Effects of planting density on growth and yield of hybrid willow (*Salix* spp.) crops.

J. Caputo and T.A. Volk

8th Annual SRWC Operations Working Group

ESF State University of New York
College of Environmental Science and Forestry

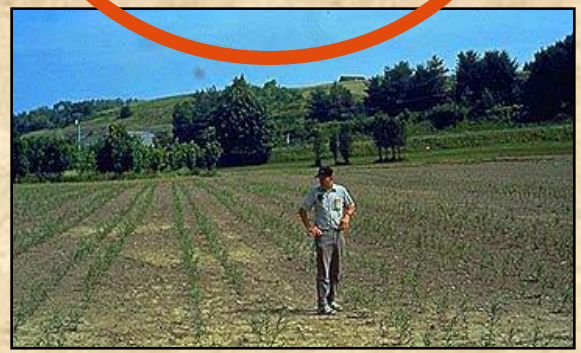
October 18, 2010

Introduction

- Wood can be used as a renewable alternative to fossil fuels in the production of energy and products.
- SRWC are widely seen as becoming key sources of consistent, reliable woody feedstocks.
- Hybrid willow (*Salix* spp.) is a promising and well-studied SRWC.

Willow Biomass Production Cycle

Planting



First year growth

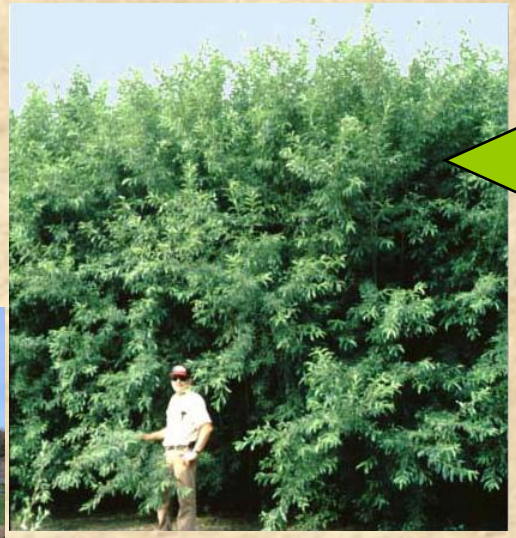
Coppice

Harvesting

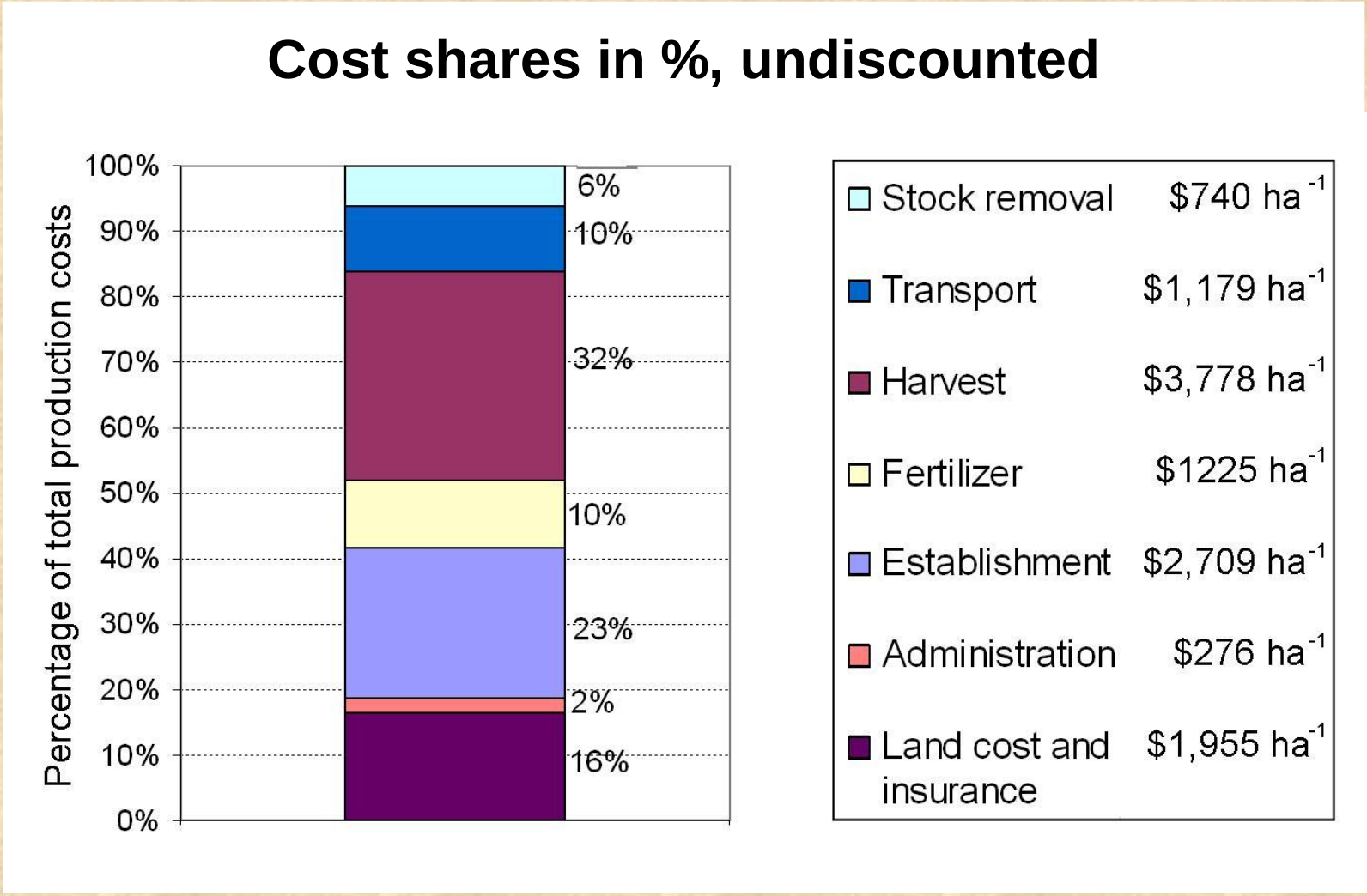
Early spring after coppicing

One-year old after coppice

Three-year old after coppice

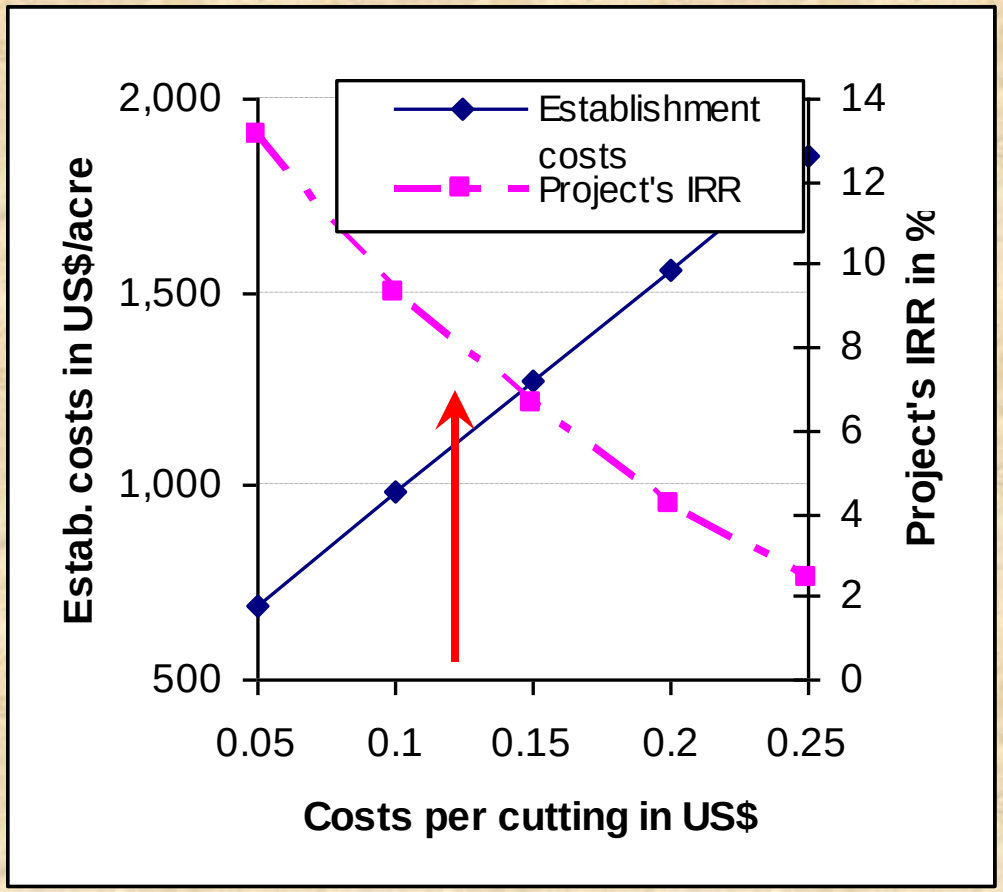


Distribution of Expenses Over 22 Years



(Buchholz and Volk 2010)

Impact of Establishment Costs



Changes in establishment costs and IRR with changes in planting stock costs

- Planting stock accounts for 60 – 80% of establishment costs.
- Current planting costs are about $0.12 per cutting.
- Reducing planting density would reduce establishment costs and increase the IRR.
- Need to better understand the effect of planting density on yield.

