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

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

...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

Subgenus Vetrix

S. bebbiana - Section Fulvae

S. viminalis
S. schmerinii
S. sachalinensis
6X S. dasyclados

S. miyabeana 4X

S. koriyanagi
S. purpurae
S. integra
S. suchowensis

S. eriocephala - Section Cordatae

Section Vimen

Section Helix

Compilation of results from US, Canadian, and European breeding programs
Inter-specific Hybridizations

**F₁ 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. 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. matsuana 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

**Multi-species hybrids**
- S. miyabeana x S. sachowensis
- S. miyabeana x S. dasyclados
- S. integra x S. sachowensis
- S. alberti x S. purpurea
- S. alberti x S. miyabeana
- S. alberti x S. viminalis

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

Dry biomass (Mg ha\(^{-1}\) yr\(^{-1}\))

- DIPLOIDS = 8.3 dry Mg ha\(^{-1}\) yr\(^{-1}\) (n=39)
- TRIPLOIDS = 12.7 dry Mg ha\(^{-1}\) yr\(^{-1}\) (n=26)
- TETRAPOLOIDS = 12.5 dry Mg ha\(^{-1}\) yr\(^{-1}\) (n=9)
- PENTAPLOIDS (n=2)

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

**Graphs:**

- **Diploid (A)**
- **Triploid (B)**
- **Tetraploid (C)**
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

NEW
x = 16.0

CURRENT
x = 13.9
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.
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