

Yield and Biomass Quality of Shrub Willow Hybrids in Differing Rotation Lengths and Row Designs

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Introduction

- Trials using shrub willow as a bioenergy crop started in the 1970's
- Studies have included potential yields of different willow cultivars
 - across a range of environments
 - nutrient amendments and cycling
 - alternative tillage practices
 - cover crops
 - harvesting systems
 - spacing and planting density studies.
- Current planting designs based on the double row system

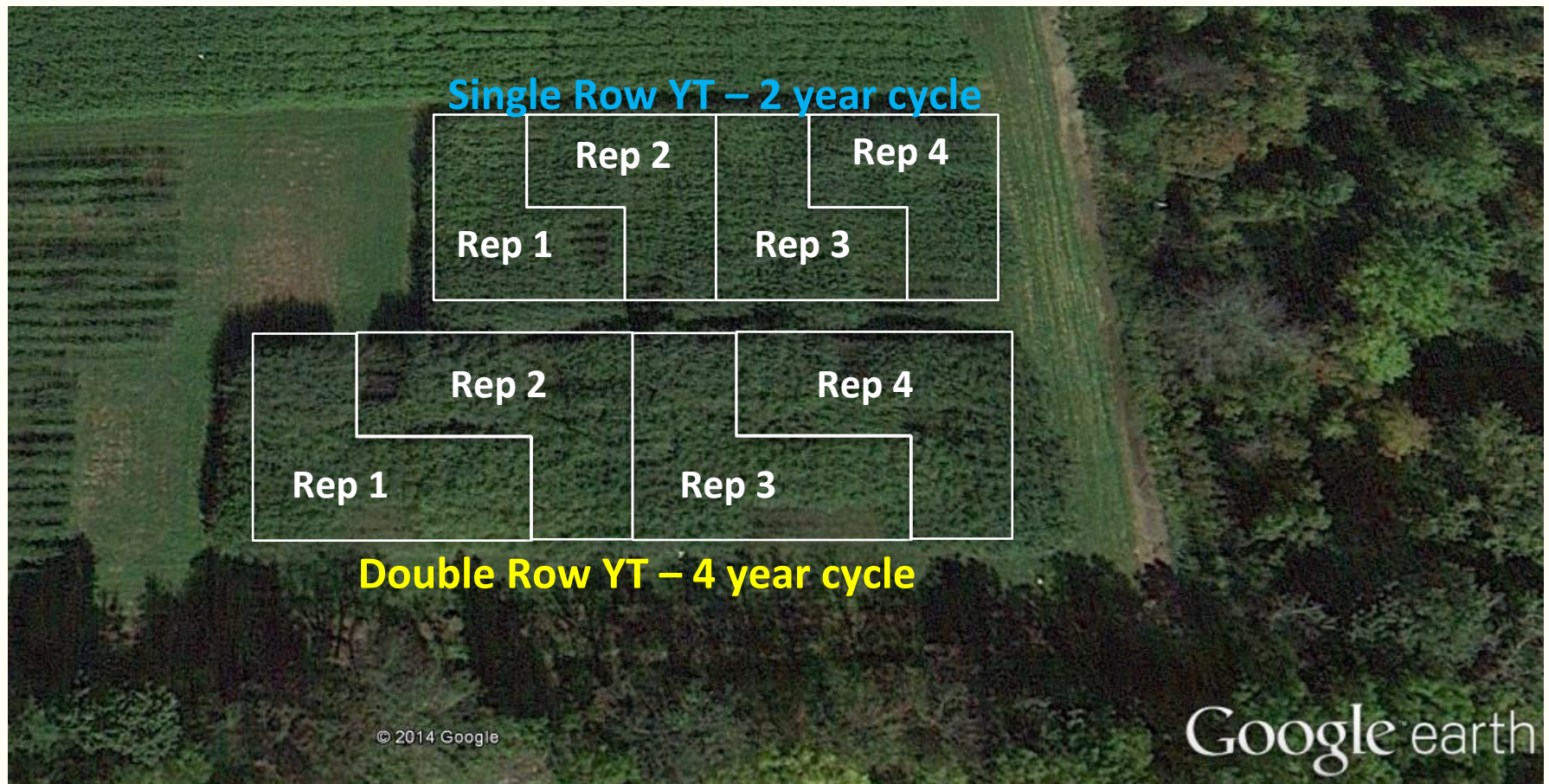


Objectives

- Report on the performance on the breeding and selection of novel species hybrids
- Evaluate growth in single row vs. double row spacing design
- Evaluate the effects of rotation length on biomass production
- Describe variation in stem diameter, stem height, density, composition, and yield