Willow Cash Flow Model

Welcome to EcoWillow v.1.0 (Beta)

An Economic Analysis Tool for
Willow Short-Rotation Coppice Plantations
for Wood Chip Production

SUNY-ESF
Improve Your World

Photo: Thomas Buchholz

Photo: Timothy Volk

Photo: Timothy Volk

Photo: Lawrence Smart

Project Name	
Location	
Acres (min. 20)	20

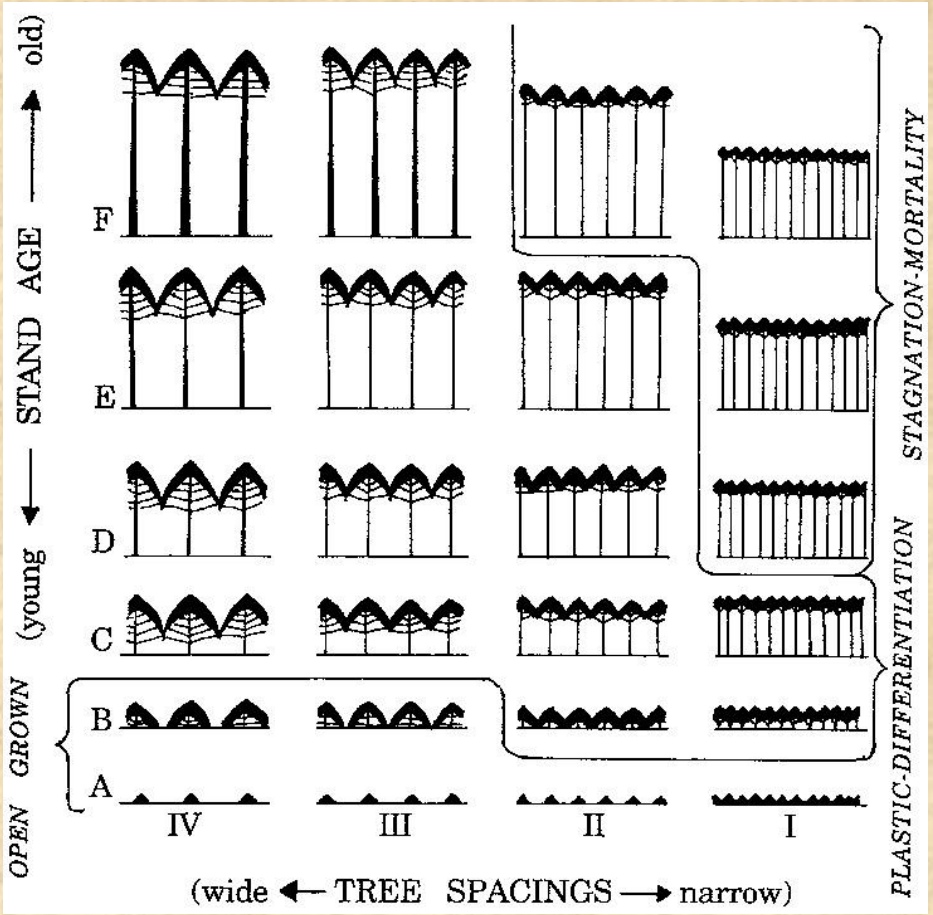
Begin

Tutorial

We acknowledge support of NYSERDA, USDA CSREES, and the State of New York, Dept. of Agriculture and Markets

(Available to download from http://www.esf.edu/willow/download.asp/)

Idealized Stand Development



(From Oliver and Larson 1996)

Density and self-thinning

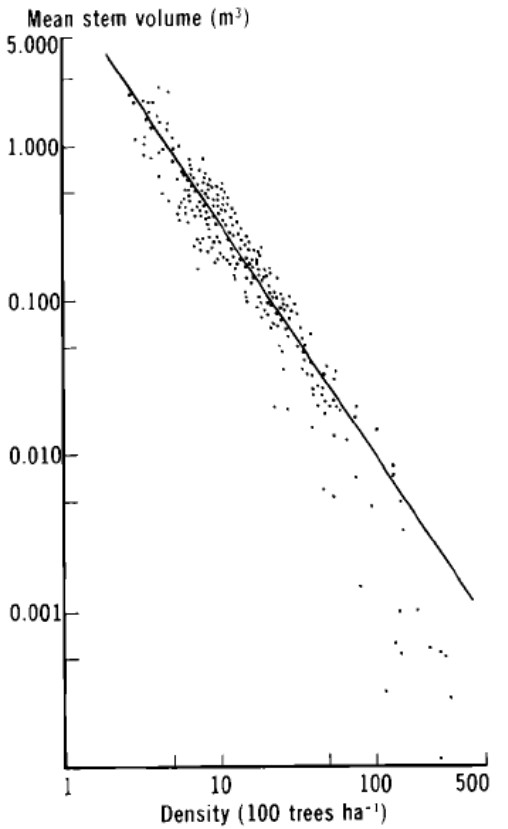


FIGURE 2. The relationship between the logarithms of mean stem volume and density in pure natural stands of *Pinus densiflora* in Honsyû, Japan (Yoda and others 1963).

(Drew and Flewelling 1977)

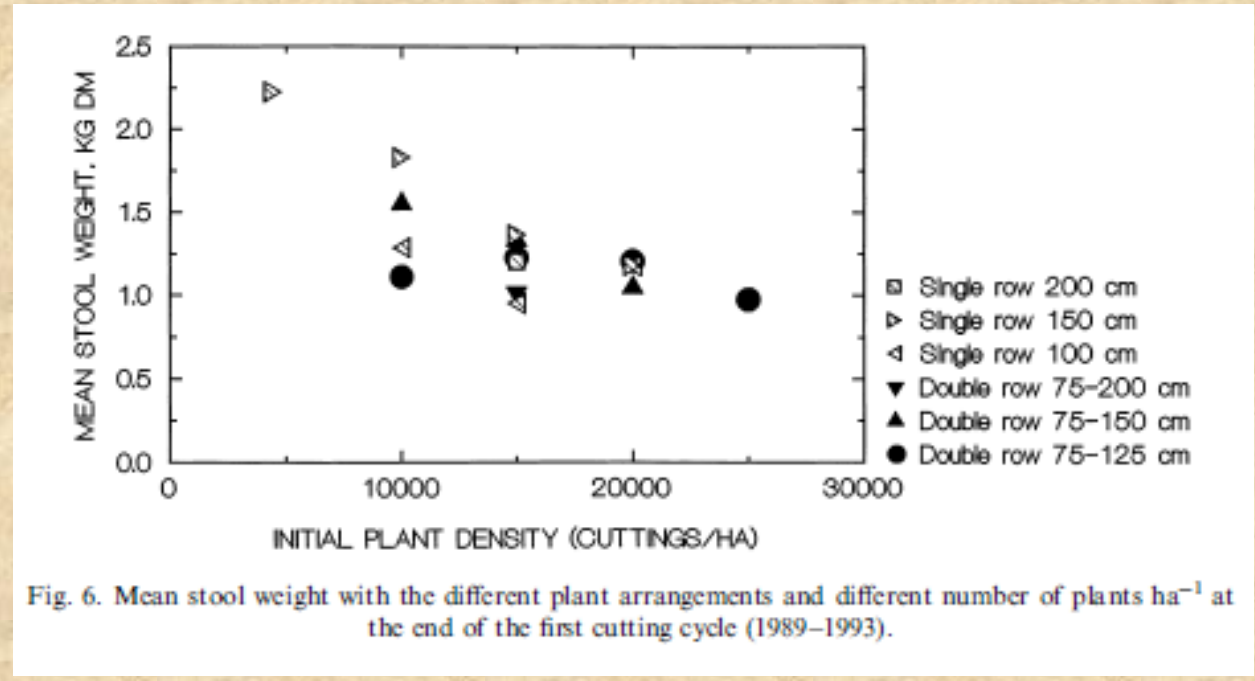


Fig. 6. Mean stool weight with the different plant arrangements and different number of plants ha^{-1} at the end of the first cutting cycle (1989–1993).

