Breeding Triploid Hybrids of Shrub Willow with Improved Yield and Biomass Composition

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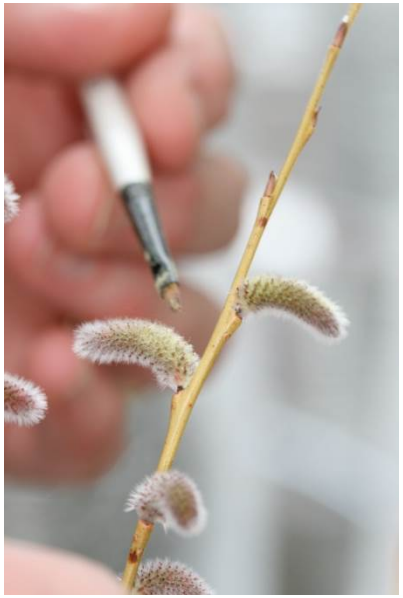

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WILLOWPEDIA http://willow.cals.cornell.edu

Willow biomass can be a feedstock for biopower, heat, and liquid biofuels

Lyonsdale Biomass Power Plant, Lyons Falls, NY
Photo: Catalyst Renewables

VeraSun Station, Brookings, SD

ACT Bioenergy Wood Boiler

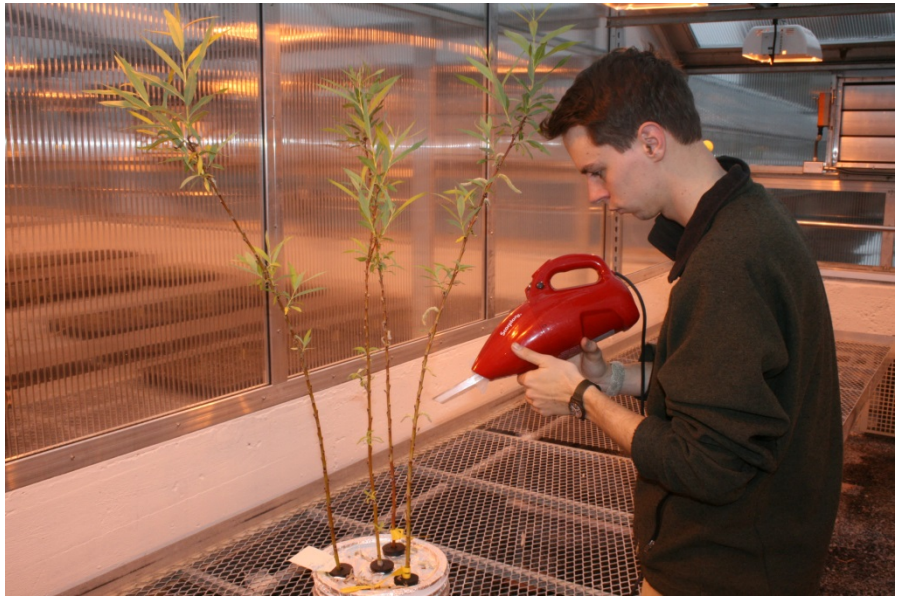
…each with its own optimal biomass composition

Shrub Willow Breeding Goals:

- Yield, yield, yield
- Pest/disease resistance
- Density/composition
- Form: harvesting/cuttings
- Stress tolerance for marginal sites