Loomis Farm – Geneva, NY

RCBD, 10 clones per block, 4 blocks per trial



Site Characteristics

Site Characteristics	Geneva, NY	
	Single Row	Double Row
Latitude	42°52'51"N	
Longitude	77°00'07"W	
Soil Type	Odessa silt loam	
2009 Precipitation (May – August; cm)	31.37	
2010 Precipitation (May – August; cm)	38.82	
2011 Precipitation (May – August; cm)	29.78	
2012 Precipitation (May – August; cm)	21	
2013 Precipitation (May – August; cm)	37.91	
Phosphorus (mg kg ⁻¹)	2.0 ± 0	2.0 ± 0
Potassium (mg kg⁻¹)*	93.25 ± 6.5	81.5 ± 5.78
Magnesium (mg kg⁻¹)*	373 ± 10.78	344 ± 58.59
Calcium (mg kg ⁻¹)	2194 ± 43.57	2148 ± 34.10
Iron (mg kg⁻¹)*	7.07 ± 1.19	9.45 ± 2.79
Aluminum (mg kg ⁻¹)	54.2 ± 8.11	57.1 ± 14.96
Manganese (mg kg ⁻¹)	19.6 ± 1.88	19.4 ± 1.37
Zinc (mg kg⁻¹)*	0.35 ± 0.05	0.43 ± 0.02
Nitrate (mg kg ⁻¹)	0 ± 0	0 ± 0
pH	6.11 ± 0.07	6.06 ± 0.17
Buffer pH	6.01 ± 0.03	6.02 ± 0.08
% Organic Matter	2.875 ± 0.16	2.92 ± 0.26

