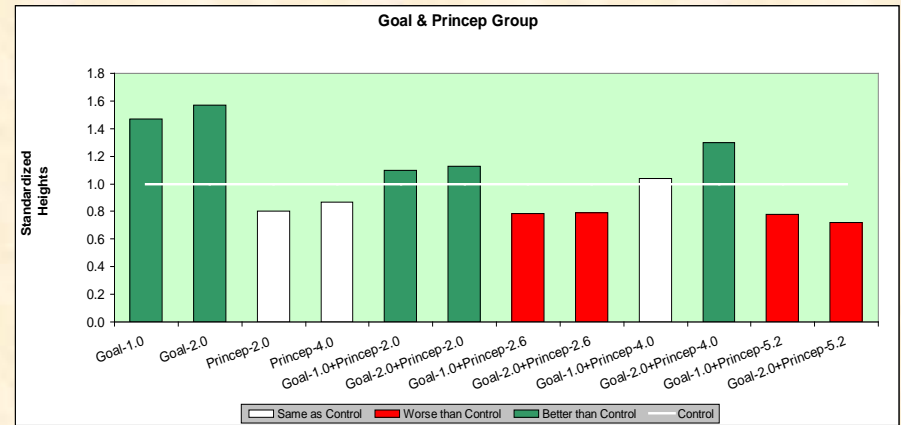
2009 Trial Design
11 incomplete blocks (over 3 sites)
3 taxa (see Table 2)
Untreated control
Mechanical weeding
SureGuard <sub>0.125</sub>
SureGuard <sub>0.25</sub>
SureGuard <sub>0.375</sub>
SureGuard <sub>0.50</sub>
SureGuard <sub>0.75</sub>
SureGuard <sub>1.0</sub>
Solicam <sub>2.0</sub>
Solicam <sub>4.0</sub>
Solicam <sub>6.0</sub>
Solicam <sub>8.0</sub>
Solicam <sub>12.0</sub>
Solicam <sub>16.0</sub>
<i>(subscripts are lbs a.i./acre)</i>

2010 Trial Design	
4 blocks	
7 taxa (see Table 2)	
Untreated control	
Mechanical weeding	
<i>Pre-emergence treatments</i>	
Goal <sub>1.0</sub>	Goal <sub>2.0</sub>
Galigan <sub>1.0</sub>	Galigan <sub>2.0</sub>
Princep <sub>2.0</sub>	Princep <sub>4.0</sub>
Prowl <sub>1.9</sub>	Prowl <sub>3.8</sub>
Dual <sub>1.9</sub>	Dual <sub>3.8</sub>
Solicam <sub>2.0</sub>	Solicam <sub>4.0</sub>
Chateau <sub>0.188</sub>	Chateau <sub>0.375</sub>
Karmex <sub>2.0</sub>	Karmex <sub>4.0</sub>
Goal <sub>1.0</sub> + Prowl <sub>1.9</sub>	
Dual <sub>1.9</sub> + Prowl <sub>1.9</sub>	
<i>Post-emergence treatments</i>	
Stinger <sub>0.125</sub>	Stinger <sub>0.25</sub>
Fusilade <sub>0.188</sub>	Fusilade <sub>0.375</sub>
Poast <sub>0.188</sub>	Poast <sub>0.375</sub>
Assure <sub>0.069</sub>	Assure <sub>0.138</sub>
Sandea <sub>0.047</sub>	Sandea <sub>0.094</sub>
<i>(subscripts are lbs a.i./acre)</i>	

# Goal & Princep Group

Treatment	Height	Survival	Weeds
Goal-1.0 (2010)	1.469	1.009	0.875
Goal-2.0 (2010)	1.568	1.000	0.500
Princep-2.0 (2010)	0.802	0.706	1.000
Princep-4.0 (2010)	0.867	0.477	1.000
Goal-1.0+Princep-2.0 (2008)	1.099	0.818	0.263
Goal-2.0+Princep-2.0 (2008)	1.127	0.831	0.158
Goal-1.0+Princep-2.6 (2007)	0.782	0.767	☒
Goal-2.0+Princep-2.6 (2007)	0.790	0.478	☒
Goal-1.0+Princep-4.0 (2008)	1.036	0.740	0.118
Goal-2.0+Princep-4.0 (2008)	1.299	0.714	0.092
Goal-1.0+Princep-5.2 (2007)	0.781	0.389	☒
Goal-2.0+Princep-5.2 (2007)	0.721	0.322	☒