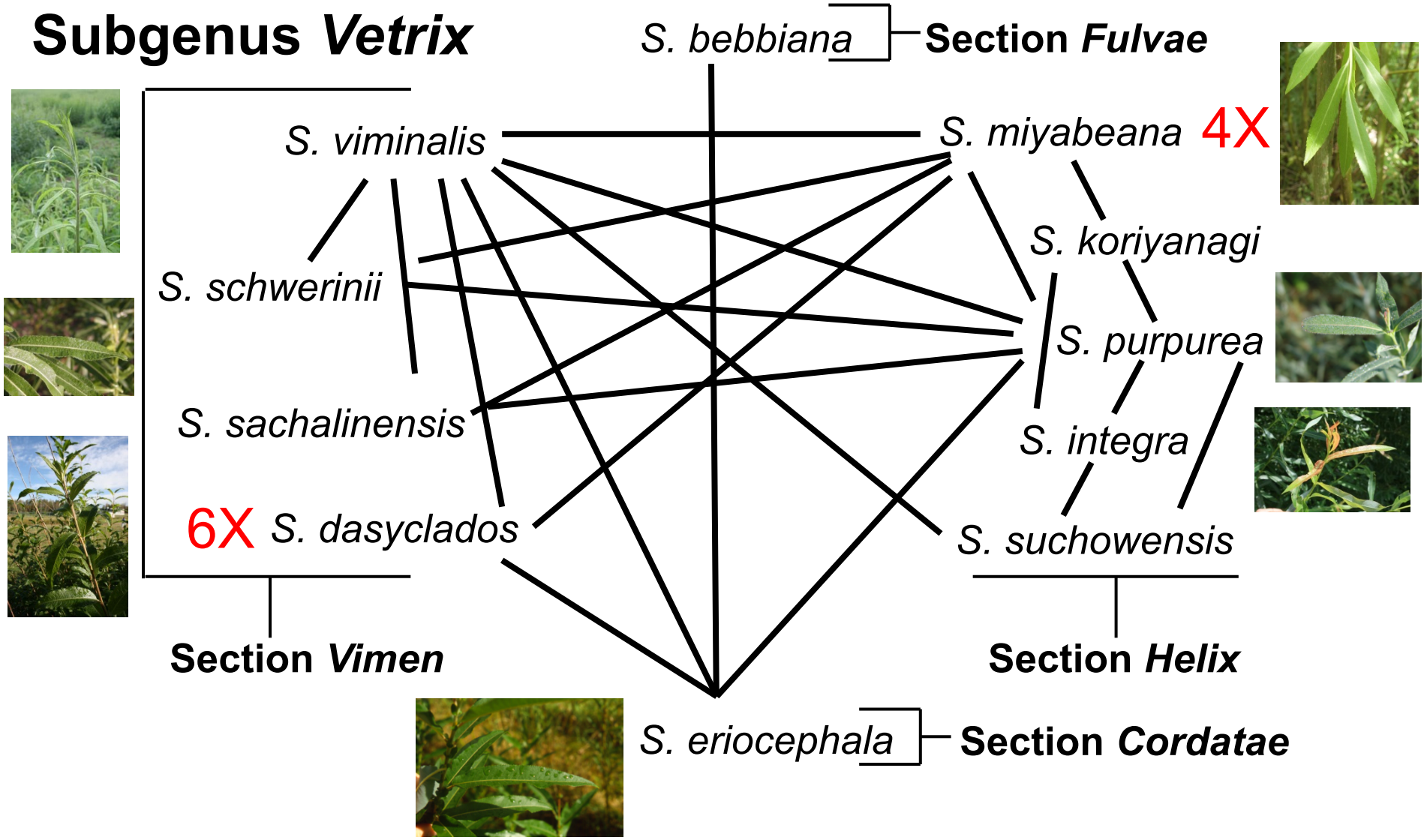
Breeding Approach:

- Capture hybrid vigor and combine traits through controlled pollination and species hybridization



Breeding Strategy:

Exploit the diversity of Salix through hybridization



Compilation of results from US, Canadian, and European breeding programs

Inter-specific Hybridizations

~10,000 seedling progeny produced in last 5 years at Cornell

F_1 hybrids

S. integra x *S. purpurea*
S. cordata x *S. eriocephala*
S. purpurea x *S. eriocephala*
S. purpurea x *S. viminalis*
S. purpurea x *S. sachalinensis*
S. purpurea x *S. gilgiana*
S. purpurea x *S. suchowensis*
S. koriyanagi x *S. purpurea*
S. koriyanagi x *S. integra*
S. koriyanagi x *S. miyabeana*
S. viminalis x *S. miyabeana*
S. viminalis x *S. eriocephala*
S. x *dasyclados* x *S. miyabeana*
S. x *dasyclados* x *S. eriocephala*
S. x *dasyclados* x *S. viminalis*
S. eriocephala x *S. purpurea*
S. matsudana x *S. alba*
S. sachalinensis x *S. eriocephala*
S. sericea x *S. purpurea*
S. sericea x *S. eriocephala*
S. sericea x *S. sachalinensis*
S. discolor x *S. cinerea*
S. discolor x *S. eriocephala*
S. miyabeana x *S. suchowensis*
S. miyabeana x *S. dasyclados*
S. integra x *S. suchowensis*
S. alberti x *S. purpurea*
S. alberti x *S. miyabeana*
S. alberti x *S. viminalis*

Multi-species hybrids

S. viminalis x (*S. purpurea* x *S. miyabeana*)
S. viminalis x (*S. viminalis* x *S. miyabeana*)
S. purpurea x (*S. purpurea* x *S. miyabeana*)
S. purpurea x (*S. viminalis* x *S. miyabeana*)
(*S. viminalis* x *S. schwerinii*) x *S. cinerea*
S. miyabeana x (*S. purpurea* x *S. miyabeana*)
(*S. kori* x *S. pur*) x *S. miyabeana*
(*S. kori* x *S. pur*) x *S. suchowensis*
(*S. kori* x *S. pur*) x (*S. kori* x *S. pur*)
(*S. pur* x *S. sach*) x (*S. pur* x *S. sach*)
(*S. suchowensis* x *S. viminalis*) x *S. purpurea*
(*S. suchowensis* x *S. viminalis*) x *S. miya*
S. miya x (*S. vim* x (*S. schwerinii* x *S. vim*))
(*S. alberti* x *S. leocopithecia*) x *S. miya*
(*S. alberti* x (*S. integra* x *S. such*)) x *S. miya*
(*S. alberti* x (*S. integra* x *S. such*)) x *S. pur*
(*S. integra* x *S. suchowensis*) x *S. purpurea*
(*S. integra* x *S. suchowensis*) x *S. such*
(*S. integra* x *S. suchowensis*) x *S. purpurea*
S. purpurea x ((*S. kori* x *S. pur*) x *S. such*)
S. vim x (*S. vim* x (*S. schw* x *S. vim*)) x *S. miya*