*Soil characteristics in bold are significantly different by field

2009 Loomis Yield Trial

Establishment Year

May 2009

***Single Row** - 10 genotypes
1.52 m between rows
0.46 m between plants*

***Double Row** - 10 genotypes
0.76 m between rows
0.46 m between double rows*

1st Year Post – Coppice - 2010

1st Year Post – Coppice - 2010

2nd Year Post – Coppice - 2011

2nd Year Post – Coppice - 2011

1st Rotation Harvest - 2011

1st Year Post – Harvest - 2012

3rd Year Post – Coppice - 2012

2nd Year Post – Harvest - 2013

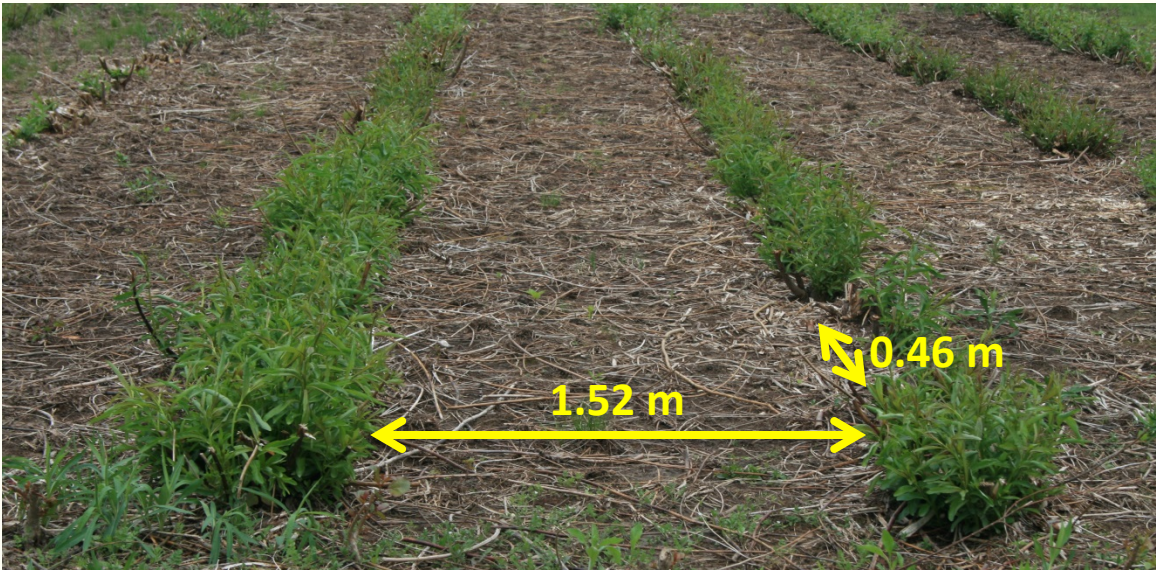
4th Year Post – Coppice - 2013

2nd Rotation Harvest - 2013

1st Rotation Harvest - 2013

Coppice

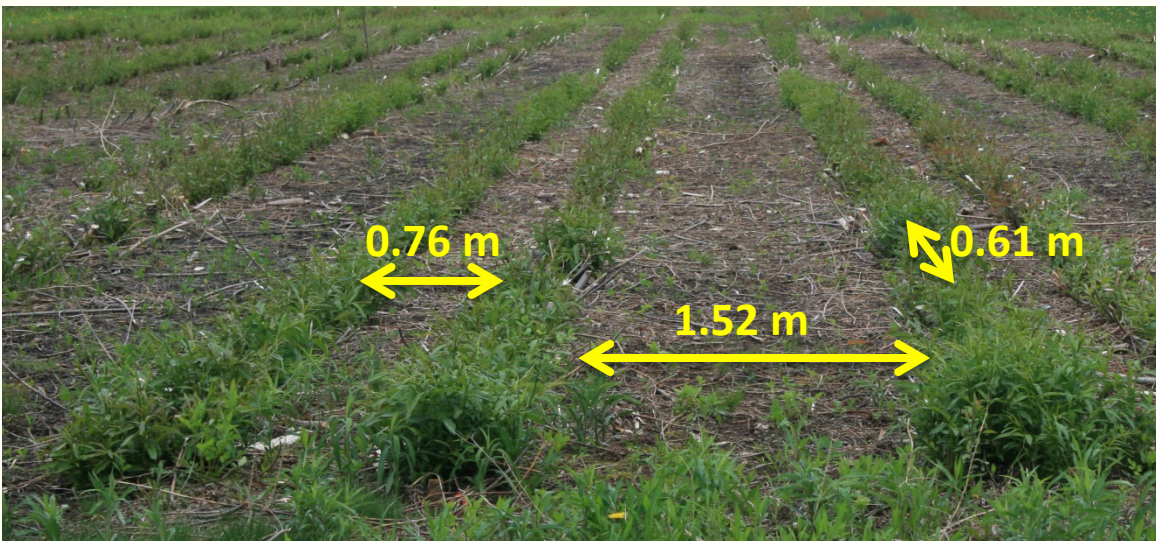
Spacing Design



- **Single Row**

- 2-year harvest cycle

Equal stand density
14,351 plants per ha



- **Double Row**

- 4-year harvest cycle

Shrub Willow Genotypes

Cultivar/ Epithet	Species/Pedigree	Nuclear DNA content (pg/ 2C)	Estimated Ploidy
'Boonville'	<i>S. koriyanagi</i> (SH3) × <i>S. purpurea</i> (94001)	1.04	2X
'Fish Creek'	<i>S. purpurea</i> (94006) × <i>S. purpurea</i> (94001)	1.02	2X
'SV1'	<i>S. × dasyclados</i>	0.87	2X
'Terra Nova'	<i>S. × mollissima</i> (LA940140) × <i>S. miyabeana</i> 'Shrubby Willow'	1.11	3X
'Nimrod'	(<i>S. schwerinii</i> × <i>S. viminalis</i>) 'Tora' × <i>S. miyabeana</i> 'Shrubby Willow'	1.15	3X
'Sheridan'	<i>S. viminalis</i> (SV2) × (<i>S. viminalis</i> × <i>S. miyabeana</i>) (99207-019)	1.22	3X
LA970253	<i>S. viminalis</i> × <i>S. cordata</i> ?	1.25	3X
'Fabius'	<i>S. viminalis</i> (SV2) × <i>S. miyabeana</i> 'SX67'	1.31	3X
'SX61'	<i>S. miyabeana</i>	1.53	4X
LA980451	<i>S. rehderiana</i> × <i>S. dasyclados</i>	2.05	5X

Results

- Stem Diameter/Area
 - Measured 8 plants per plot
- Stem Height
 - Measured 4 plants per plot
- Wood Density and Composition
- Yield

Double Row - Stem Area

Year 1

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	0.92	0.4460
Clone	9	4.41	0.0015

Year 2

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	0.11	0.66
Clone	9	5.38	0.0003

Year 3

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	11.13	<0.0001
Clone	9	18.49	<0.0001

Year 4

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	24.81	0.0002
Clone	9	24.61	0.0024



Single Row - Stem Area

Year 1 – 1st Rotation

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	4.48	0.0287
Clone	9	4.86	0.0033

Year 2 – 1st Rotation

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	1.22	0.3252
Clone	9	5.29	0.0005

