



CHICAGO BOTANIC GARDEN



Consequences of fecundity reduction in cultivars of invasive plants

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The Invasive Problem



- Invasive species are the 2nd largest threat to biodiversity
- We depend on biodiversity
 - Food, Medicines
 - Shelter
 - Ecosystem services
- Invasive species cost the US \$138 billion/year, invasive plant costs are conservatively \$35 billion/year
- Many invasive species (~65%) enter new countries as horticultural introductions, particularly woody invasives

Botanic Gardens and Invasive Plants

- Many gardens, recognizing the role horticulture has played in introduction of invasive species, are developing policies to be more responsible about what they import and display
- CBG, and several other U.S. gardens, have signed voluntary codes of conduct

(<http://www.centerforplantconservation.org/invasives/invasives.asp>)

- We are continually assessing our collection and removing invasives
- We have recently been grappling with how to deal with cultivars of invasive species



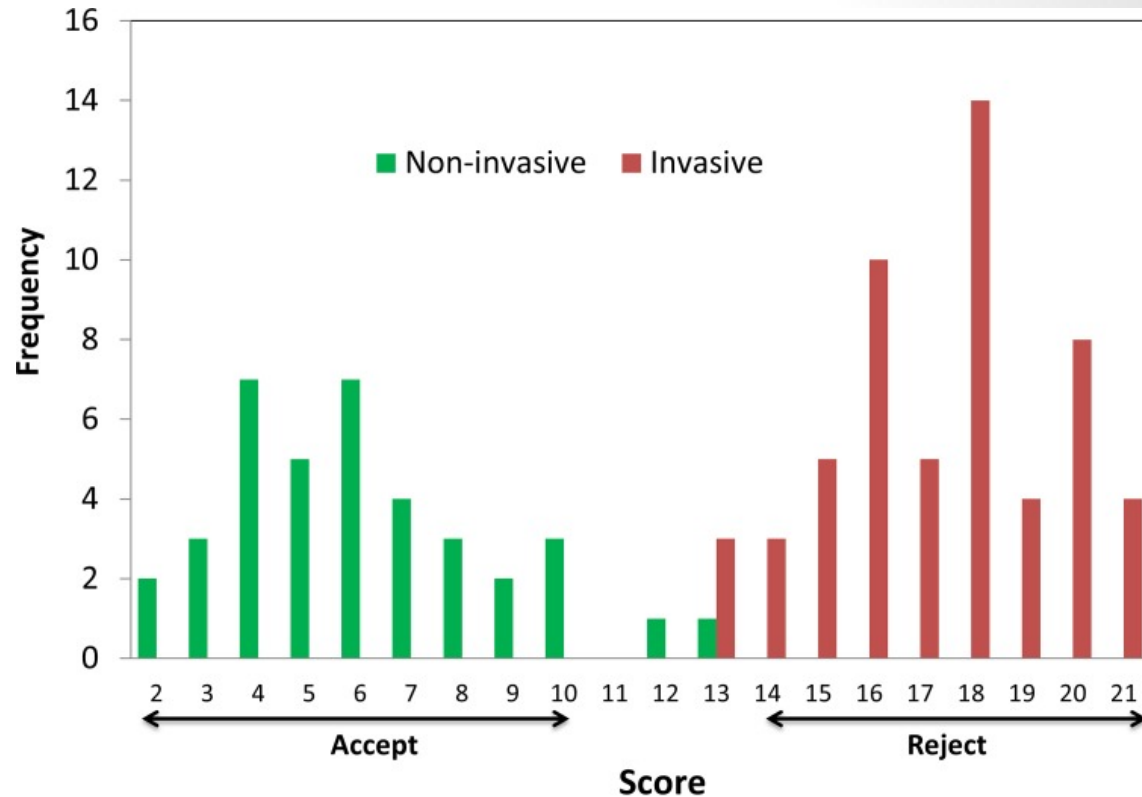
Weed Risk Assessment

- Typically uses a decision tree to look at plant traits associated with invasiveness...some of those traits include:
 - Taxa invasive in other regions
 - Short juvenile period
 - Vegetative reproduction
 - Broad ecological amplitude
 - Short generation time
 - Seeds that germinate without pretreatment
 - And, is there a climate match?