Selection and Scale-up Strategy

Controlled pollinations
- start seeds in gr chamber
- transplant to greenhouse

Plant seedlings in field
1,000's

Family Screening Trial
Single-plant plots in family rows

2-3 years

Select, propagate
60-80

Selection Trial
Single site, replicated, multi-plant plots

Select *12-15*
2-4 years

Yield Trials

Selection and Scale-up Strategy

Controlled pollinations
- start seeds in chamber
- transplant to greenhouse

Plant seedlings in field

Family Nursery Beds
Single-plant plots in family rows

Propagate all in families

2013 Selection Trial
284 clones, 4 reps
3-plant plots

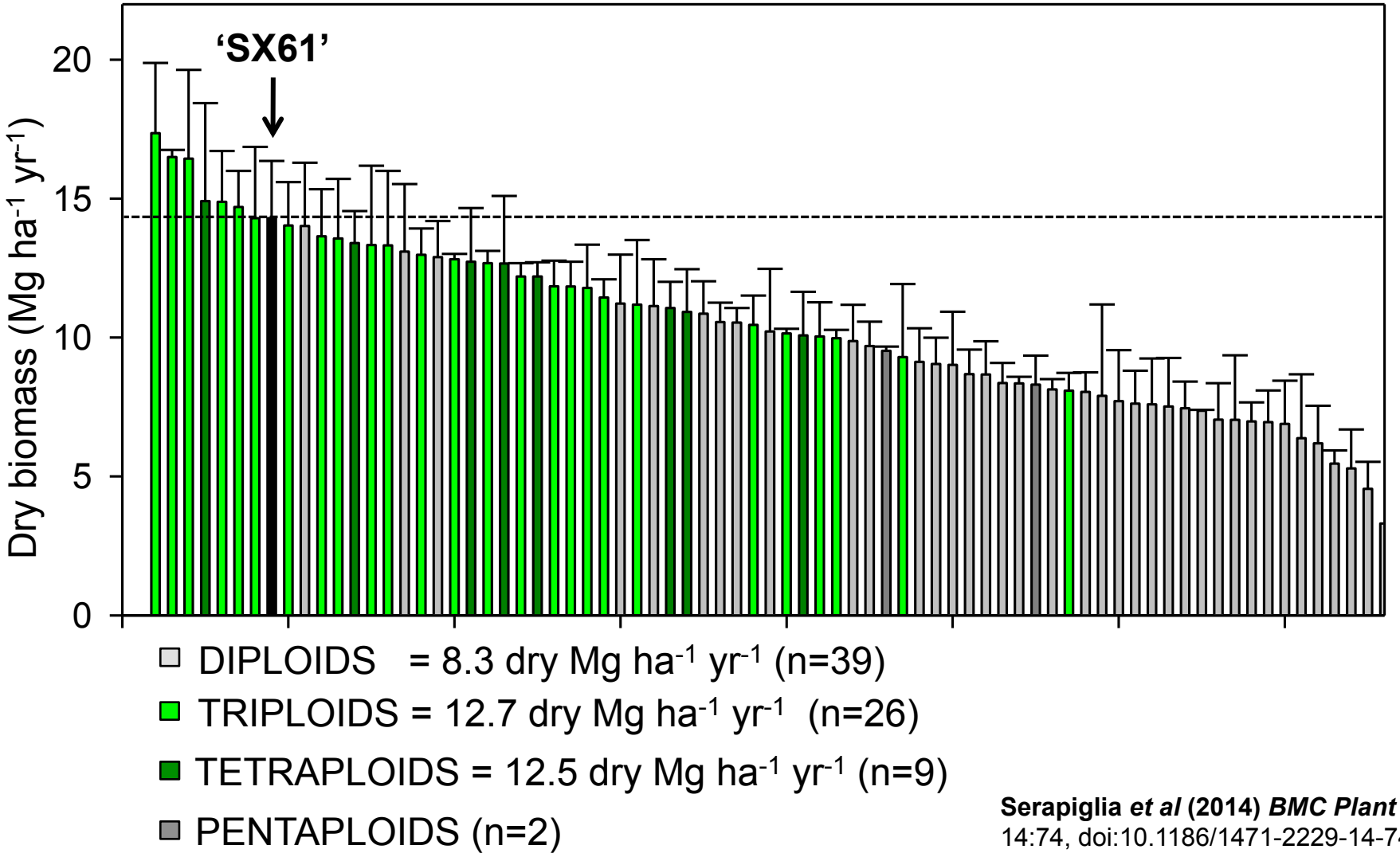
2014 Selection/QTL Trial
1085 clones, 4 reps
3-plant plots

2008 Genetic Selection Trial - Geneva, NY

- 24-plant plots, 3 replicates, 75 clones
- Biomass harvested from middle 8 plants in Dec. 2011