(Bergkvist and Ledin 1998)

Density-Yield Relationships

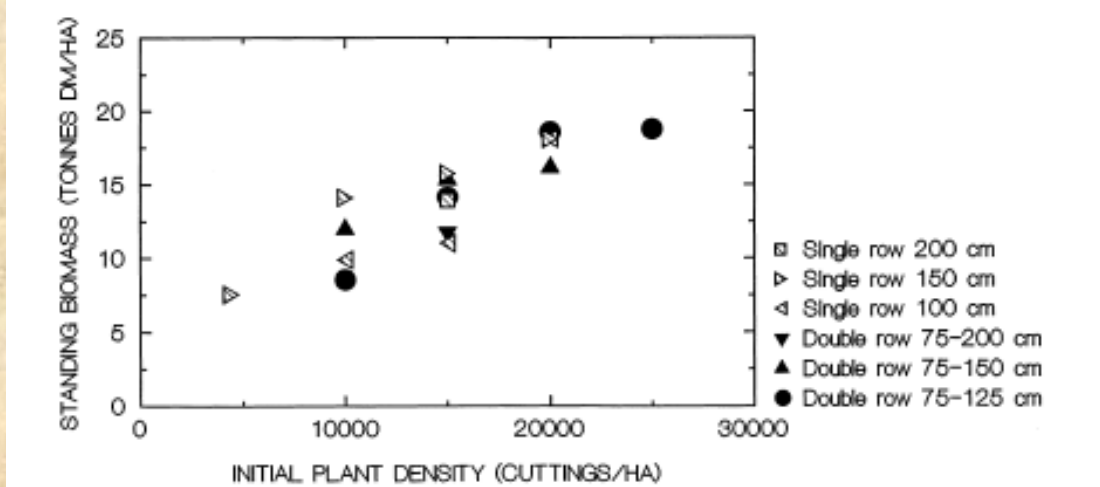


Fig. 2. Stem biomass production (tonnes DM ha^{-1}) with the different plant arrangements and different number of plants ha^{-1} at the end of the first cutting cycle (1989–1993).

(Bergkvist and Ledin 1998)

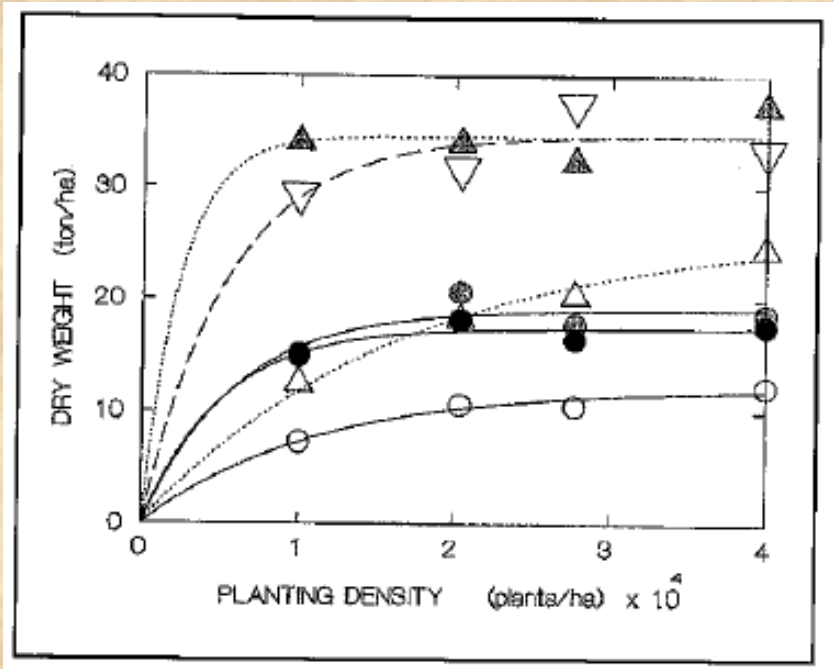


Figure 3. Standing dry weight-density relations for 2 (—, o), 3 (----, Δ) and 4-year rotation periods (– –, ∇). Open symbols indicate a first harvest, grey symbols a second harvest and black symbols a third harvest. Data were fitted with the Mitscherlich function.

(Willebrand and Verwijst 1993)

Density and Sprouting…

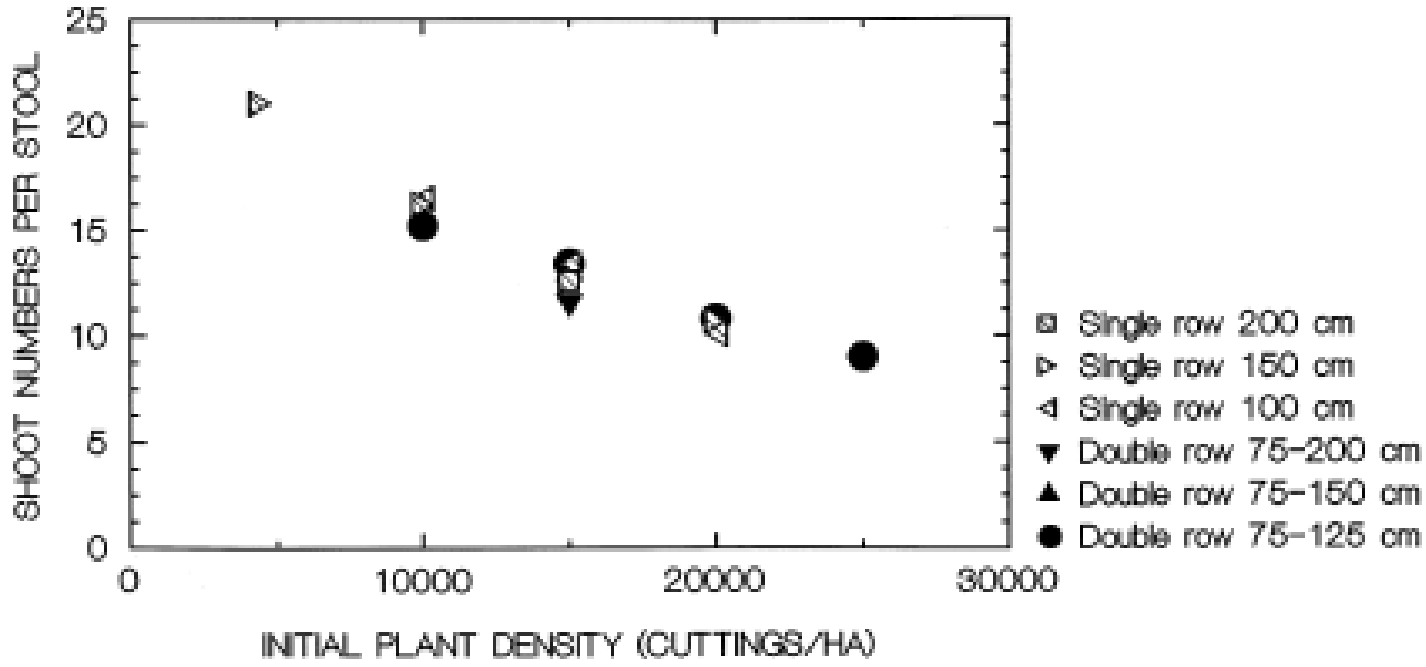


Fig. 3. Shoot numbers per stool with the different plant arrangements and different number of plants ha^{-1} 2 years after first harvest.