Year 1 – 2nd Rotation

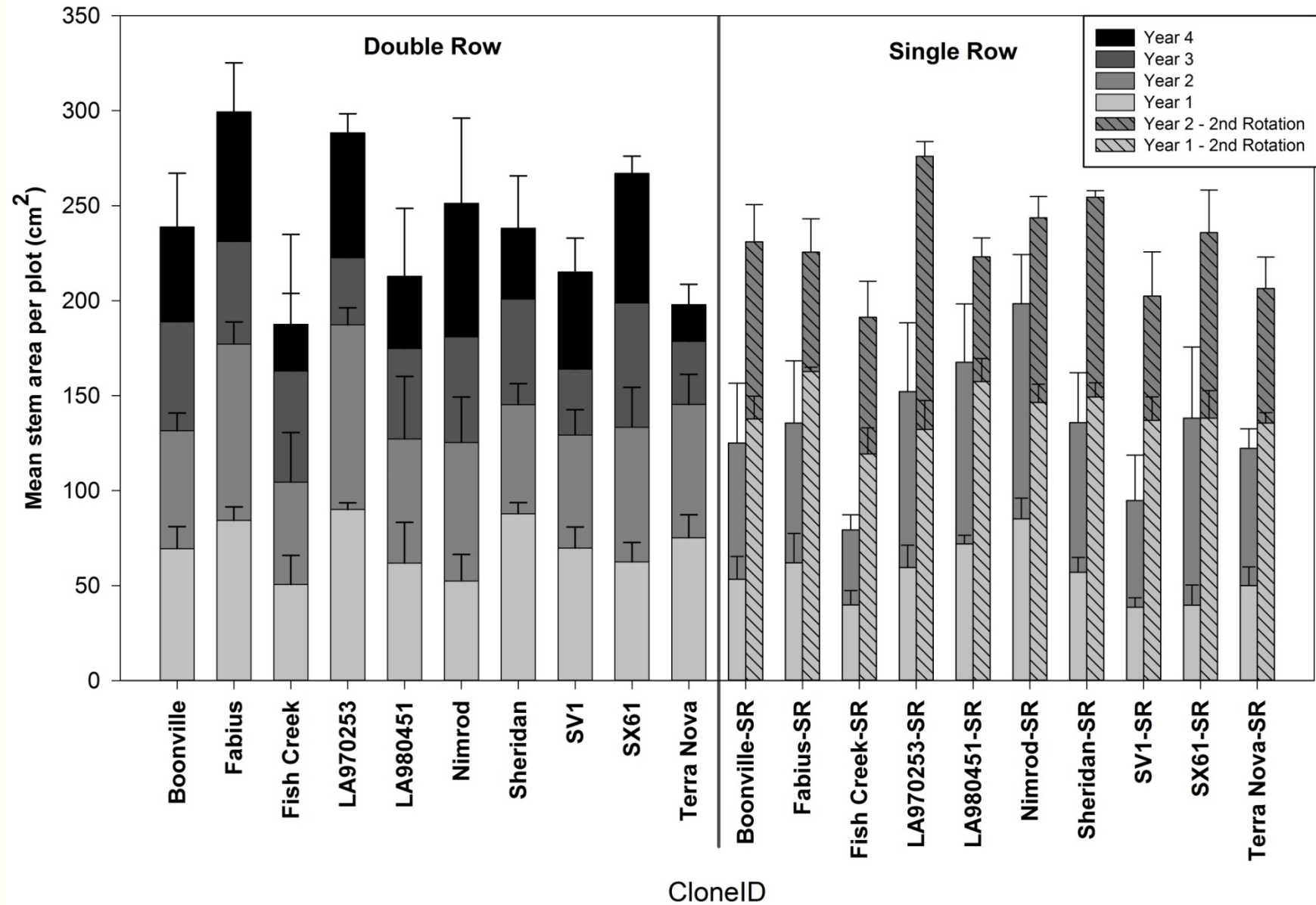
Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	9.67	0.0002
Clone	9	4.15	0.0024

Year 4 – 2nd Rotation

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	24.81	0.0002
Clone	9	24.61	0.0024



2009 Loomis YT - Stem Area



Double Row - Stem Height

Year 1

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	3.16	0.0409
Clone	9	0.85	0.5780

Year 2

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	9.14	0.0002
Clone	9	4.49	0.0011

Year 3

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	5.08	0.0064
Clone	9	7.29	<0.0001

Year 4

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	4.21	0.0144
Clone	9	4.01	0.0024



Single Row - Stem Height

Year 1 – 1st Rotation

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	2.85	0.0561
Clone	9	2.55	0.0291

Year 2 – 1st Rotation

Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	1.74	0.1270
Clone	9	4.58	0.0010

Year 1 – 2nd Rotation

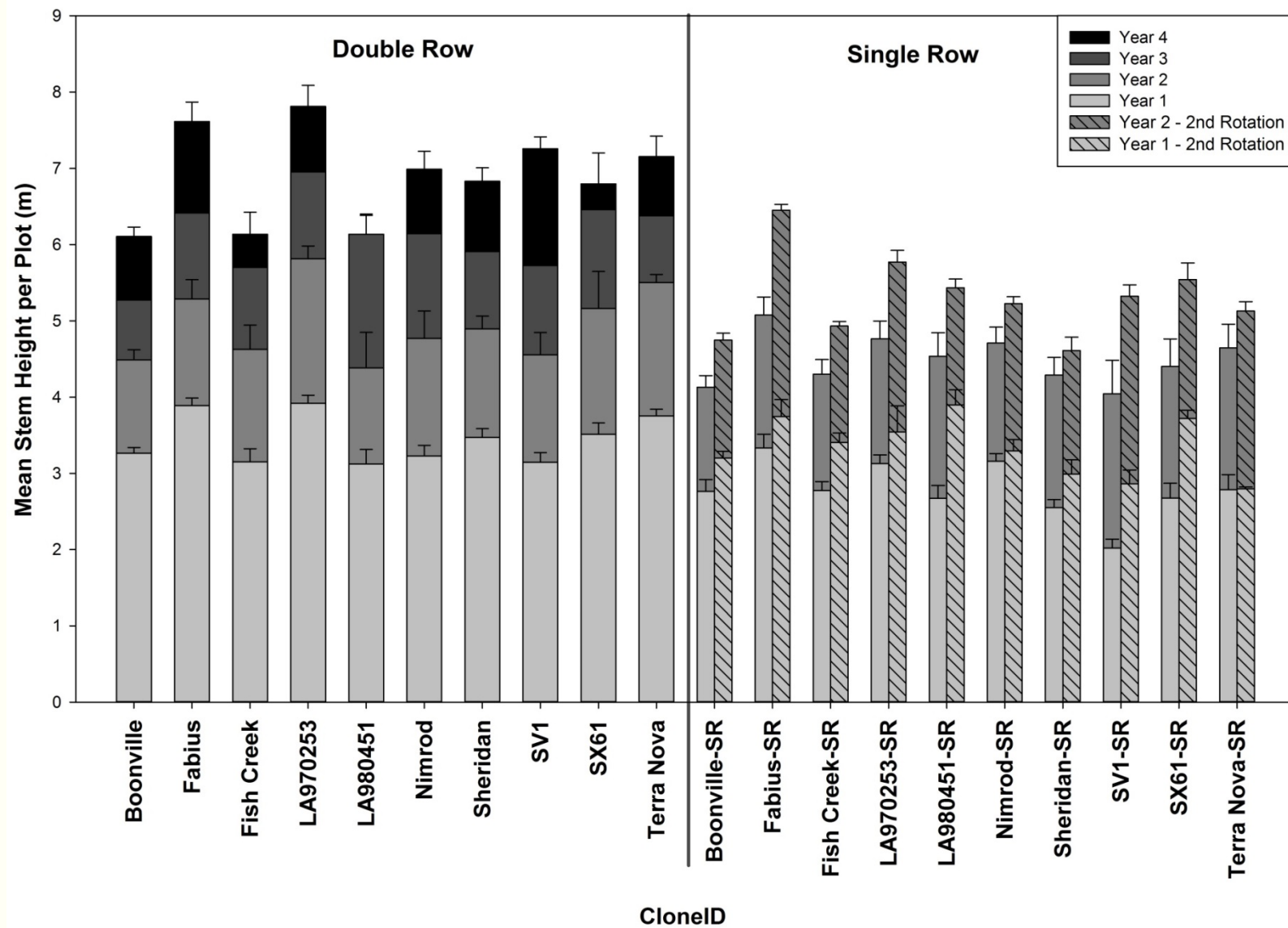
Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	1.19	0.3324
Clone	9	4.52	0.0011