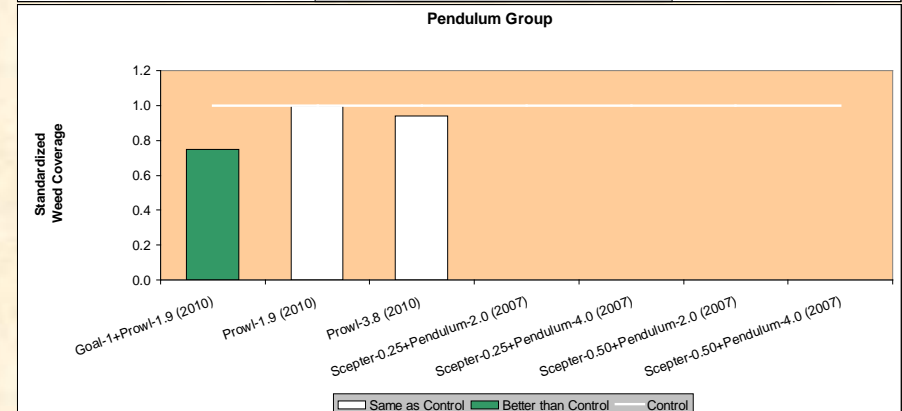
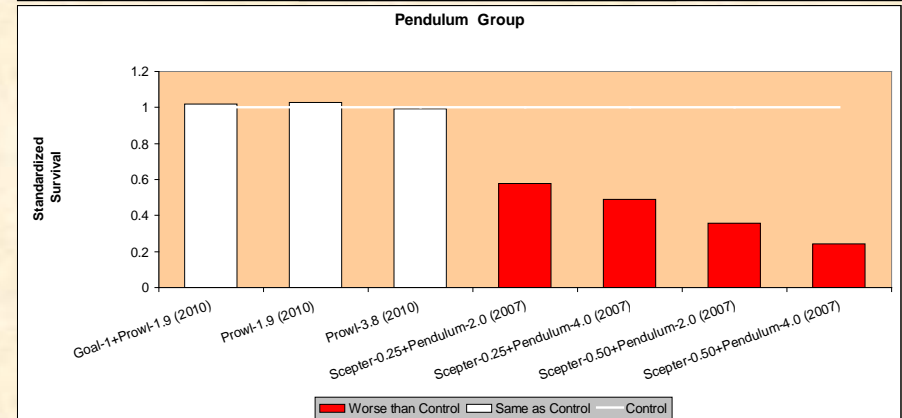
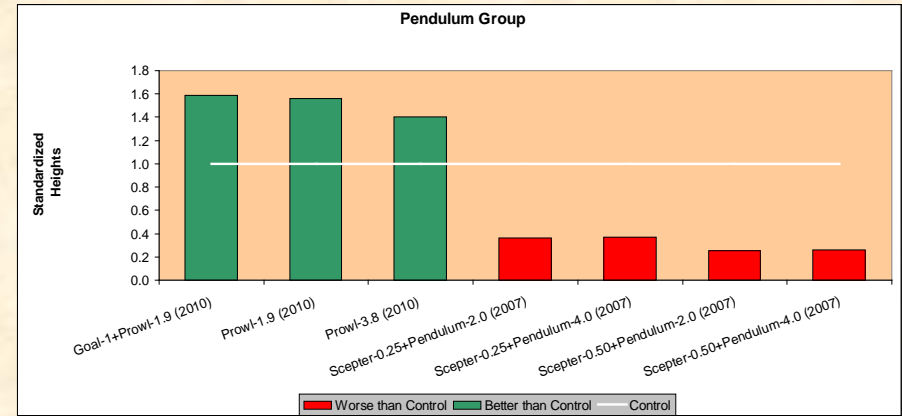
Goal alone was more reliably successful than combinations with Princep. Cutting survival was the main problem.