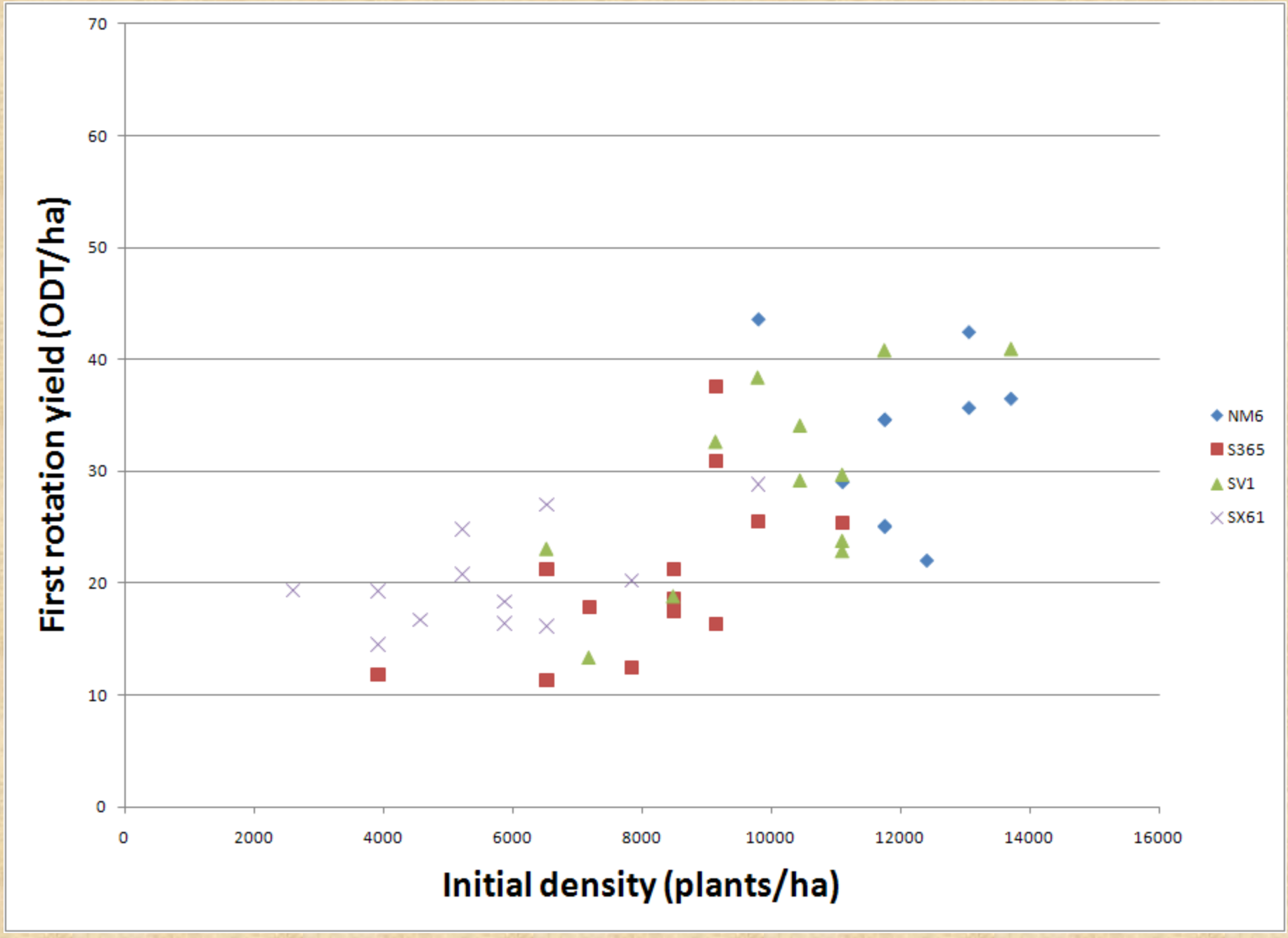
(Bergkvist and Ledin 1998)

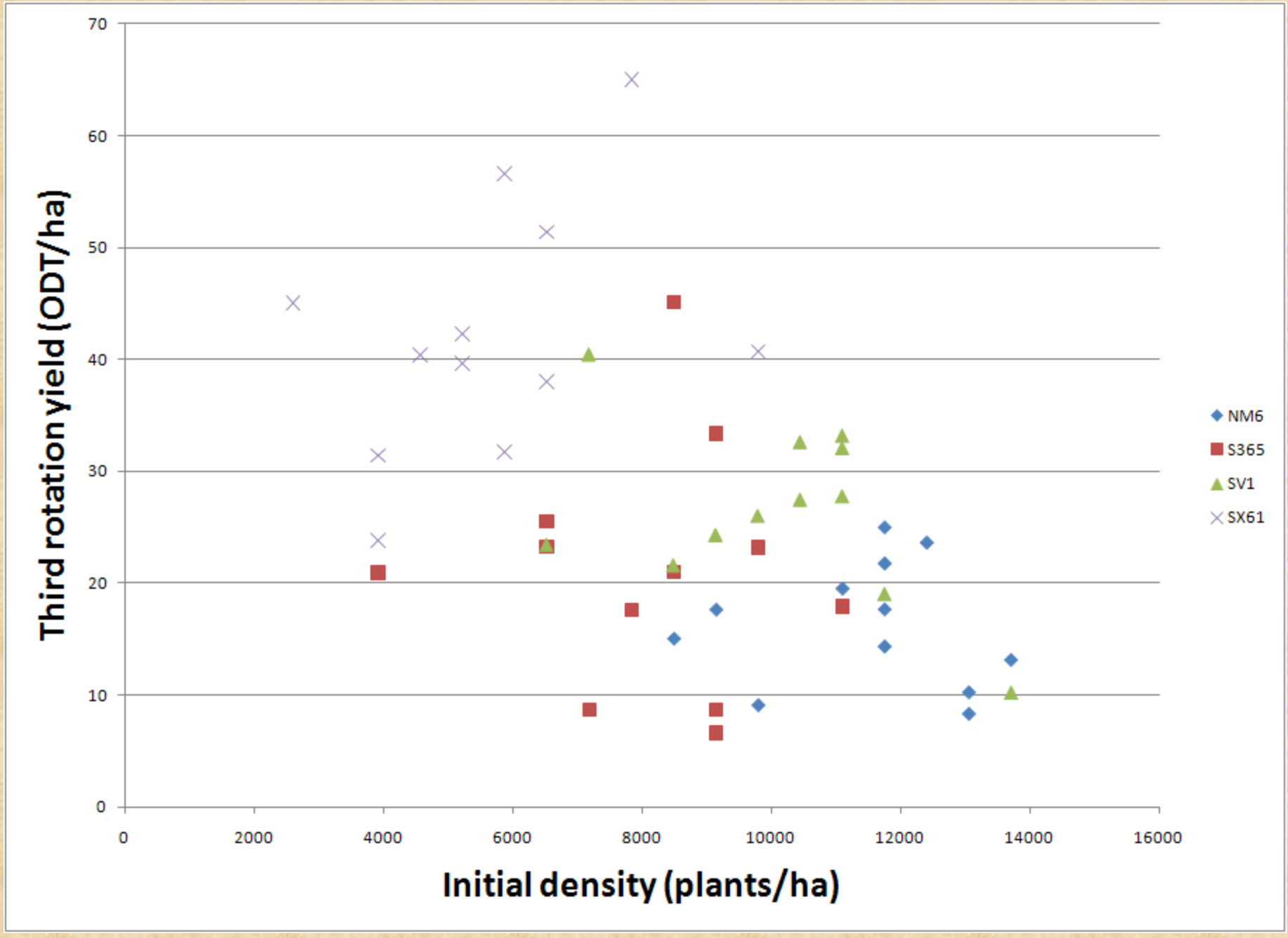
Current Recommendations

- 15,400 plants/ha ($1848/ha if $0.12 per cutting)
- Research on *S. viminalis* in Europe.
- Research from North America on ‘SV1’ (*S. dasyclados*), densities ranging from 15,151-111,111 plants/ha.
- No research on lower densities, or differences between different varieties or growth forms.

Unplanned Experiment

- Canastota, NY
- Part of a larger experiment exploring the response of willow to different coppicing treatments.
- Variable mortality in the establishment year lead to variable density.
- Includes 3 willow varieties (S365, SV1, SX61) and 1 hybrid poplar (NM6)