2008 Genetic Selection Trial - Geneva, NY

- **6 new genotypes ranked higher than 'SX61'**
- **Top genotype produced 21% greater yield**

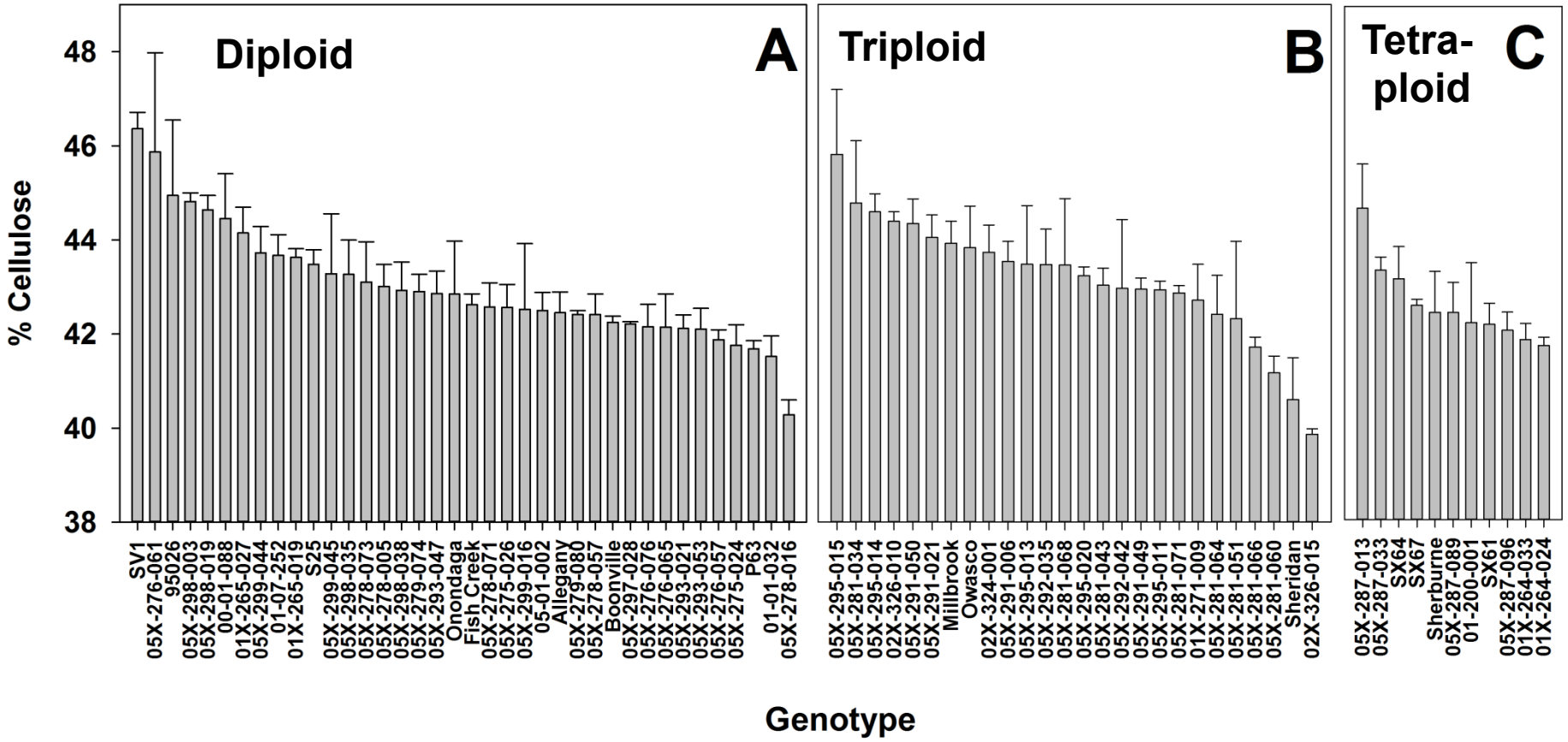


Serapiglia *et al* (2014) *BMC Plant Biol.* 14:74, doi:10.1186/1471-2229-14-74.