# Pendulum Group

Treatment	Height	Survival	Weeds
Goal-1+Prowl-1.9 (2010)	1.590	1.018	0.750
Prowl-1.9 (2010)	1.558	1.028	1.000
Prowl-3.8 (2010)	1.403	0.991	0.938
Scepter-0.25+Pendulum-2.0 (2007)	0.360	0.578	☒
Scepter-0.25+Pendulum-4.0 (2007)	0.370	0.489	☒
Scepter-0.50+Pendulum-2.0 (2007)	0.252	0.356	☒
Scepter-0.50+Pendulum-4.0 (2007)	0.260	0.244	☒

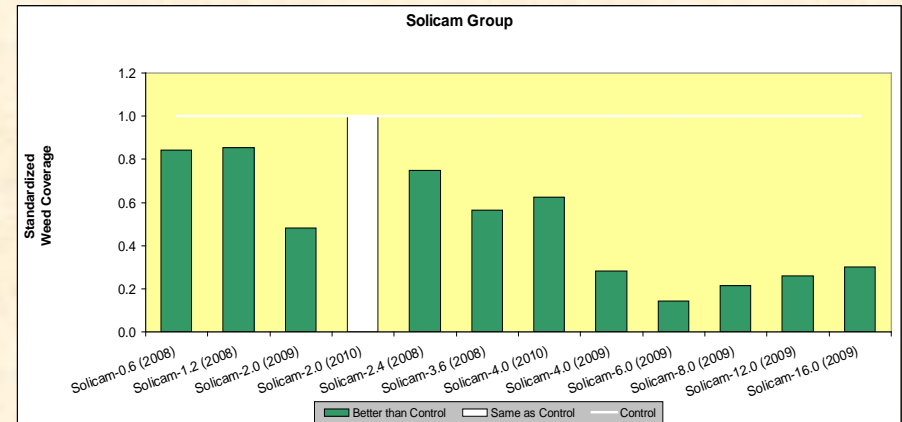
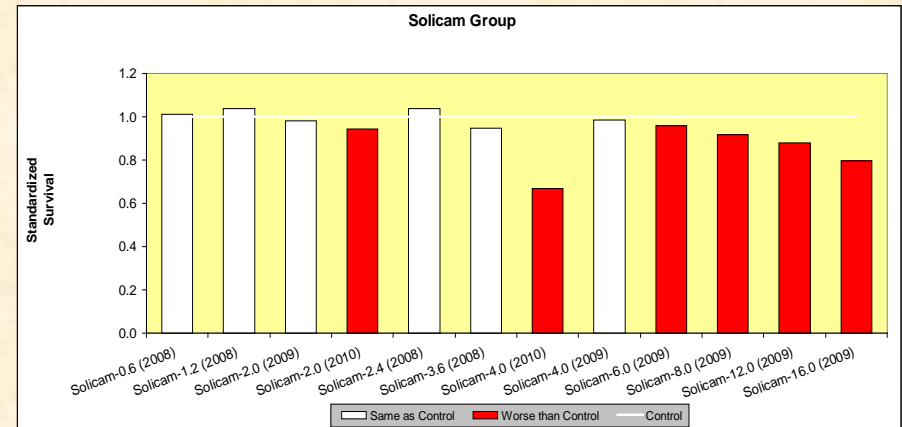
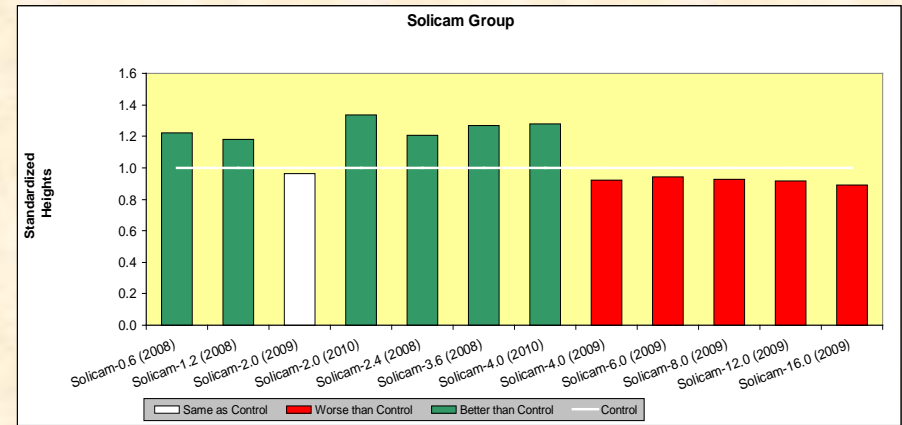
Problems with Scepter-Pendulum combinations occurred in 2007 when weather conditions were abnormal and bear repeating in light of subsequent performance.