Density and Stand Closure

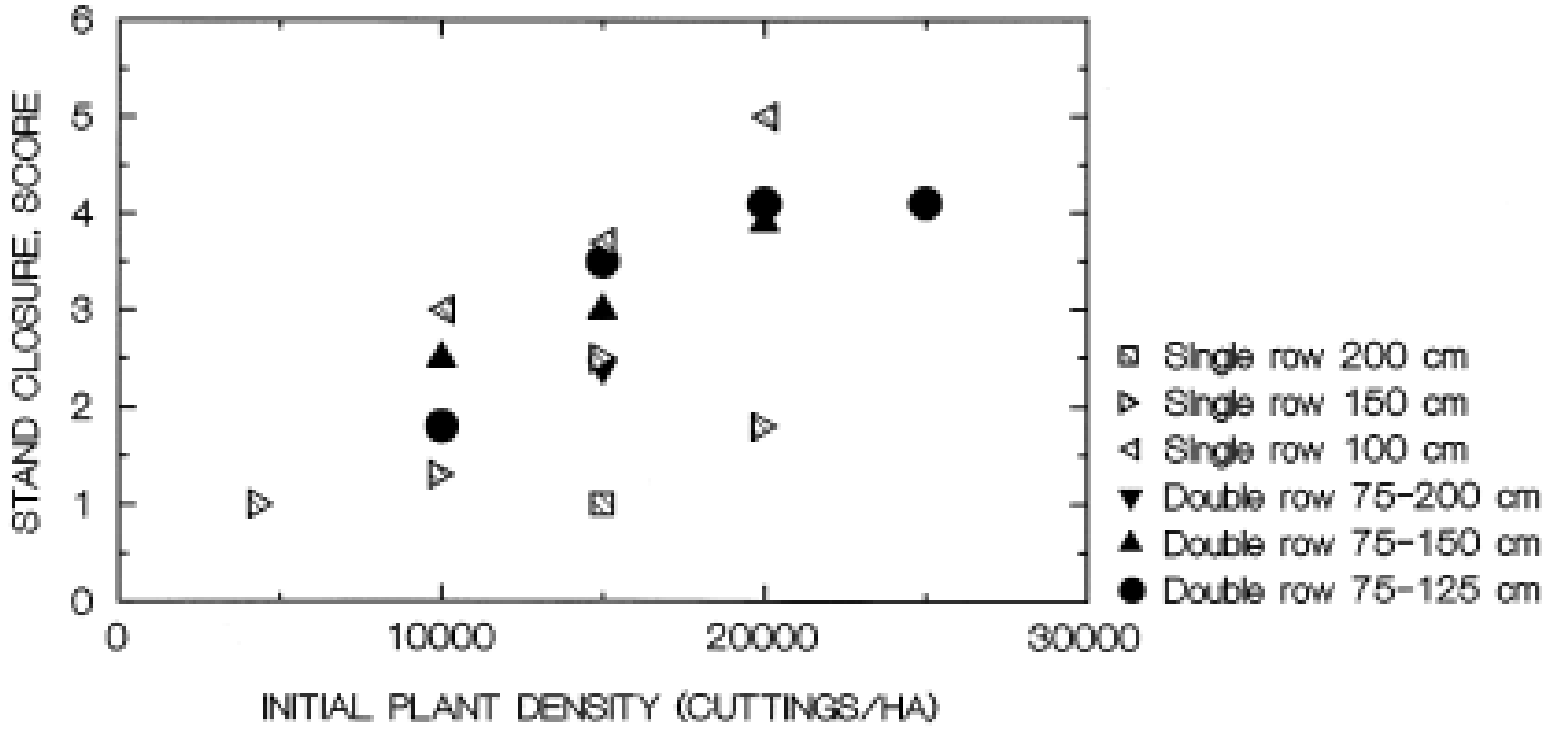


Fig. 1. Stand closure scores in the second year after planting in the different arrangements and spacings. Lowest score (1) indicates that stand closure will not occur within two seasons and active weed control will be needed until then. Highest score (5) indicates that stand closure has occurred and no active weed control will be needed.

(Bergkvist and Ledin 1998)

Planned Density Trial

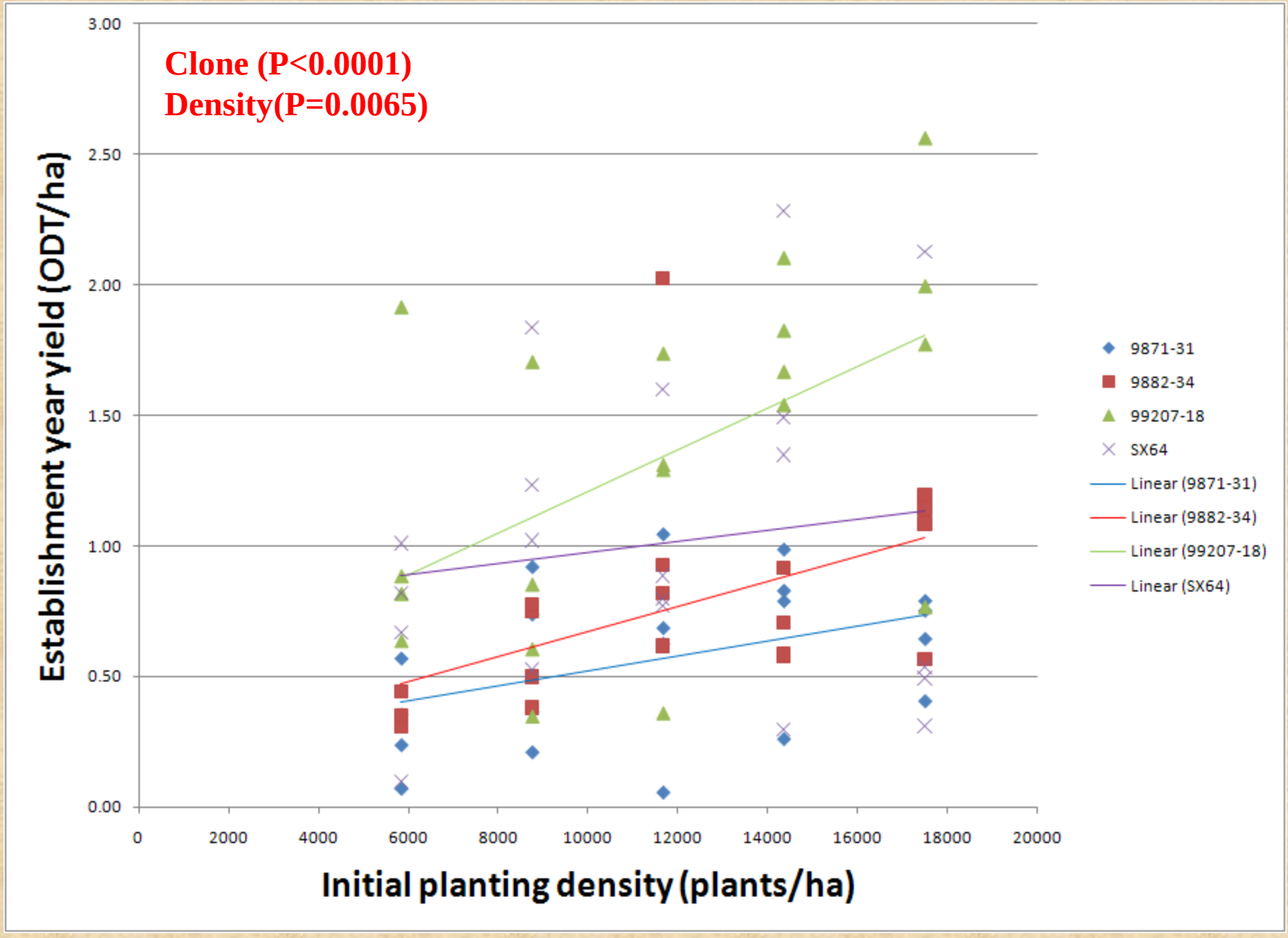
- Tully, NY.
- Fully replicated complete block design (5 densities, 4 varieties, 4 reps, n=80).
- Established in 2007.
- Survival and yield (coppice) data in 2007
- Survival, stem diameters data in 2008, 2009.
- Sister study in Waseca, MN.