A new WRA tool – “PRE”

- We are beta testers for a new web-based tool designed for the green industry called “PRE” developed by PlantRight
- Can make evaluations public, thus benefitting the community
- Conser C, Seebacher L, Fujino DW, Reichard S, DiTomaso JM (2015) The Development of a Plant Risk Evaluation (PRE) Tool for Assessing the Invasive Potential of Ornamental Plants. PLoS ONE 10(3): e0121053



Scores: Invasive >13; Non-invasive <11; Evaluate Further = 11-13

The “Cultivar Issue”

THREE-YEAR PHASE-OUT
by July 1, 2013

Cultivar of Barberry	UConn Research Seed/Fruit
Tara	9926
Crimson Velvet	6675
Sparkle	5543
'Anderson' Lustre Green™	4257
Marshall Upright	3249
Erecta	2912
'Bailgreen' Jade Carousel®	2267
Angel Wings	1847
'Bailtwo' Burgundy Carousel®	1377
Red Rocket	1332
'Monomb' Cherry Bomb™	1225
Painter's Palette	1177
Inermis	1152
Wild type/parent species	1105 (green)
var. <i>atropurpurea</i>	1045
'Bailone' Ruby Carousel®	1011
Pow Wow	1004
JN Redleaf	998
Gold Ring	954
Rose Glow	939
Kelleris	855
Kobold	842
'JN Variegated' Stardust™	768
'Bailsel' Golden Carousel®	
<i>B. koreana</i> x <i>B. thunbergii</i> hybrid	681
Silver Mile	638
Antares	620

OK FOR SALE/PRODUCTION

Cultivar of Barberry	UConn Research Seed/Fruit
Green Pygmy	556
Crimson Ruby	523
Royal Cloak	504
Stan's Variegated	432
Crimson Pygmy	429
Concorde	254
Lime Glow	254
Sunsation	222
Crimson Dwarf	191
Helmond Pillar	153
Bonanza Gold	108
Royal Burgundy	106
Gold Nugget	22
Aurea Nana	11
Aurea	7
Bagatelle	5
Golden Devine	0
<i>B. x mentorensis</i>	0

- Cultivars can vary significantly in their fecundity
- When a wild type and/or one or more cultivars are invasive, should all be banned?
- Are “sterile” cultivars always sterile?



Japanese Barberry (*Berberis thunbergii*)

A popular horticultural shrub that has become a natural area invader



The reasons? Sheer growability... hardy to zone 4, can take sun or shade, wet or dry, and will come back strong after a beating.”
--A Nursery Catalog

***“one of the most destructive invasive plants in Connecticut”
--Connecticut Botanical Society***

Why the resistance?

*Japanese Barberry sales in Connecticut Alone
--\$15-20 million USD*



Why the resistance?

Over 35 Cultivars of Japanese Barberry

- Aurea
- Bonanza Gold
- Angel Wings
- Crimson Giant
- Rosy Glow

Individuals within these range from producing less than 100 to over 9000 seeds per year



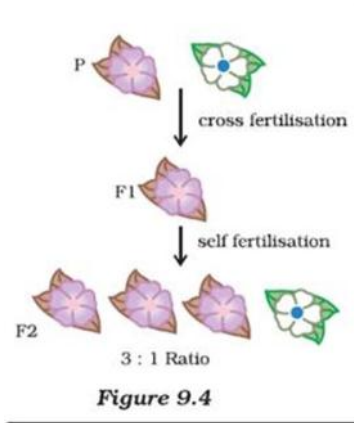
Not seeing problems in the garden:

"I know that some Barberries have become invasive but mine doesn't really set any seed and my plants are only 2 feet high after almost 5 years in the ground." –A gardening blog

"The only Barberry plants I've seen invade are green; the purple leaved varieties must be safe." –A nursery professional



Important points about cultivars



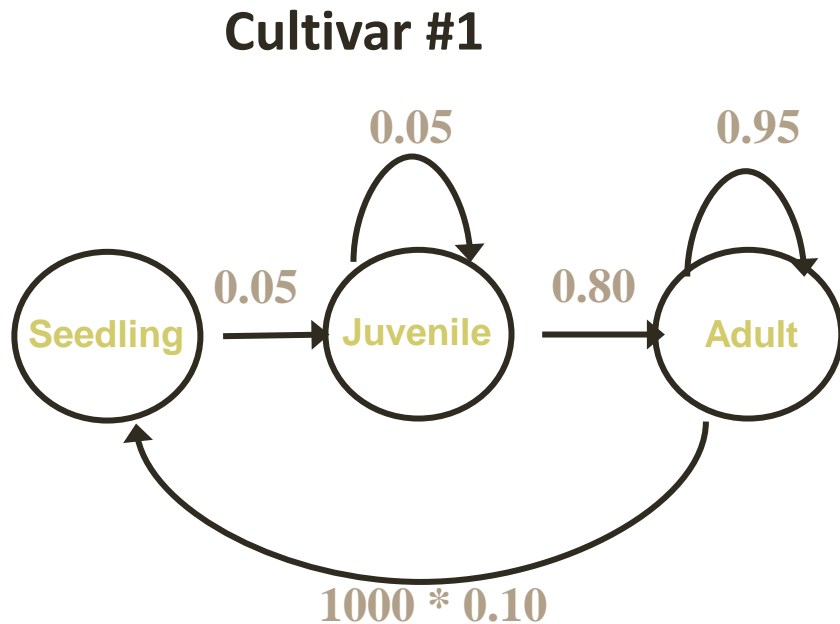
- Cultivars don't invade (unless they spread by runners), **their offspring invade**
- Their offspring may not resemble the cultivar, most cultivars do not “breed true”
- Self-incompatible is not the same as sterile