2008 Genetic Selection Trial - Geneva, NY

Third-year cellulose content

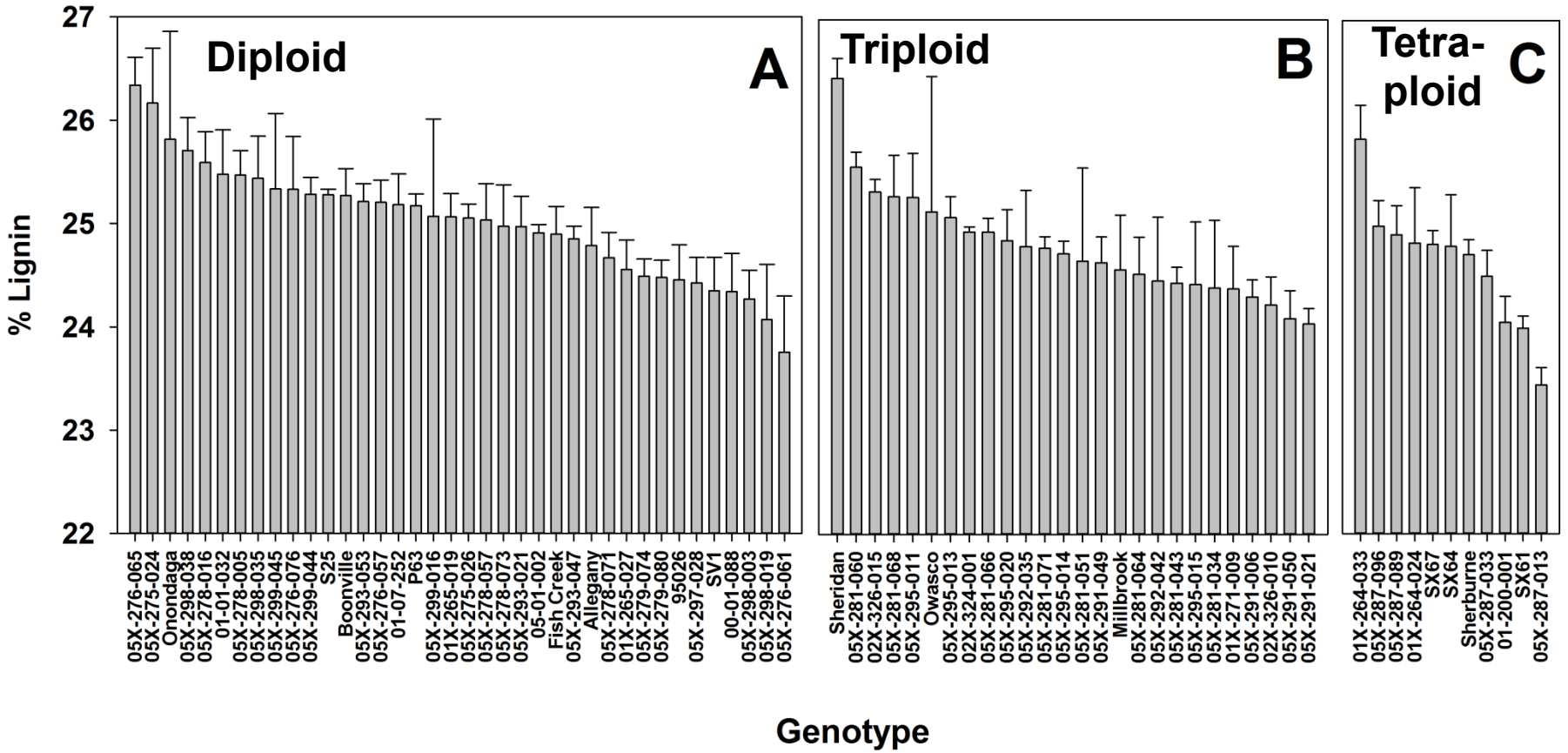
- positively correlated with yield
- strongly negatively correlated with lignin and ash
- not significantly different by ploidy



2008 Genetic Selection Trial - Geneva, NY

Third-year lignin content

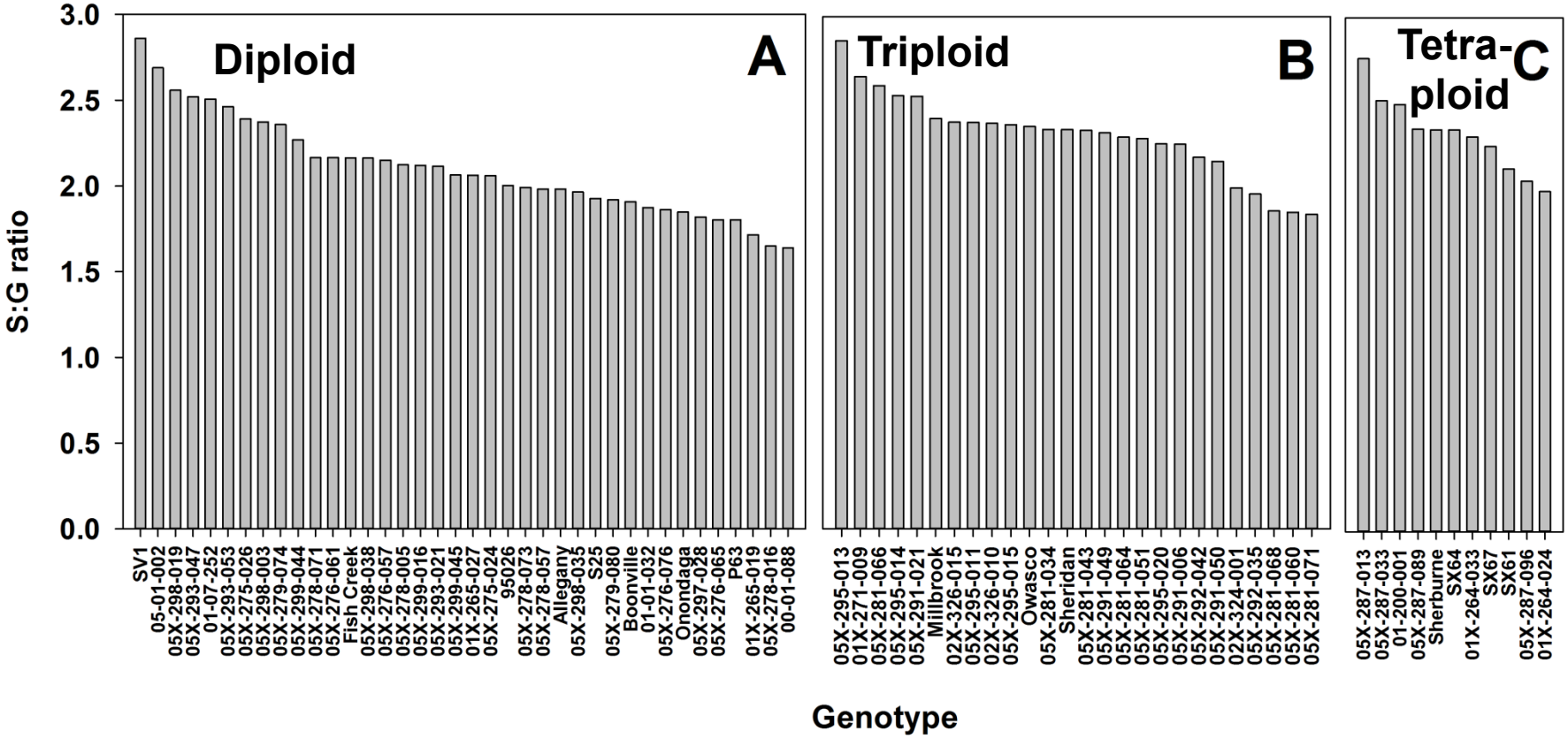
- negatively correlated with yield and height
- negatively correlated with cellulose, positively with ash
- significantly *lower* in triploids and tetraploids