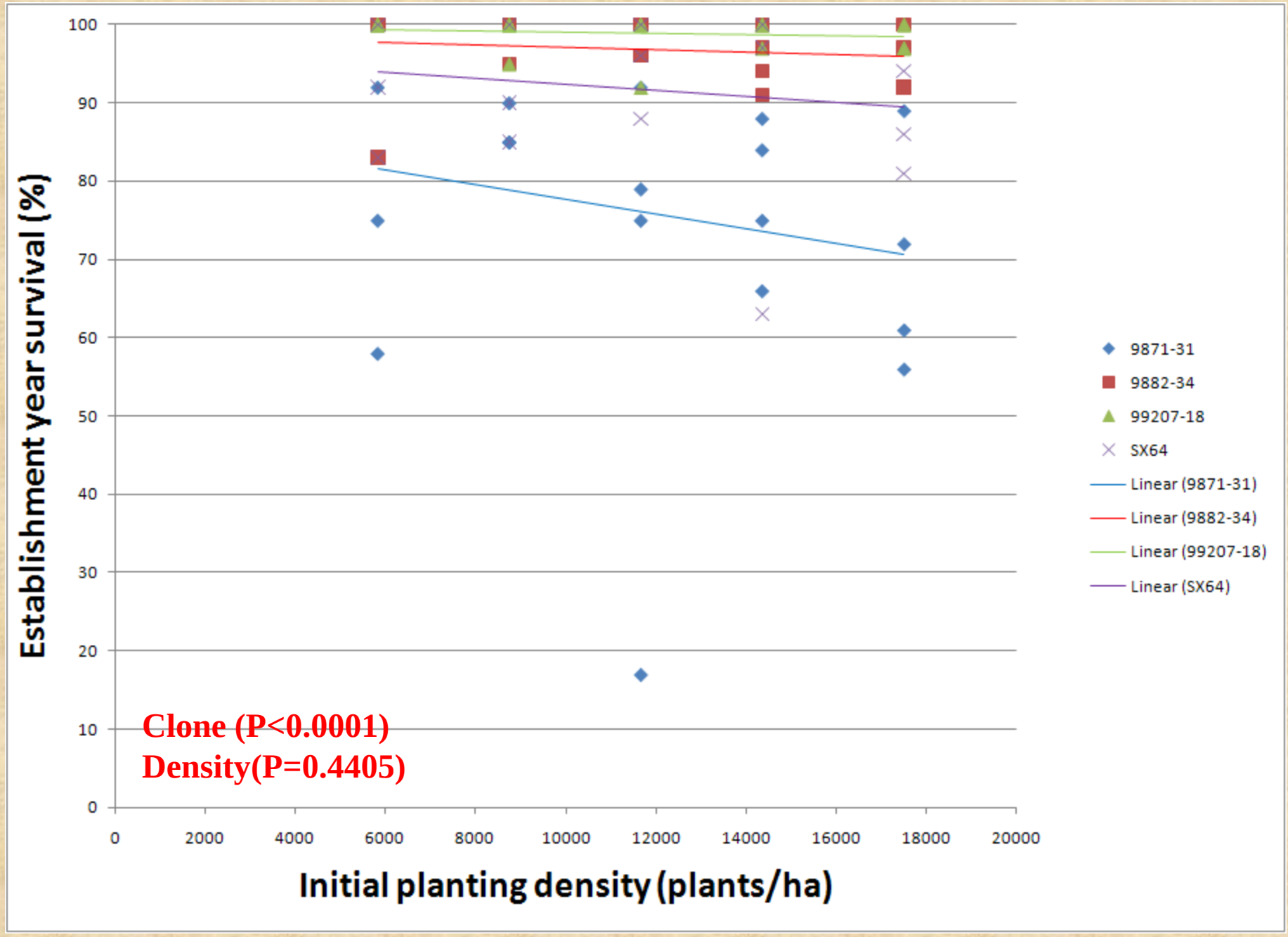
Four willow varieties

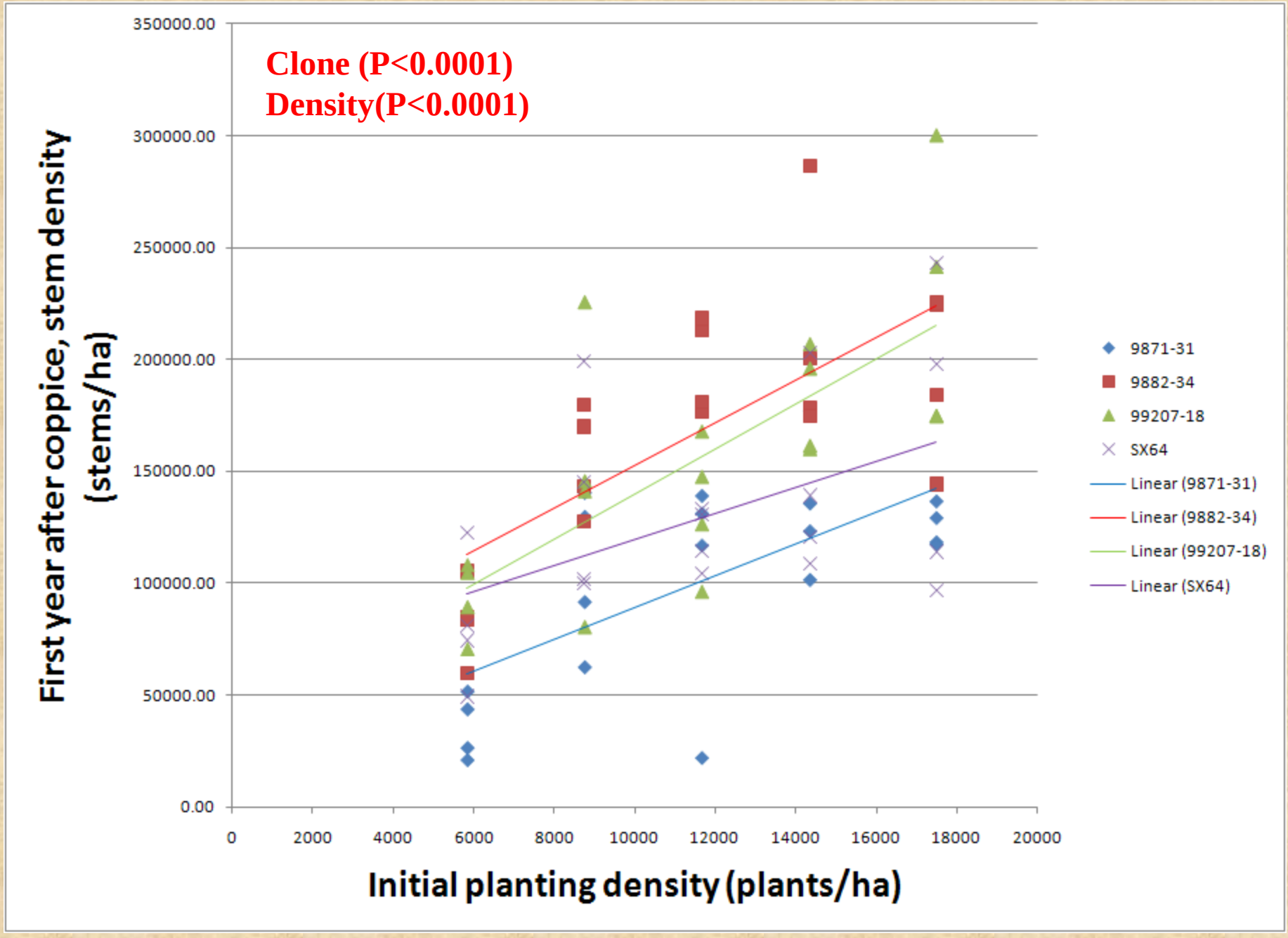
Variety	Commercial Name	Species
9871-31	Sherburne	*Salix sachalinenis* x *Salix miyabeana*
9882-34	Fish Creek	*Salix purpurea*
99207-18	Owasco	*Salix viminalis* x *Salix miyabeana*
SX64	SX64	*Salix miyabeana*