Modeling effect of fecundity on population growth rate

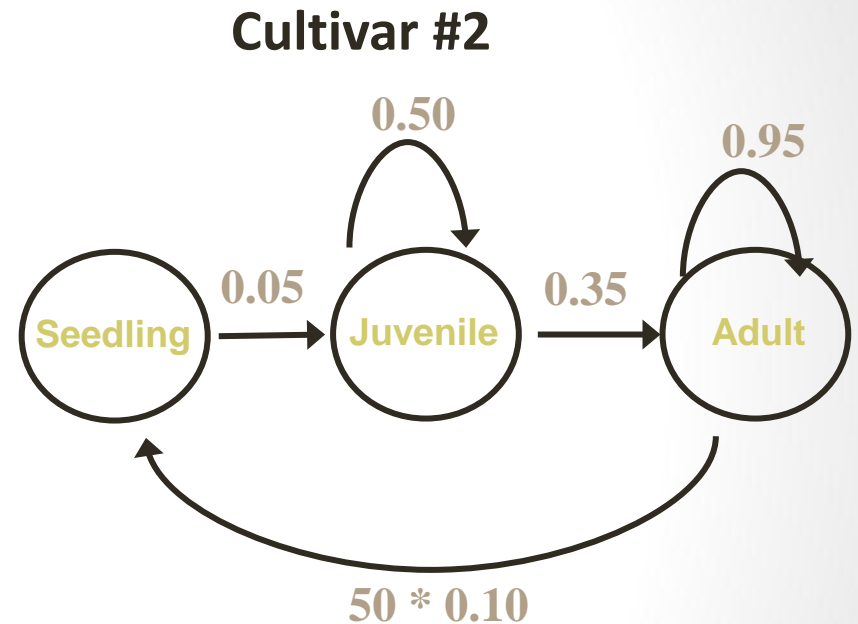
- We took a demographic approach to ask, “When reducing fecundity of cultivars, how much is enough to create a plant that will not be invasive?”
- Modeling was done by Tiffany Knight (iDiv in Germany)