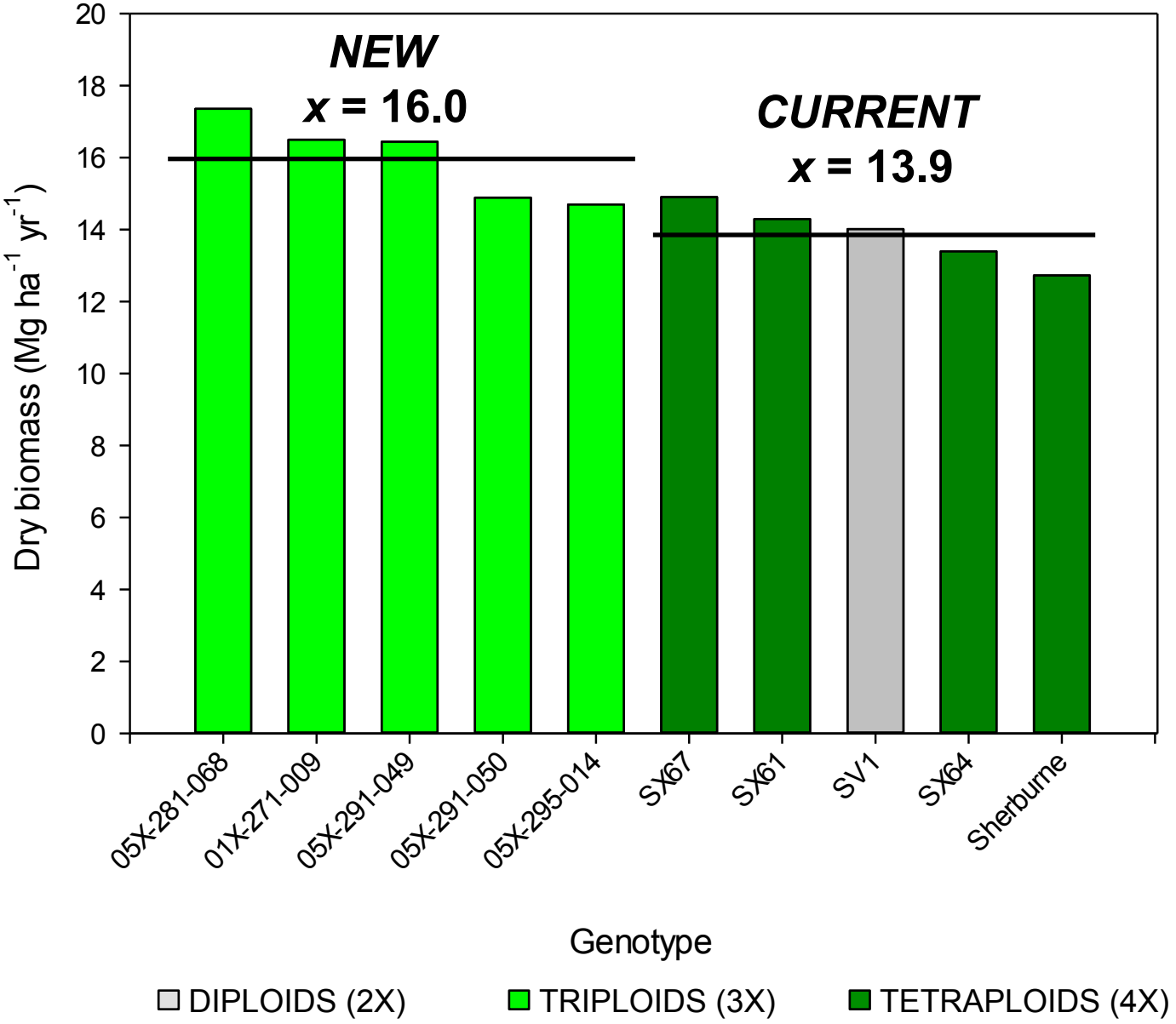
2008 Genetic Selection Trial - Geneva, NY