Year 4 – 2nd Rotation

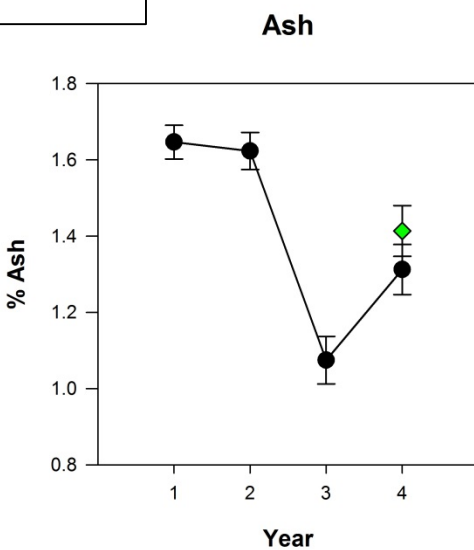
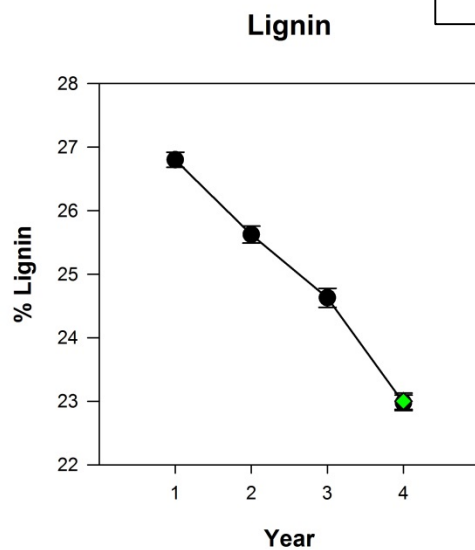
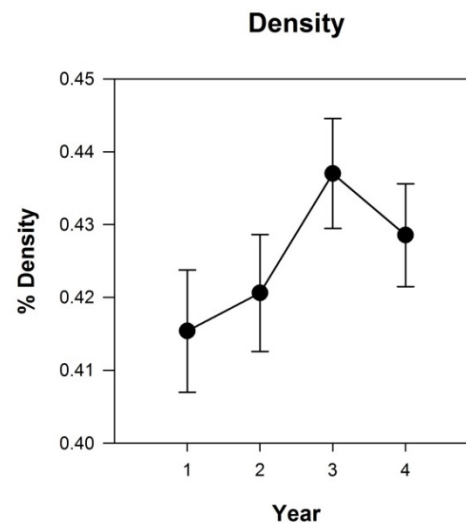
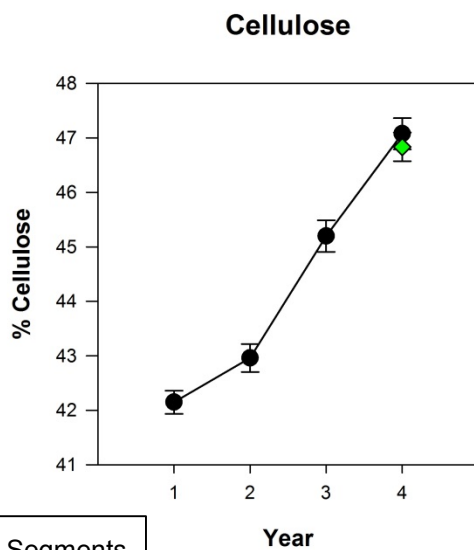
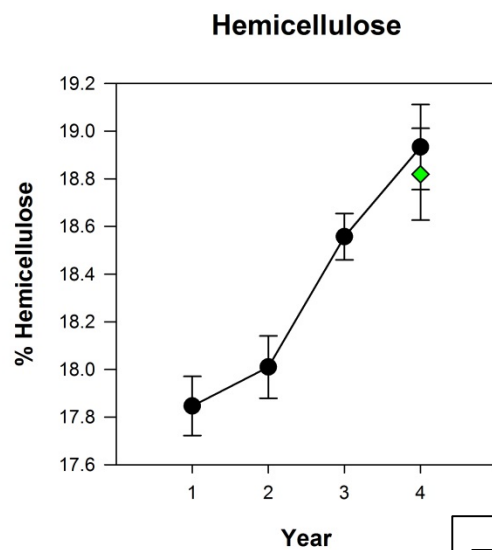
Source Effect	d.f.	<i>F</i>	<i>P</i> -value
Rep	3	1.16	0.3347
Clone	9	8.06	<0.0001