A demographic approach



$\lambda=1.50$

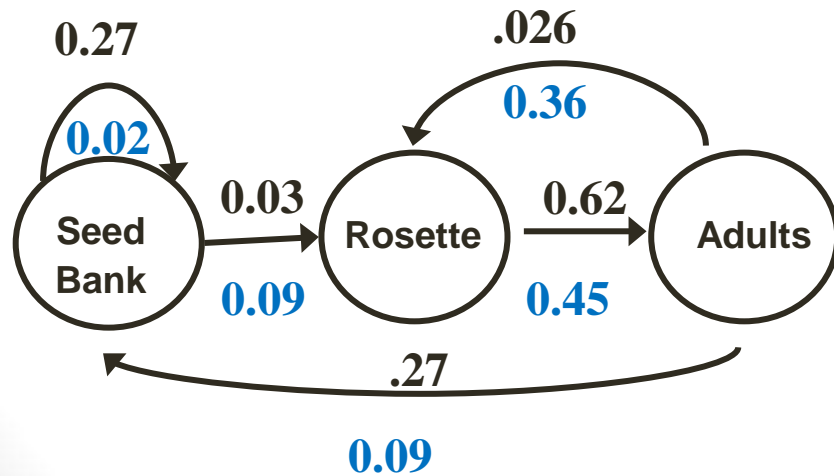


$\lambda=1.00$

Plant invasions and matrix models

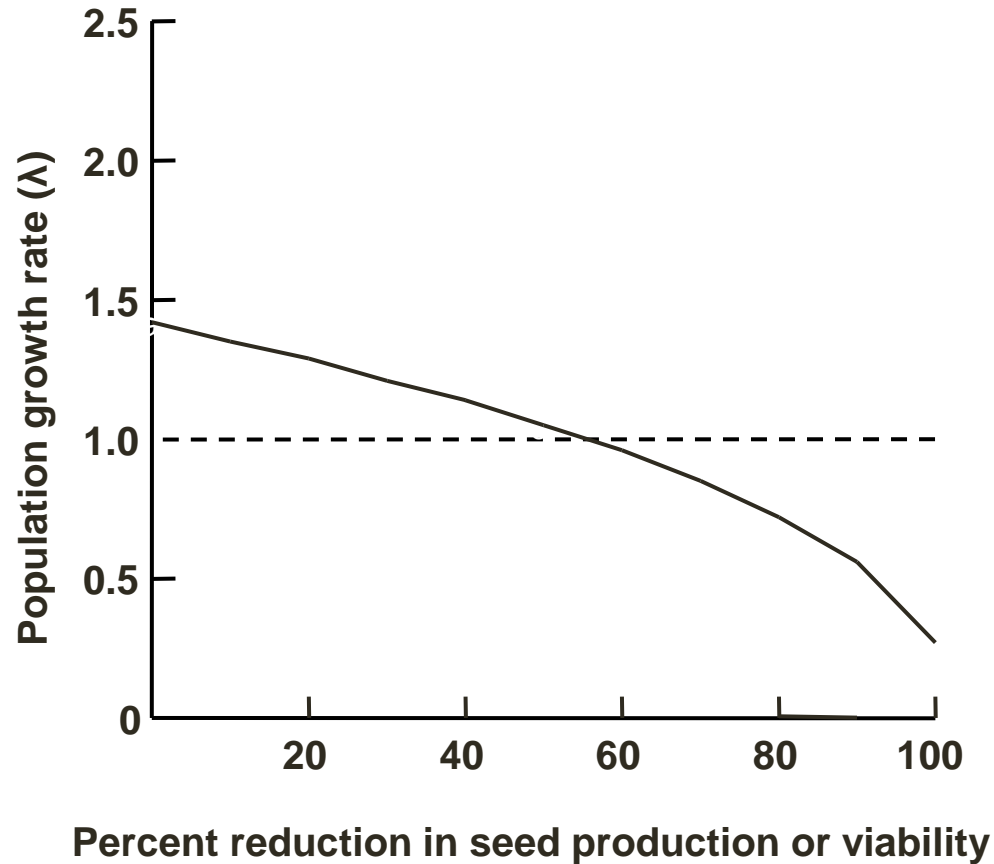
Plant	Life form	Invasive Range	Selected Reference
<i>Dipsacus sylvestris</i>	Biennial	USA	Werner and Caswell 1978
<i>Alliaria petiolata</i>	Biennial	USA	Davis et al. 2006
<i>Carduus nutans</i>	Monocarpic herb	New Zealand	Shea and Kelly 1998
<i>Heracleum mantegazzianum</i>	Monocarpic herb	Europe	Nehrbass et al. 2006
<i>Cirsium vulgare</i>	Monocarpic herb	USA	Tenhumberg et al. 2007
<i>Molinia caerulea</i>	Perennial grass	Western Europe	Jacquemyn et al. 2005
<i>Agropyron cristatum</i>	Perennial grass	USA	Hansen and Wilson 2006
<i>Lespedeza cuneata</i>	Perennial herb	USA	Schutzenhofer and Knight 2007
<i>Centaurea maculosa</i>	Perennial herb	USA	Emery and Gross 2005
<i>Clidemia hirta</i>	Shrub	USA	DeWalt 2006
<i>Ardisia elliptica</i>	Shrub	USA	Koop and Horvitz 2005
<i>Cytisus scoparius</i>	Shrub	USA	Parker 2000
<i>Pinus nigra</i>	Tree	New Zealand	Buckley et al. 2005