Third-year lignin S:G ratio

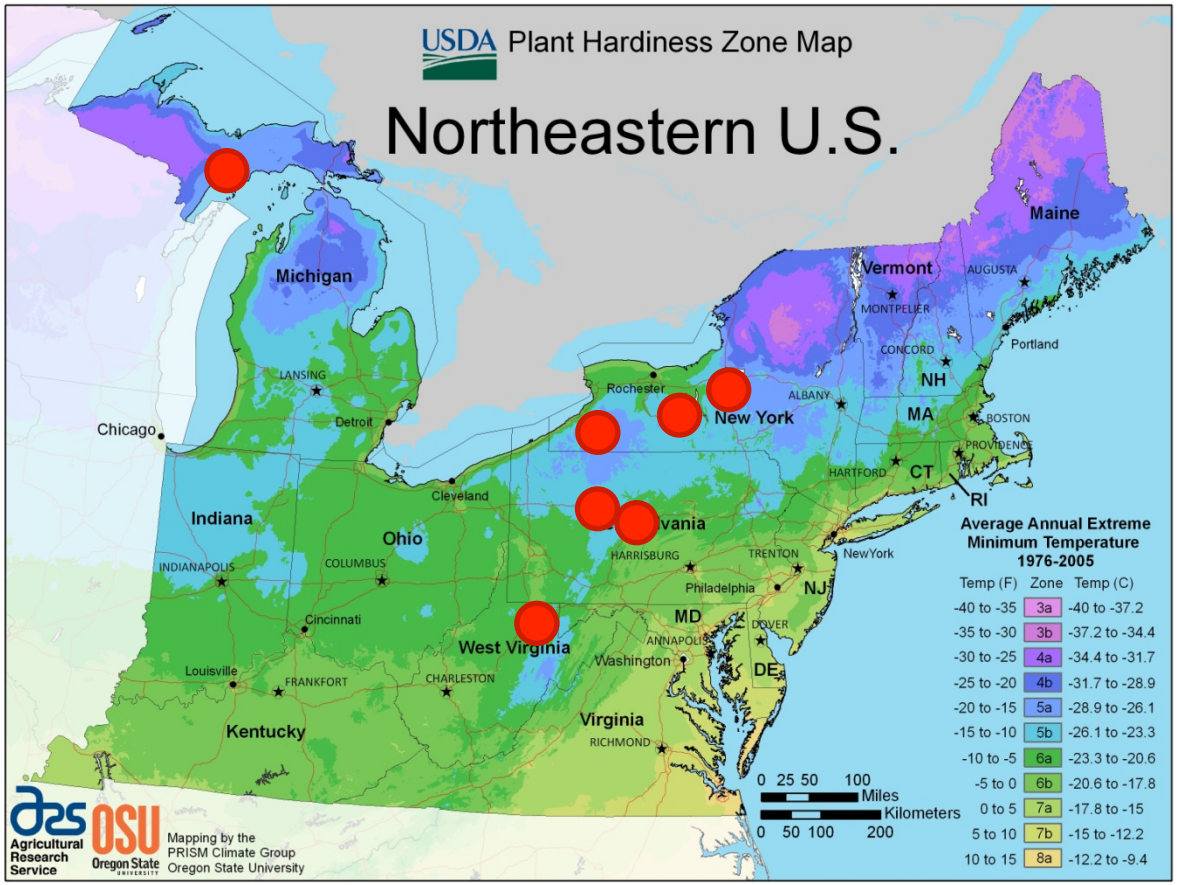
- *positively* correlated with yield, height, density, cellulose
  - negatively correlated with lignin and ash
  - only one rep analyzed from year 3 due to cost