# Solicam Group

Treatment	Height	Survival	Weeds
Solicam-0.6 (2008)	1.220	1.013	0.842
Solicam-1.2 (2008)	1.180	1.039	0.855
Solicam-2.0 (2009)	0.961	0.981	0.481
Solicam-2.0 (2010)	1.337	0.945	1.000
Solicam-2.4 (2008)	1.204	1.039	0.750
Solicam-3.6 (2008)	1.271	0.948	0.566
Solicam-4.0 (2010)	1.279	0.670	0.625
Solicam-4.0 (2009)	0.922	0.985	0.284
Solicam-6.0 (2009)	0.940	0.957	0.143
Solicam-8.0 (2009)	0.929	0.918	0.215
Solicam-12.0 (2009)	0.914	0.881	0.260
Solicam-16.0 (2009)	0.890	0.797	0.301

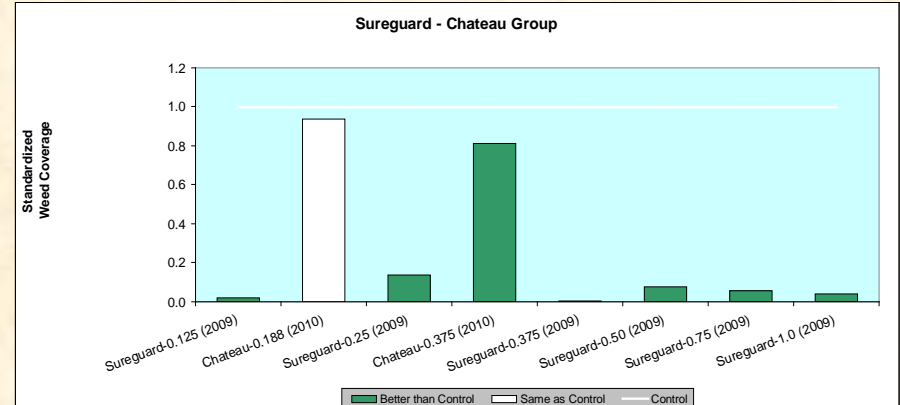
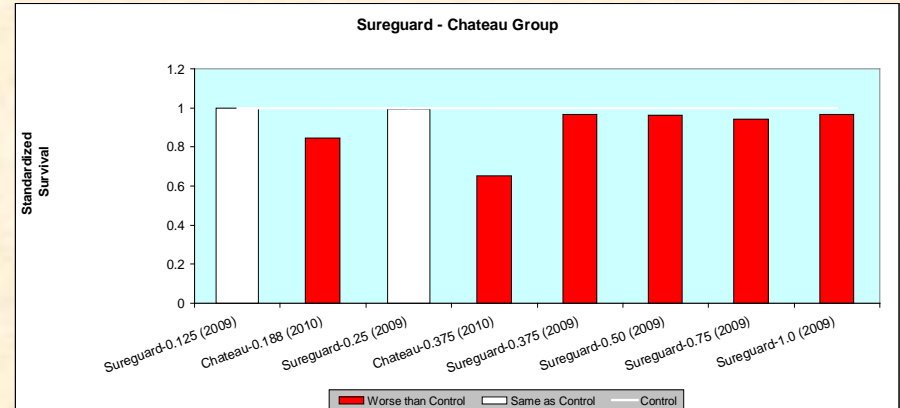
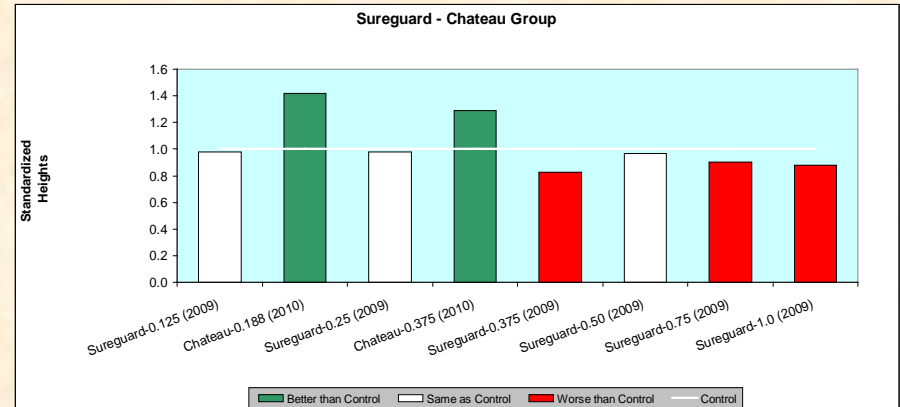
Solicam at rates below about 3# a.i./acre seems quite promising (see 2<sup>nd</sup> year surprise, below).