Alliaria petiolata (Garlic mustard): A typical short-lived
invasive plant



$$\lambda = 1.42$$

Reducing seed output reduces population growth of garlic mustard



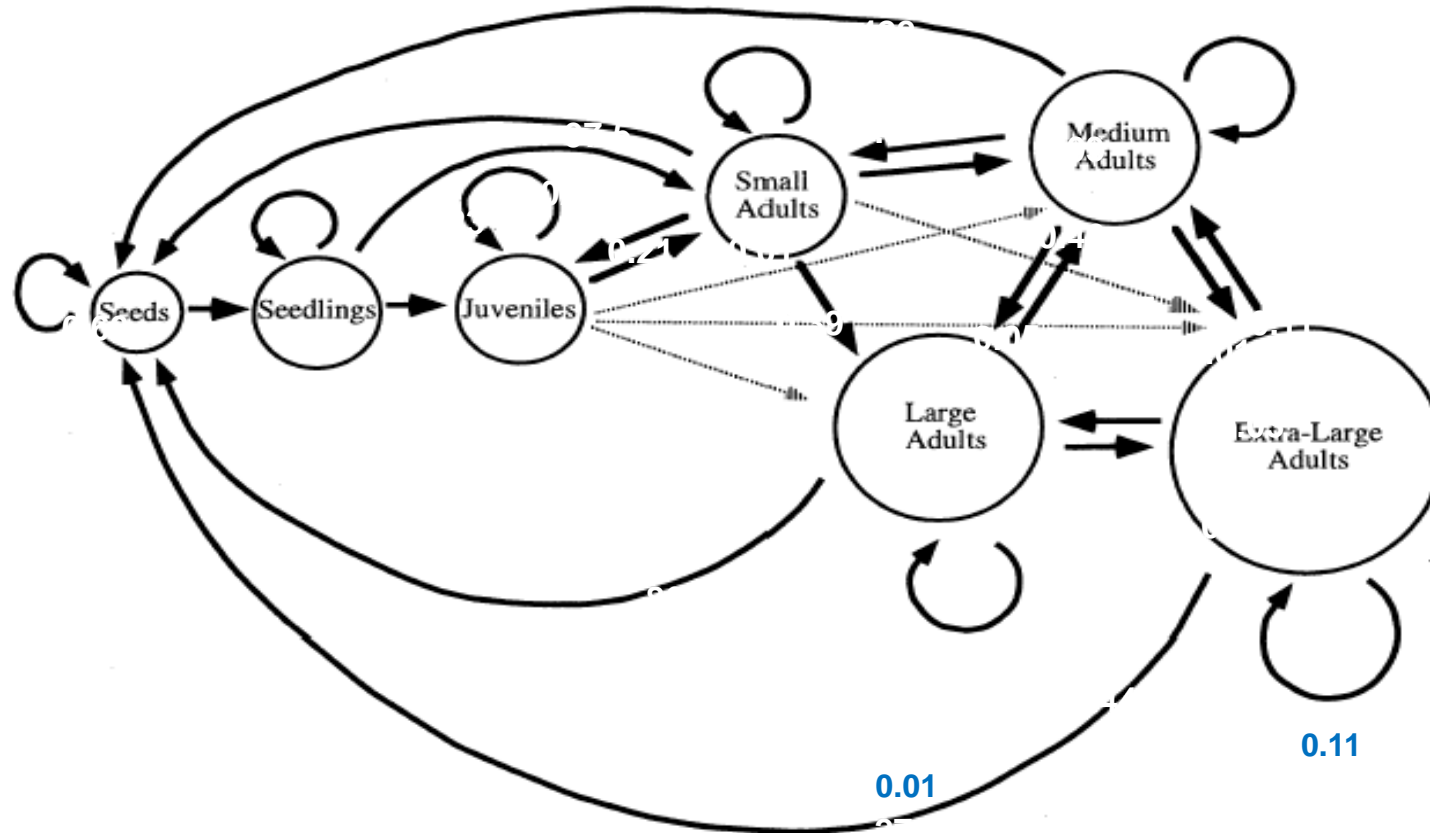
So, reduced seed output is likely to reduce population growth of short-lived species....

.....But, what about long-lived species such as shrubs and trees?

Scotch Broom (*Cytisus scoparius*)