Mean of Top Five New vs. Current Cultivars
= *15% increase*



NEWBio Regional Trials



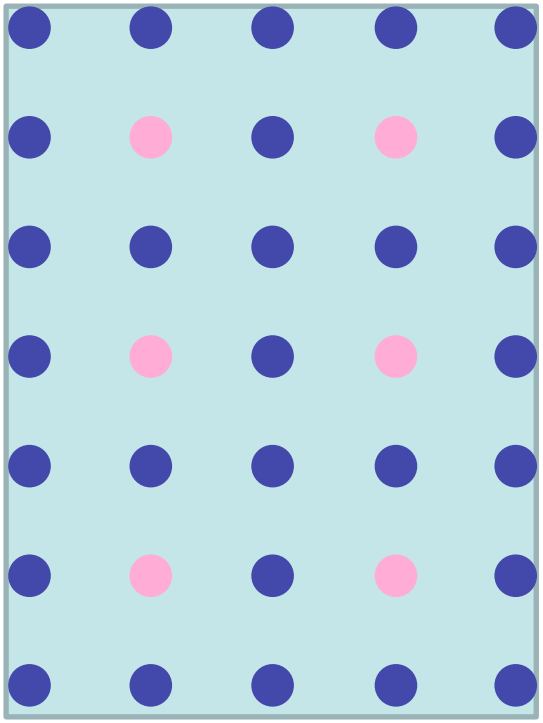
- Yield Trials (24 cultivars, 48 plant plots)
  - *two sites are reclaimed mine land*
  - *one site – paired amended/unamended*

Long-term Triploid Breeding Strategy:

Population improvement of diploids and tetraploids

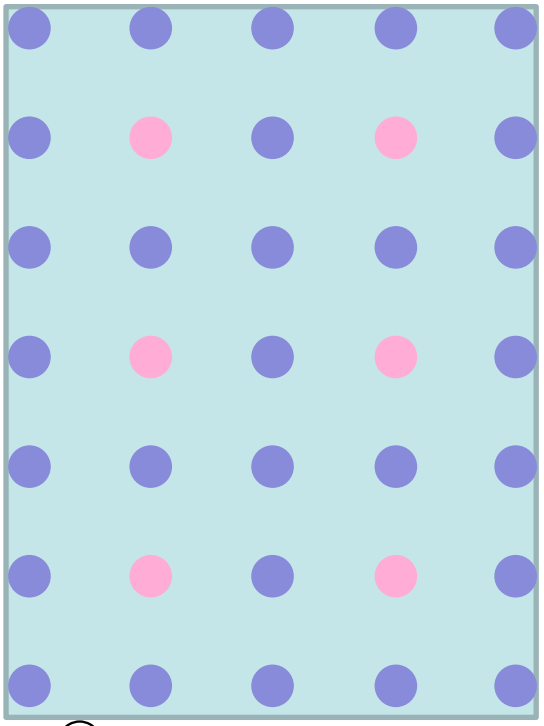
Crossing blocks, half-sib seed collected in the field

Foundation



♀, ♂ = unimproved tetraploids

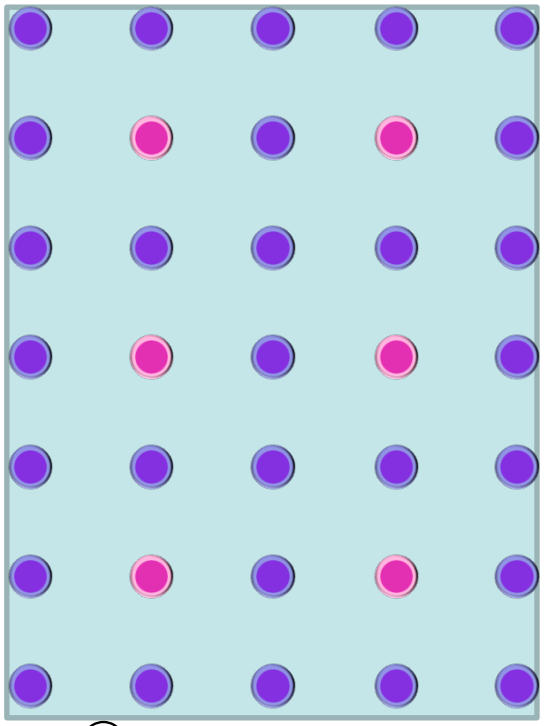
Unimproved



♀= unimproved tetraploids

♂ = unimproved diploids

Improved



♀= improved tetraploids

♂ = improved diploids

Conclusions…

- We can capture hybrid vigor in willow through hybridization of diverse species.
- Natural variation in ploidy among *Salix* spp. can be exploited to produce triploid progeny.
- Biomass composition traits vary significantly among diverse genotypes and are correlated with yield and height; some traits differ by ploidy.
- Most promising commercial cultivars are triploid and are essentially sterile.

Thanks to…

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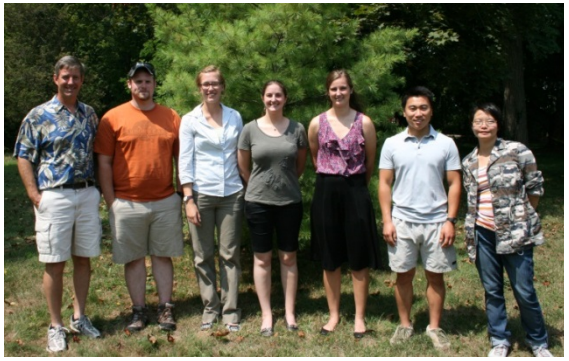


USDA United States Department of Agriculture National Institute of Food and Agriculture

United States Department of Energy

NEWBio

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