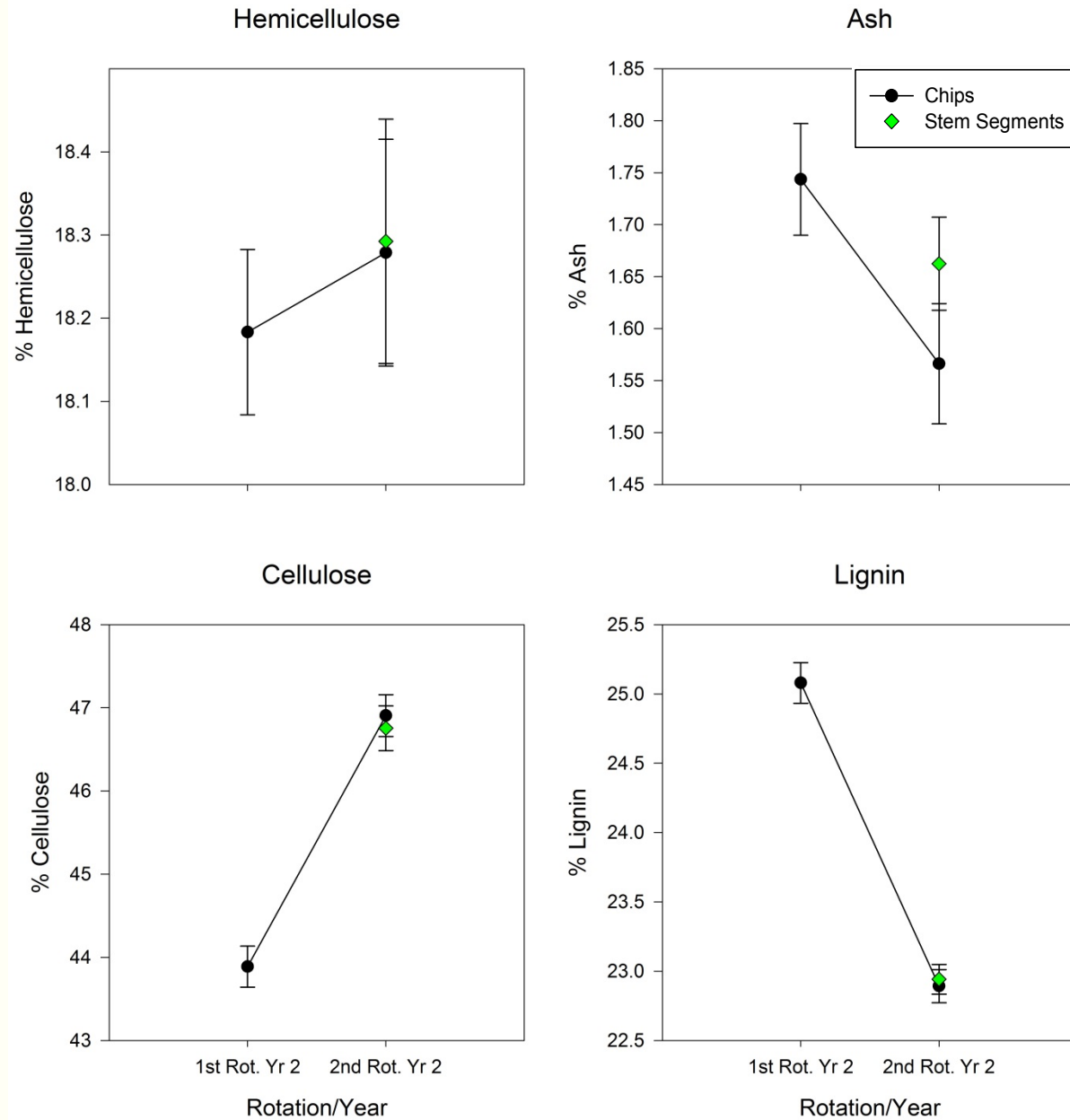
2009 Loomis YT - Stem Height



Double Row – Density and Composition



Single Row – Density and Composition



Single Row Correlations of Growth Traits with Yield

	Stem Diameter	Stem Area	Stem Number	Yield
1st Rotation – Year 2 - SR				
Height	0.38689 0.0137	0.48681 0.0014	0.05354 0.7428	0.71332 <.0001
Stem Diameter	-	0.90376 <0.0001	0.73665 <0.0001	0.69489 <0.0001
Stem Area		-	0.38752 0.0135	0.7552 <0.0001
Stem Number			-	0.33489 0.0347
2nd Rotation – Year 2 - SR				
Height	0.00569 0.9722	0.50498 0.0009	-0.18936 0.2419	0.52383 0.0005
Stem Diameter	-	0.58528 <0.0001	0.90111 <0.0001	0.00769 0.9611
Stem Area		-	0.22738 0.1582	0.55039 0.0002
Stem Number			-	-0.19139 0.2368

Double row correlations of growth traits with yield