# SureGuard- Chateau Group

Treatment	Height	Survival	Weeds
Sureguard-0.125 (2009)	0.976	1.000	0.022
Chateau-0.188 (2010)	1.419	0.844	0.938
Sureguard-0.25 (2009)	0.980	0.994	0.136
Chateau-0.375 (2010)	1.289	0.651	0.813
Sureguard-0.375 (2009)	0.829	0.967	0.000
Sureguard-0.50 (2009)	0.969	0.961	0.075
Sureguard-0.75 (2009)	0.904	0.941	0.055
Sureguard-1.0 (2009)	0.880	0.966	0.041

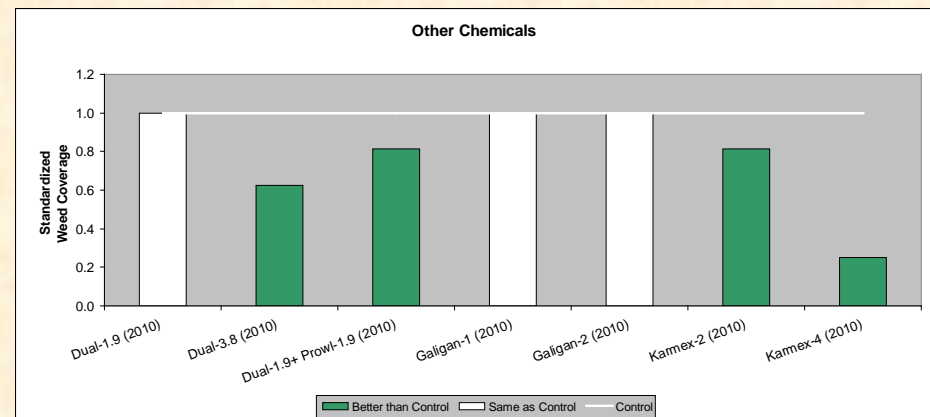
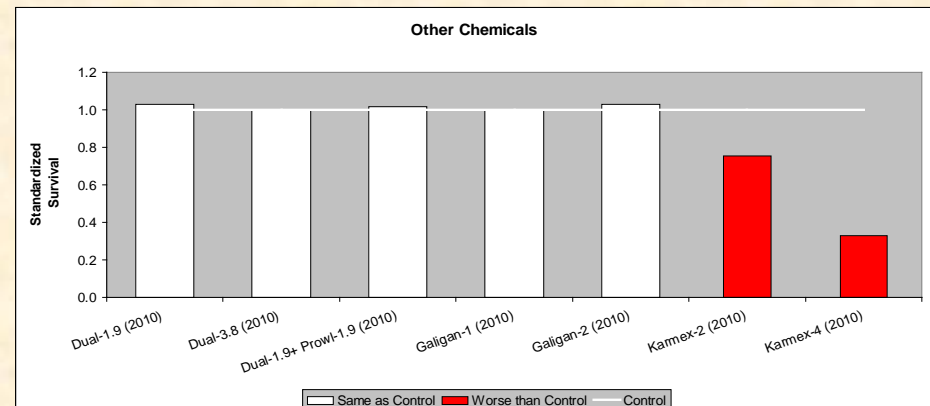
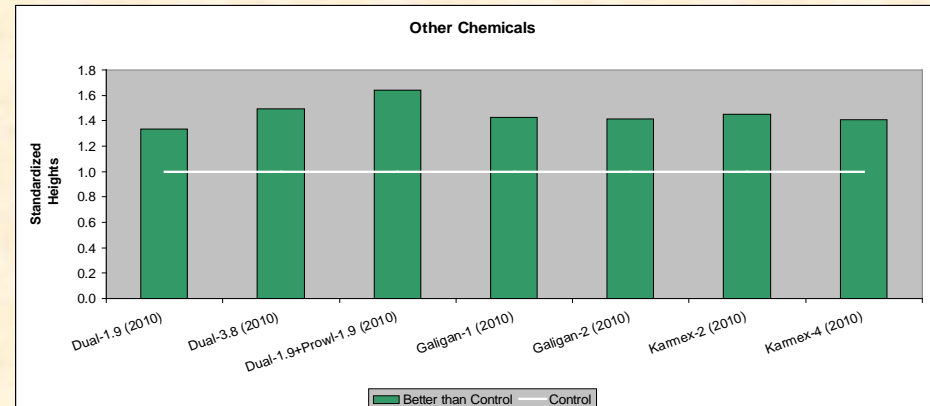
SureGuard/Chateau at rates below about 0.30# a.i./acre seem effective (see 2<sup>nd</sup> year surprise, below).