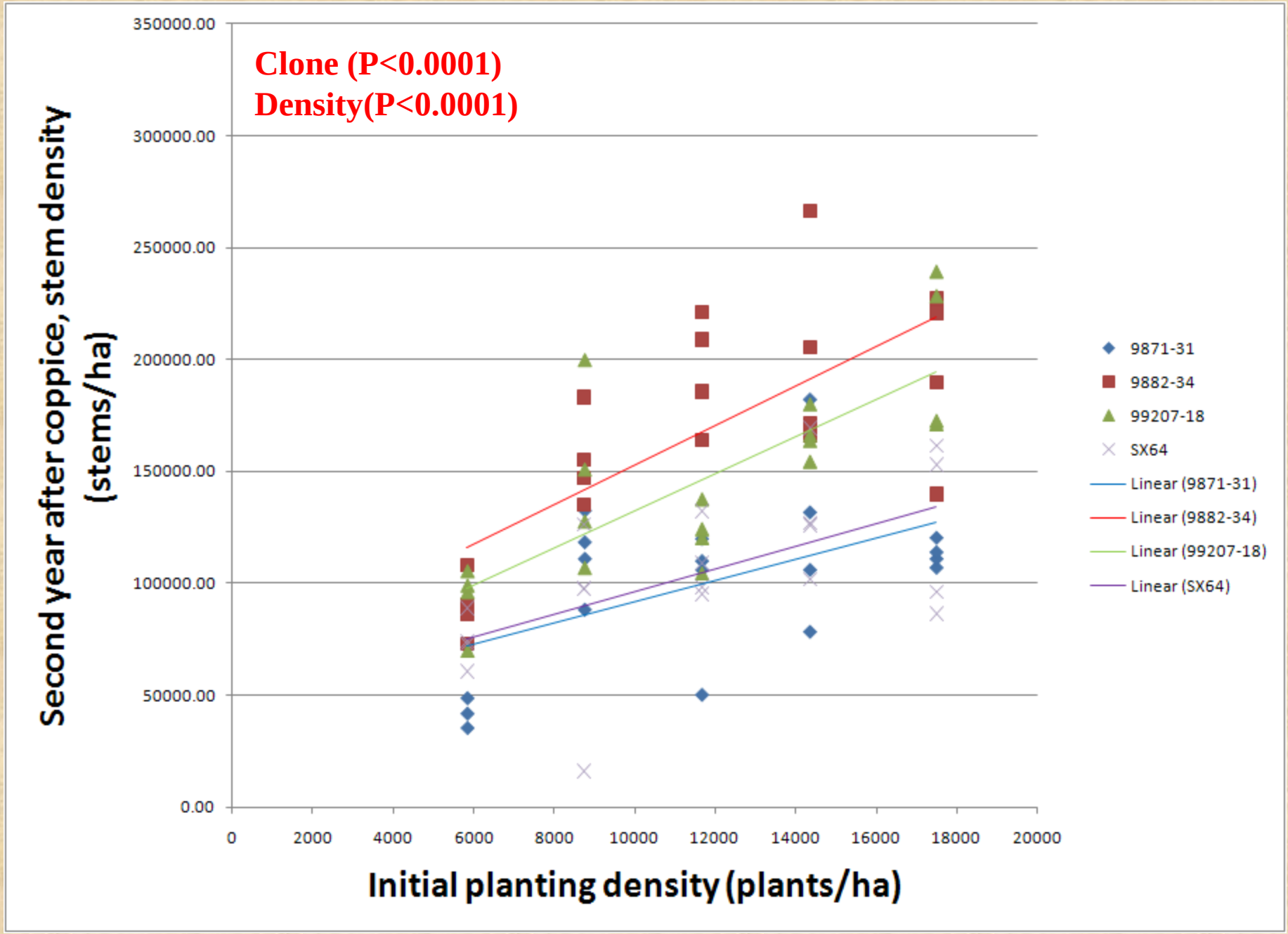
Five density treatments

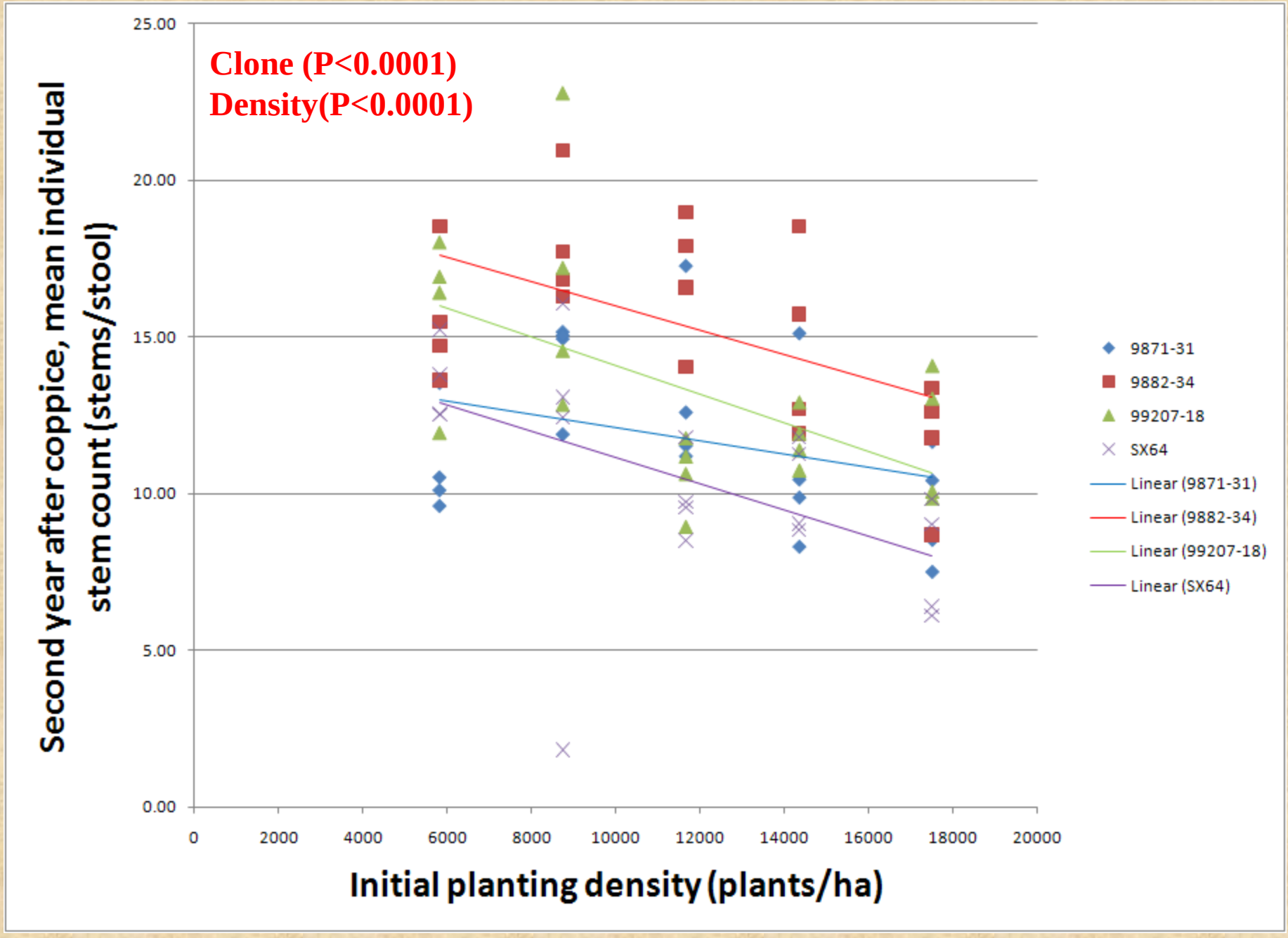
Spacing (m)	Density (plants/ha)	Planting Cost ($/ha)
0.5	17,498	$2099.76
0.6	14,352	$1722.24
0.75	11,665	$1399.80
1.0	8,749	$1049.88
1.5	5,833	$699.96