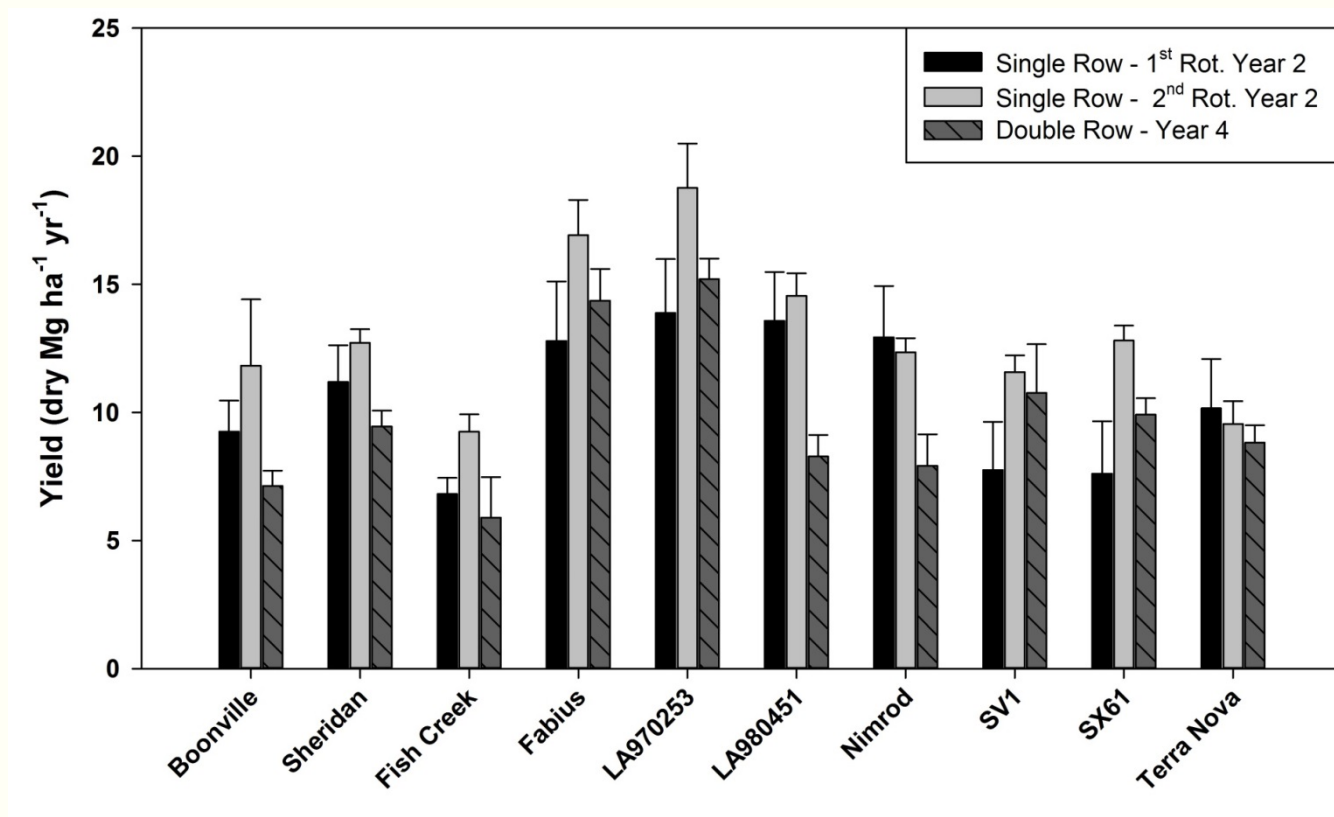
	Stem Diameter	Stem Area	Stem Number	Specific Gravity	Yield
Year 1 - DR					
Height	0.65104 <0.0001	0.78617 <0.0001	0.50109 0.0010	-0.07270 0.6557	0.60260 <0.0001
Stem Diameter	-	0.93851 <0.0001	0.96127 <0.0001	0.96127 <0.0001	0.46987 0.0022
Stem Area		-	0.81356 <0.0001	-0.04066 0.8033	0.57141 0.0001
Stem Number			-	-0.05248 0.7478	0.38264 0.0148
Specific Gravity				-	0.05221 0.7490
Year 2 - DR					
Height	0.50093 0.0010	0.69784 <0.0001	0.31276 0.0494	-0.05964 0.7147	0.49247 0.0012
Stem Diameter	-	0.86011 <0.0001	0.92298 <0.0001	0.21422 0.1844	0.54011 0.0003
Stem Area		-	0.61366 <0.0001	0.22163 0.1693	0.66958 <0.0001
Stem Number			-	0.16918 0.2967	0.40177 0.0102
Specific Gravity				-	0.10978 0.5001