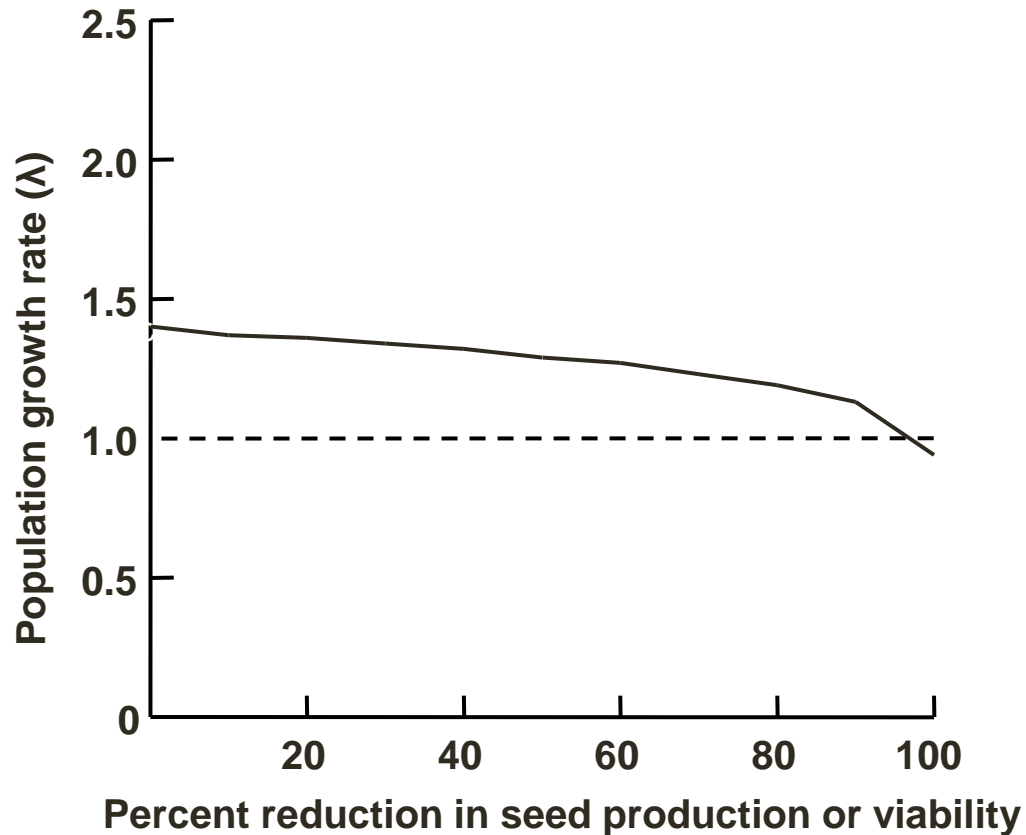


Cytisus scoparius (Scotch Broom)



$\lambda=1.40$

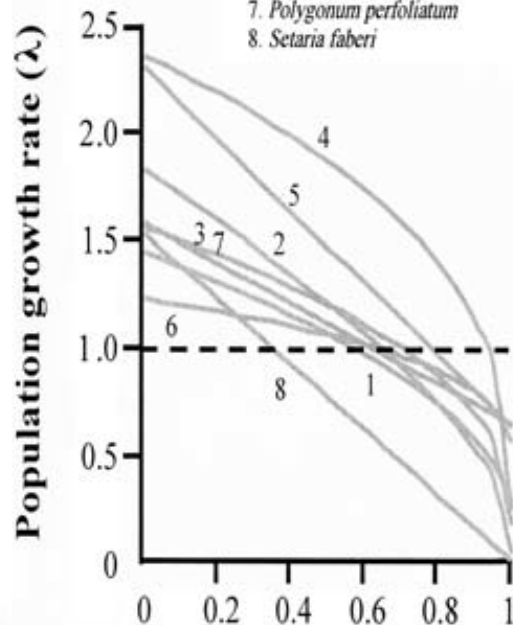
Reducing seed output has minor effects on scotch broom



Reduction in population growth rate relative to fecundity

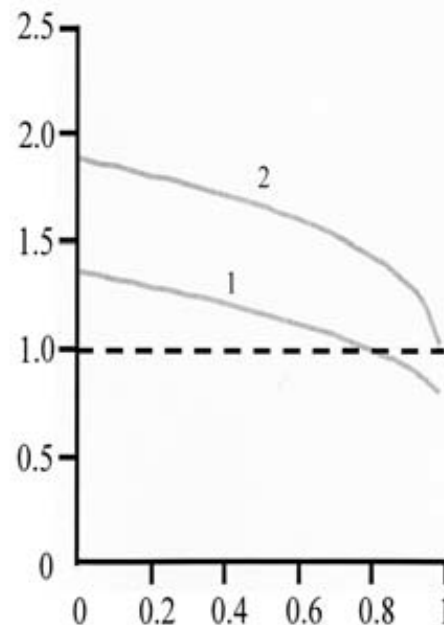
a Monocarpic herbs and grasses

1. *Alliaria petiolata*
2. *Carduus nutans*
3. *Cirsium vulgare*
4. *Dipsacus sylvestris*
5. *Echium vulgare*
6. *Heracleum mantegazzianum*
7. *Polygonum perfoliatum*
8. *Setaria faberi*