# Other Chemicals

Treatment	Height	Survival	Weeds
Dual-1.9 (2010)	1.337	1.028	1.000
Dual-3.8 (2010)	1.493	1.000	0.625
Dual-1.9+Prowl-1.9 (2010)	1.641	1.018	0.813
Galigan-1 (2010)	1.429	1.000	1.000
Galigan-2 (2010)	1.415	1.028	1.000
Karmex-2 (2010)	1.453	0.752	0.813
Karmex-4 (2010)	1.407	0.330	0.250

Karmex causes excessive mortality of willow. Other chemicals look promising.



# Results at one of the 2009 sites

First & Second year response to weed control in U08ap

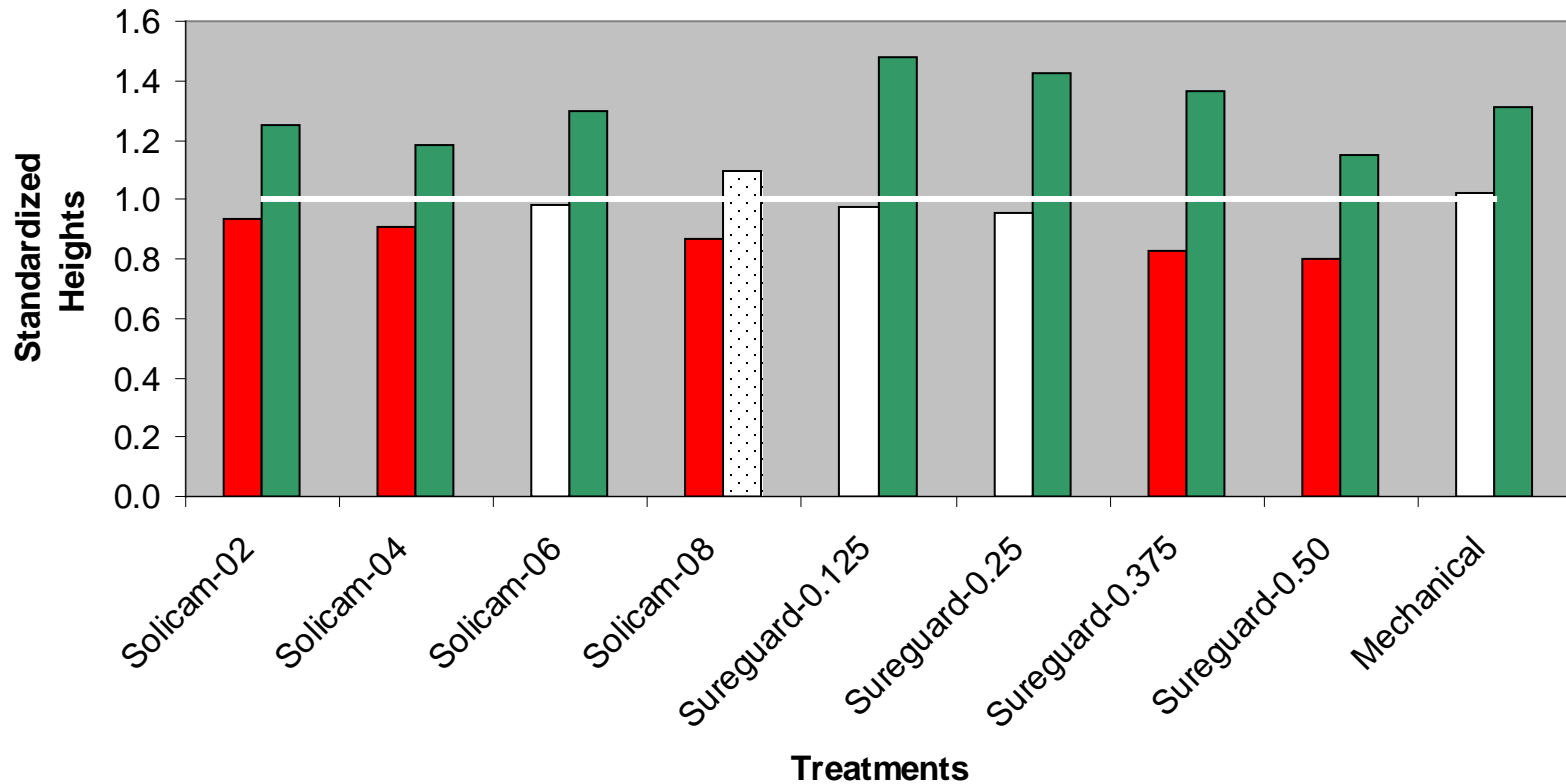
	Weeds	Height	Stems
Treatment	2009	2009	2009
Solicam-02	0.267	0.935	1.049
Solicam-04	0.083	0.905	1.032
Solicam-06	0.100	0.979	0.998
Solicam-08	0.017	0.870	0.954
Sureguard-0.125	0.017	0.976	1.020
Sureguard-0.25	0.017	0.956	0.918
Sureguard-0.375	0.000	0.829	0.939
Sureguard-0.50	0.000	0.803	0.869
Mechanical	0.133	1.020	1.067
<i>LSD</i>	<i>0.107</i>	<i>0.054</i>	<i>0.084</i>
<i>upper bound</i>	<i>1.107</i>	<i>1.054</i>	<i>1.084</i>
<i>lower bound</i>	<i>0.893</i>	<i>0.946</i>	<i>0.916</i>