Double row correlations of growth traits with yield

	Stem Diameter	Stem Area	Stem Number	Specific Gravity	Yield
Year 3 - DR					
Height	-0.26963	0.18335	0.44552	-0.38463	0.39287
	0.0925	0.2574	0.0040	0.0143	0.0122
Stem Diameter	-	0.78963	0.88035	0.22340	0.32205
		<0.0001	<0.0001	0.1658	0.0427
Stem Area		-	0.44999	0.06722	0.60305
			0.0036	0.6803	<0.0001
Stem Number			-	0.27692	0.13478
				0.0837	0.4070
Specific Gravity				-	0.21832
					0.1759
Year 4 - DR					
Height	0.34665	0.38937	0.37520	0.04832	0.63582
	0.0284	0.0130	0.0170	0.7672	<0.0001
Stem Diameter	-	0.80545	0.87654	0.26620	0.47312
		<0.0001	<0.0001	0.0969	0.0020
Stem Area		-	0.48324	0.11981	0.67647
			0.0016	0.4615	<0.0001
Stem Number			-	0.27934	0.36340
				0.0809	0.0213
Specific Gravity				-	0.19238
					0.2343

Final Yield

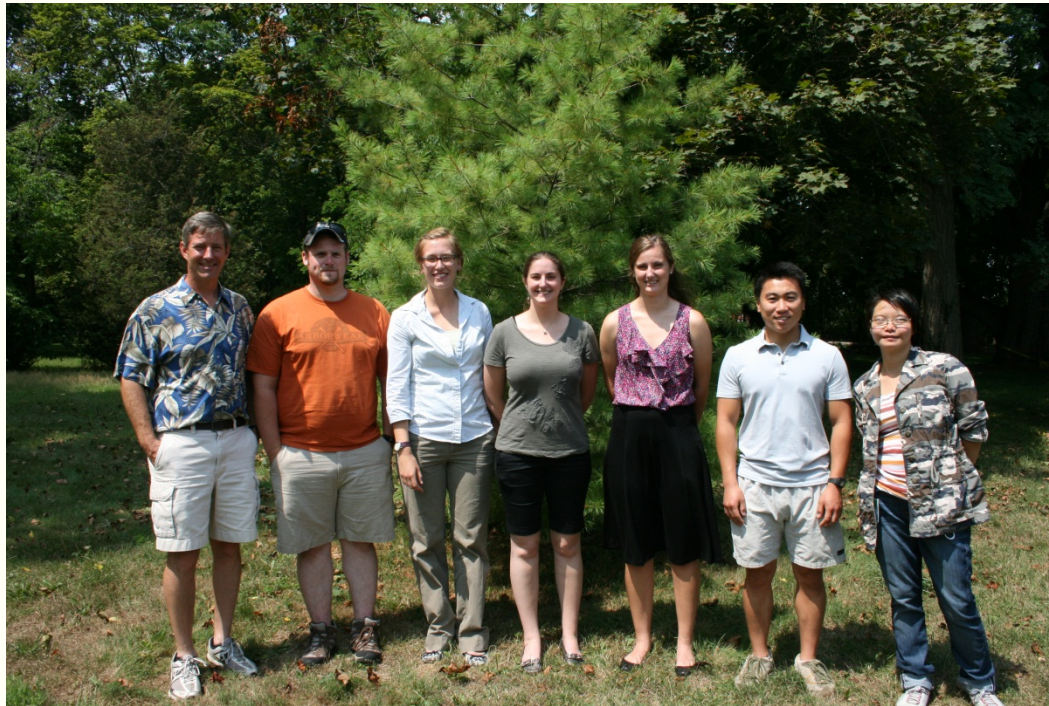
- Mean yield over 4 years
 - Single Row – 11.82 dry Mg ha⁻¹ yr⁻¹
 - Double Row – 9.78 dry Mg ha⁻¹ yr⁻¹
- 20% increase from 1st to 2nd rotation
- Two biennial, single-row harvests 47.3 dry Mg ha⁻¹
- One double row harvest 39.1 dry Mg ha⁻¹
- LA970253 had highest mean annual production



Conclusions

- The total yield of the two biennial, single-row harvests was significantly more productive than a single four-year, double-row harvest
- Triploid hybrid from the UK, LA970253, produced the greatest yield in both trials
- In the single- and double-row trials hemicellulose and cellulose content increased across years, while lignin content decreased.
- The results of this study indicate there are certain cultivars better suited to different cutting cycles

Thank You



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