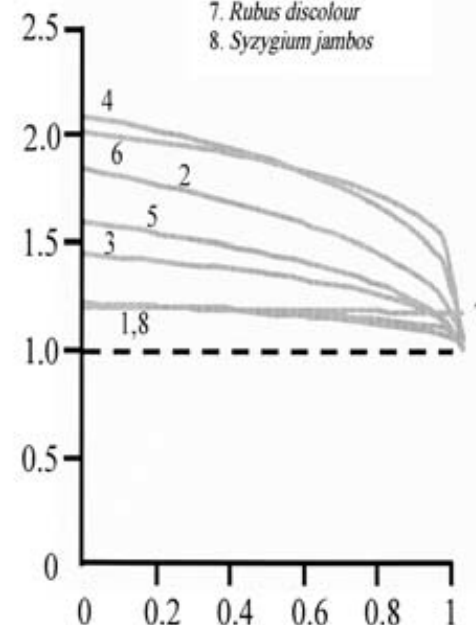
b Polycarpic herbs and grasses

1. *Centaurea maculosa*
2. *Molinia caerulea*



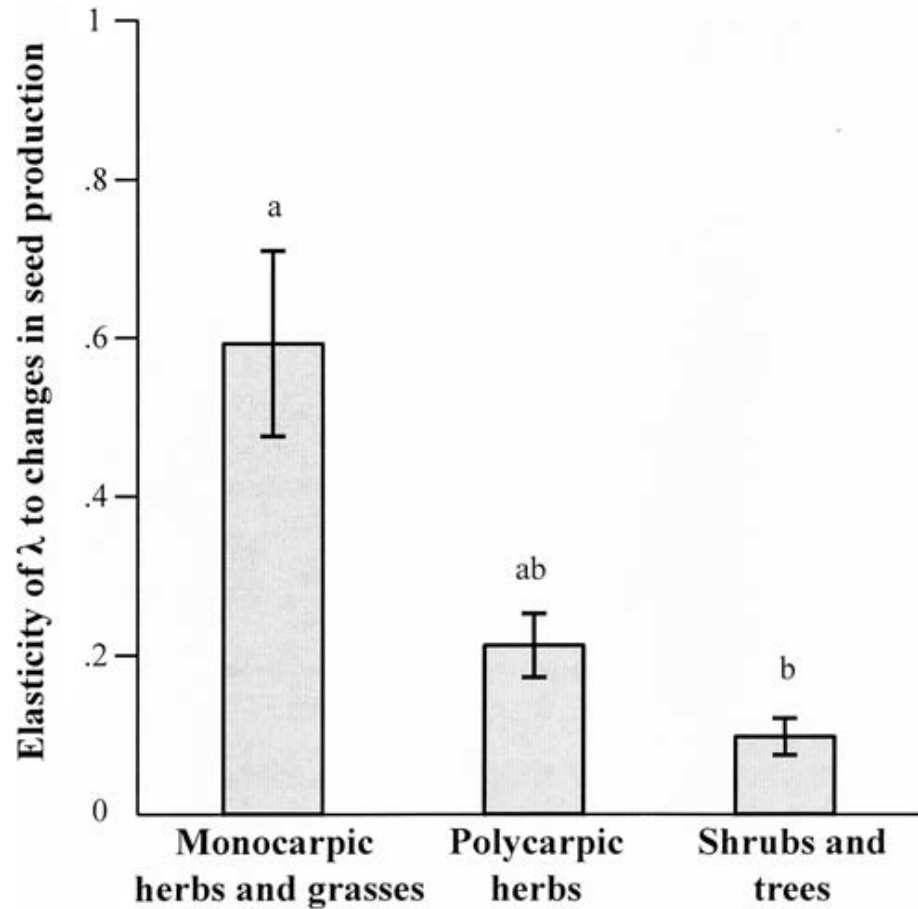
c Shrubs and trees

1. *Ardisia elliptica*
2. *Clidemia hirta*
3. *Cytisus scoparius*
4. *Gleditsia triacanthos*
5. *Parkinsonia aculeata*
6. *Pinus nigra*
7. *Rubus discolor*
8. *Syzygium jambos*



Proportion reduction in seed production or seed viability

How sensitive is population growth rate to fecundity changes?



Modeling Conclusions



Reductions in seed output will not necessarily result in non-invasive cultivars, particular for long-lived species

Demographic modeling can illuminate the invasive potential of different cultivars if you have the data

- seed output, seed viability

- life history (time to reproduction)

It can also illuminate ways to control the species



Evaluation of *Miscanthus sinensis* cultivars

- A long lived perennial grass that forms large clumps (doesn't run like *M. sacchariflorus*)
- Known to invade in eastern U.S.
- Fecundity will need to be zero (or extremely close to zero) in order for the cultivar to be unlikely to invade
- Glen Madeja (former NU grad student) evaluated 35 cultivars for fecundity in the Chicago region