# 2nd Year Surprise



# 2<sup>nd</sup> Year Surprise

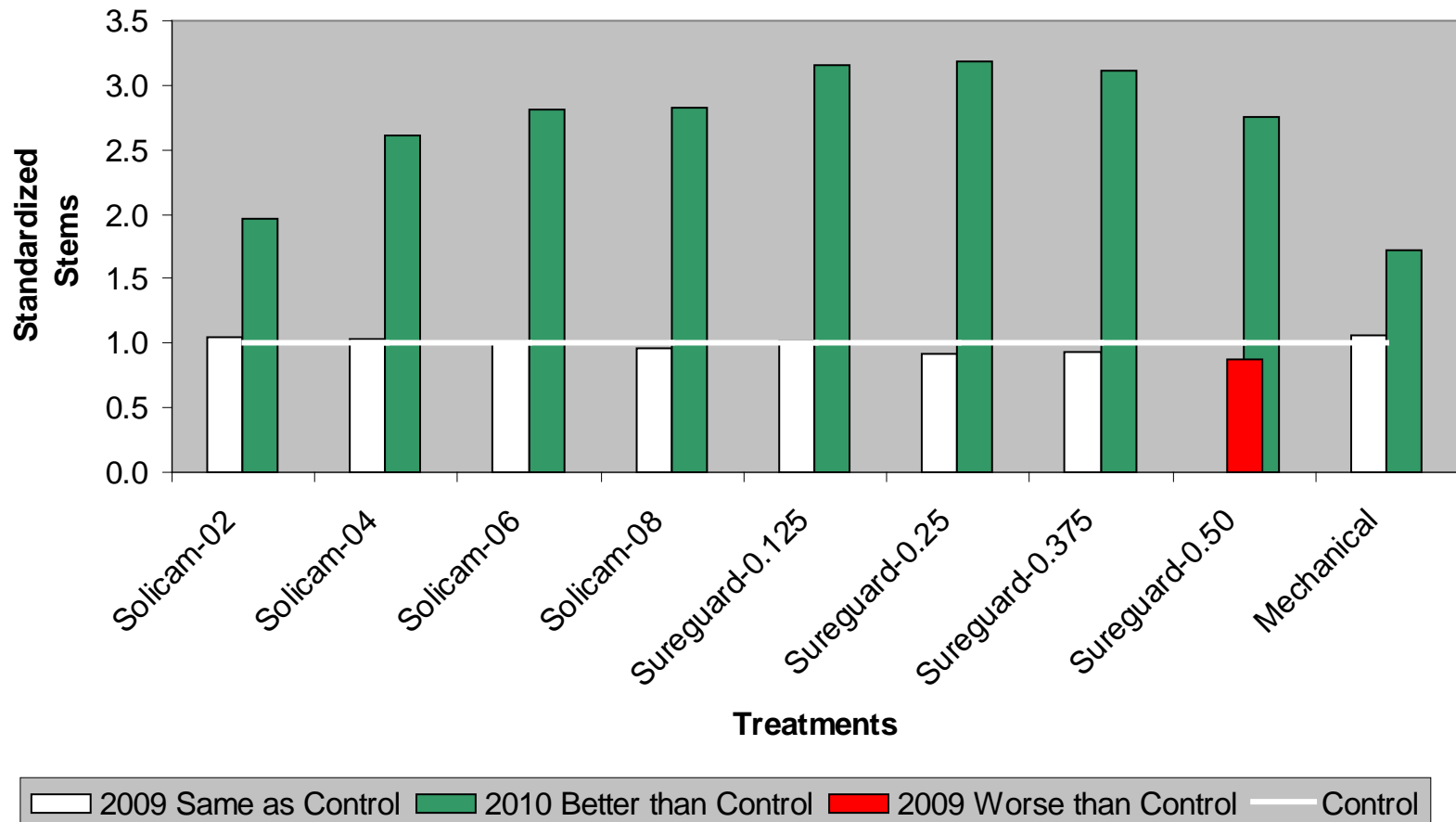
**Willow Herbicide Trial  
2009 & 2010 Solicam, Sureguard**



Legend:  
Red: 2009 Worse than Control  
Green: 2010 Better than Control  
White: 2009 Same as Control  
Dotted: 2010 Same as Control  
White line: Control

# 2<sup>nd</sup> Year Surprise

**Willow Herbicide Trial  
2008 & 2009, Solicam, Sureguard**



# Conclusions

- Mixtures containing Princep can cause excessive mortality in the first year – particularly on light soils.
- Substitution of pendimethalin (Pendulum or Prowl) for Princep with either Goal or Dual seems to improve survival and growth.
- Both Solicam and SureGuard look favorable (particularly at the lower rates).
- Resprouting and growth in the first year post-coppice benefits greatly from good weed control in the planting year.

# Acknowledgements

- Michigan Agricultural Experiment Station
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  - BASF
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  - Gowan
  - Makhteshim-Agan
  - Syngenta
  - Valent

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