Density and Sprouting…

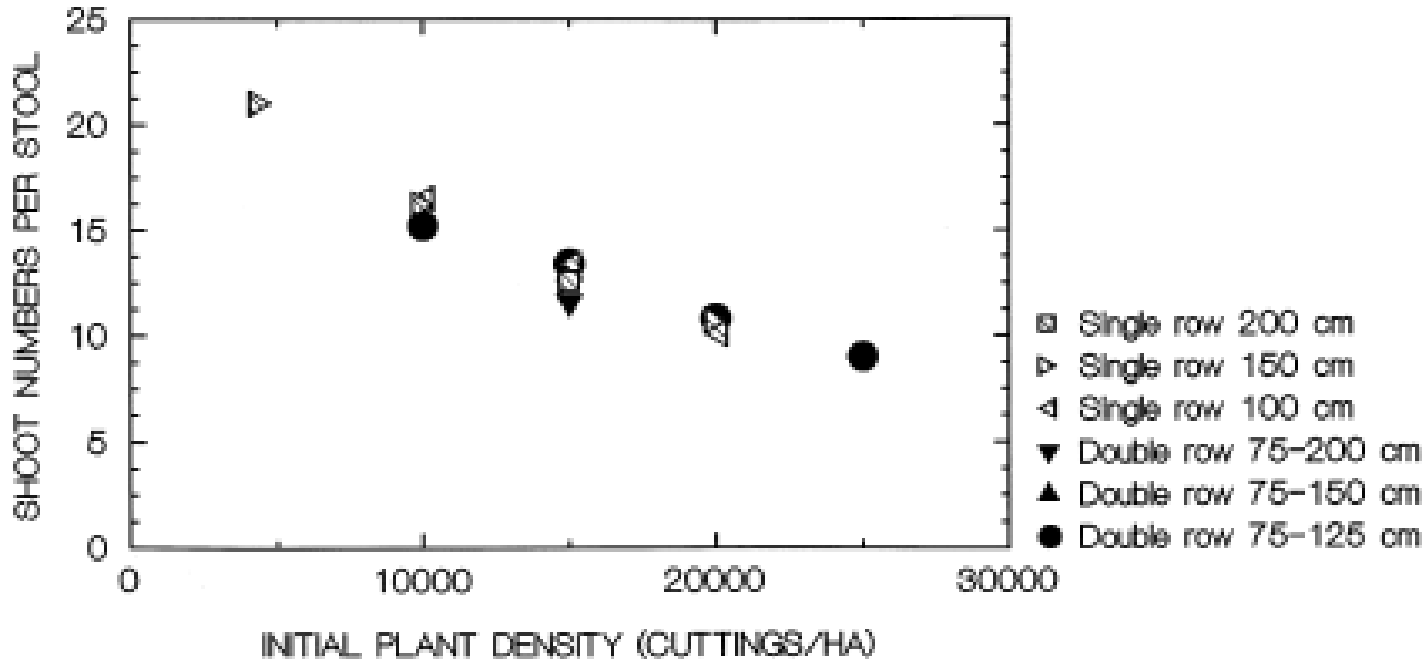
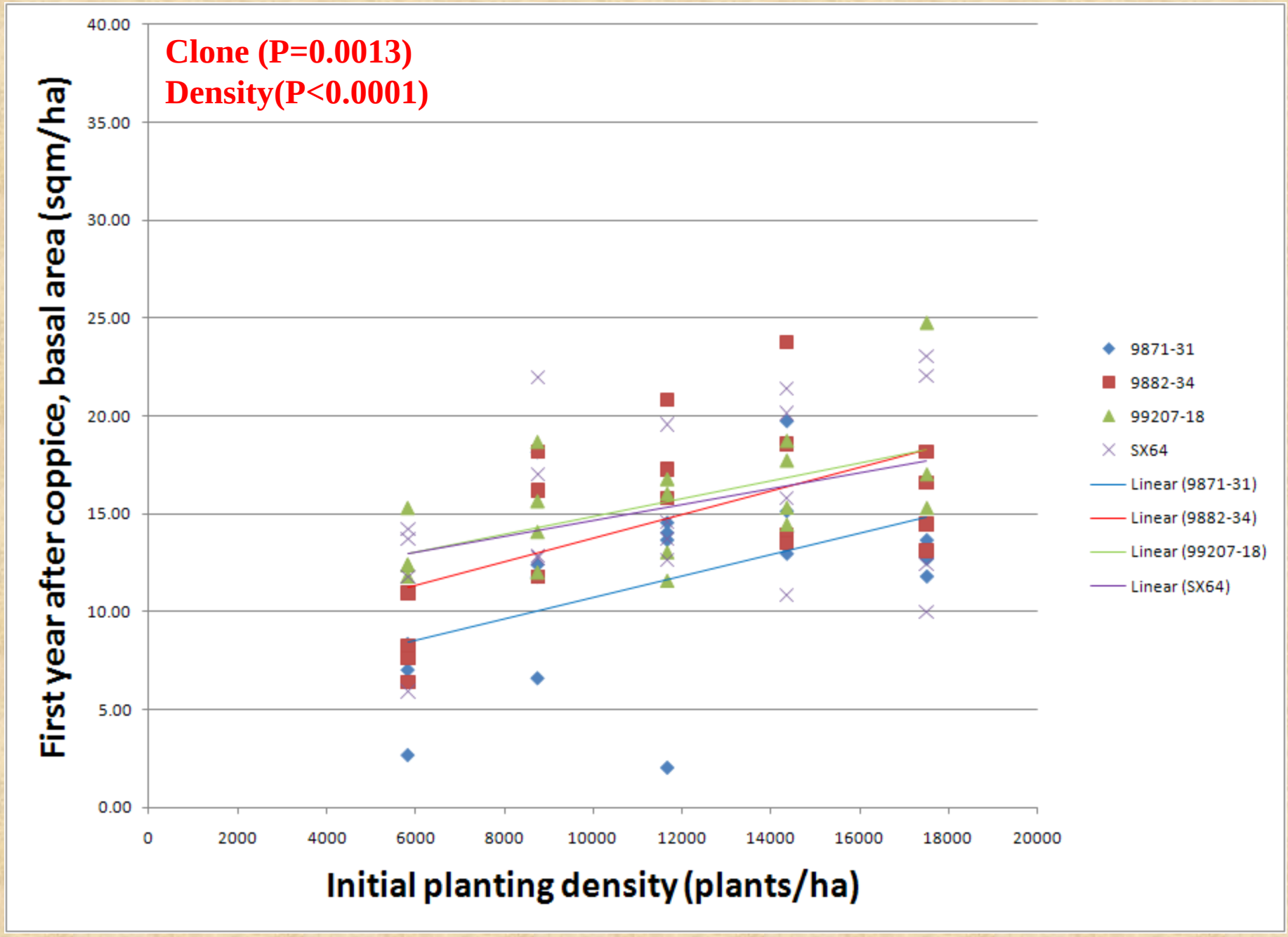
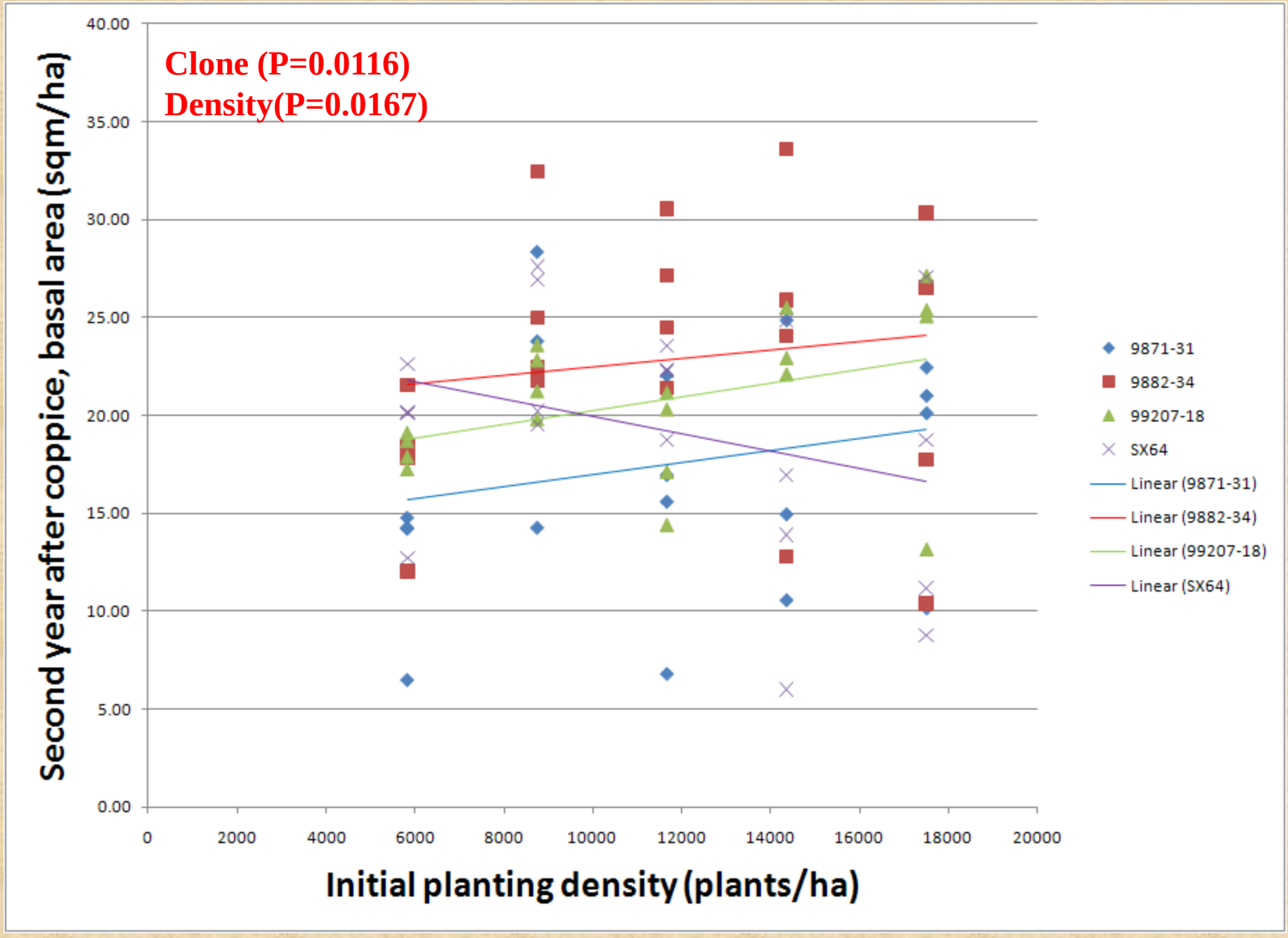


Fig. 3. Shoot numbers per stool with the different plant arrangements and different number of plants ha^{-1} 2 years after first harvest.

(Bergkvist and Ledin 1998)





Next steps and conclusions

- Collect additional stem data this year, begin to put together allometric equations for estimating biomass.
- Collect harvest data across multiple rotations, necessary to determine long-term trends.
- Analyze data from Waseca, MN.
- Update EcoWillow Model

References…

Bergvist, P. and S. Ledin. 1998. Stem biomass yields at different planting designs and spacings in willow coppice systems. Biomass and Bioenergy 14(2): 149-156.

Buchholz , T. and T.A. Volk. 2010 Improving the profitability of willow crops – identifying opportunities with a crop budget model. Bioenergy Research. Published online.

Drew, T.J. and J.W. Flewelling. 1977. Some recent Japanese theories of yield-density relationships and their application to Monterrey pine plantations. Forest Science 23(4): 517–534.

Oliver, C.D. and B.C. Larson. 1996. Forest Stand Dynamics. Update Edition. John Wiley and Sons, New York. 521 p.

Willebrand , E. and T. Verquist. 1993. Population dynamics of willow coppice systems and their implications for management of short-rotation forests. The Forestry Chronicle 69(6): 699-704.

Acknowledgements

- USDA NIFA
- USDA Rural Development
- Godfrey Ofezu, Phillip Castellano, Rebecca Allmond, Ken Burns, Erica Fabio and a number of undergraduate students.