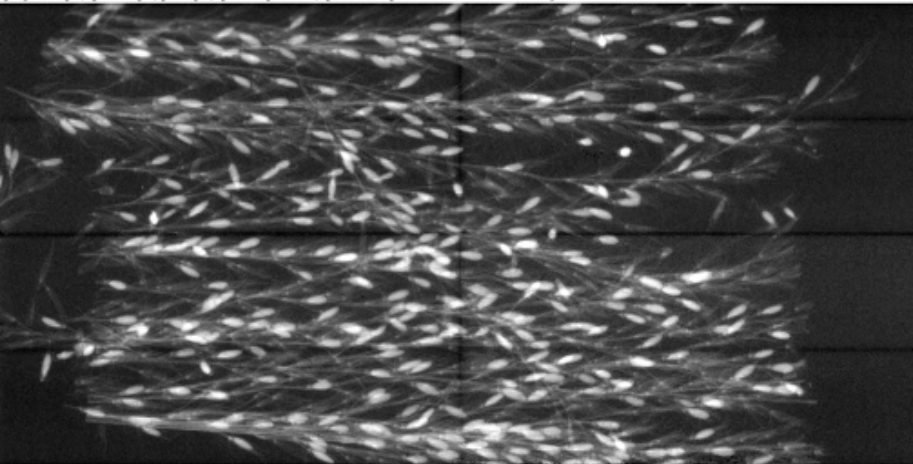


Miscanthus trials



Quantifying seed set

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[File]: I20101028144741, [StudyID]: ., [Study]: ., [Proc]: ., [Position]:
[Physician]: ., [TechID]: ., [Tech]: ., [Station]: OPGC, [Institution]: The Ohio State University



- Randomly harvested 3 inflorescences per individual
- X-rayed inflorescences
- 2 people independently counted filled seeds and averaged
- Multiplied by number of inflorescences on individual
- Averaged filled seed set over 4 individuals per cultivar

Cultivar	Average Filled Seed Set	Cultivar	Average Filled Seed Set
Kleine Silberspinne	191,202	Ferner Osten	9,190
Rotsilber	179,957	Goliath	7,137
Autumn Light	157,936	Sarabande	3,278
Malepartus	106,172	Gracillimus	3,146
Blutenwunder	91,569	Little Zebra	1,359
Graziella	90,984	Superstripe	1,226
Nippon	81,024	Gold Bar	1,031
Huron Sunrise	77,925	Morning Light	968
Minuett	69,997	Strictus	907
Andante	61,103	Dixieland	785
Silberfeder	49,060	<i>M. sacchariflorus</i>	746, but runs!
Adagio	27,078	Variegatus	211
Puenktchen	19,376	Yaku-jima	138
Silberturm	19,133	Hinjo	0
Zebrinus	16,621	Silberpfeil	0
Purpurascens	13,390	<i>M. x giganteus</i>	0
Autumn Red	12,995	Cabaret	0, but died out

Conclusions

- Three ornamental cultivars ('Silberpfiel', 'Hinjo' and 'Cabaret') of *Miscanthus sinensis* and the hybrid *Miscanthus x. giganteus* (used ornamentally and as a potential biofuel crop) have not set seed in Chicago and thus appear to have a low invasion risk.
- 'Cabaret' was not reliably hardy, so was not recommended.
- These results should be interpreted with caution because it is possible they may be able to set seed as the plants mature and/or as the climate warms. These cultivars may be able to mature seed in warmer regions of the US. One of our seedless cultivars ('Hinjo') did set seed in Zone 5 in another trial.



Take home messages

- For perennial and woody invasive plants, cultivars should be considered potentially invasive unless completely sterile
- At CBG, our invasive policy previously stated that we would evaluate all cultivars of horticulturally-desirable invasives (such as *Miscanthus sinensis*, *Euonymus alatus*, *Fallopia japonica*, et al.) to determine their invasiveness. Now we can simply look at seed set, saving considerable time and money.





Invasive research references:

Knight, T.M., K. Havens and P. Vitt. 2011. Will the use of less fecund cultivars reduce the invasiveness of perennial plants? *BioScience* 61: 816-822.

Madeja, G., L. Umek, and K. Havens. 2012. Differences in Seed Set and Viability of *Miscanthus* Cultivars Grown in Zone 5 and Their Potential for Invasiveness. *Journal of Environmental Horticulture* 30: 42-50.

Warneke, C. 2015. Host preferences of biocontrol weevils on a threatened thistle and an invasive weed: implications for management and conservation. MS Thesis, Northwestern University.

Jefferson, L., K. Havens and J. Ault. 2004. Implementing invasive screening procedures: The Chicago Botanic Garden model. *Weed Technology* 18: 1434-1440.

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