What's Coming Up in Forages: New Species and Traits?

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Outline for Today's Talk

- OVERVIEW
- Tall fescue: Soft leaves and endophytes
- Meadow fescue: Back to the Future
- Ryegrasses: Species characteristics
- Festulolium: What is this?
- Orchardgrass: Eliminating flowering heads?
- Bromegrasses: Combining traits into hybrids
- Red clover: Increasing persistency
- Alfalfa: GMO traits and status

Grass Breeding and Genetics

- New and improved varieties are created by grass breeders
- In the USA and Canada, most grass breeding is conducted by university or government reseachers.
- In Europe, Australia, and New Zealand, most grass breeding is conducted by private companies.
- New varieties require about 12-15 years of development and testing. The cost of creating a new variety is about $200,000 - 500,000 (US).

The Process to Develop a New Variety

- Assemble plant materials of the target species
- Identify the most appropriate breeding goals
- Create the best environment and testing scheme to achieve those goals
- Evaluate thousands or hundreds of thousands plants and select only those with the desired traits
- Cross selected plants with each other to create the next generation
- Repeat if necessary
- Conduct field trials of the selected materials

Selection for Tolerance to Frequent Grazing

Selection for large plants and persistency is easy!

Selection for forage yield is very difficult. Population sizes are severely limited by work loads and equipment requirements.

Prioritizing Breeding Goals

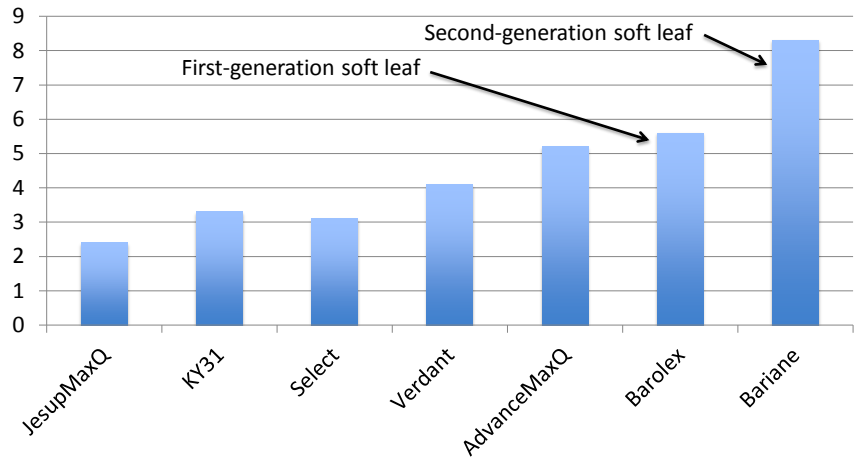
- Does the species have any deficiencies?
- Is the trait heritable? Can it be easily measured and is the measurement repeatable?
- What is the prognosis for improvement? Can significant improvement be achieved within a few years or will it require decades?
- What is the potential economic impact of the improvement?
- Is breeding the best solution to the problem or is there a better solution, e.g. management?

Soft-leaf Tall Fescues

Soft-leaf Tall Fescue

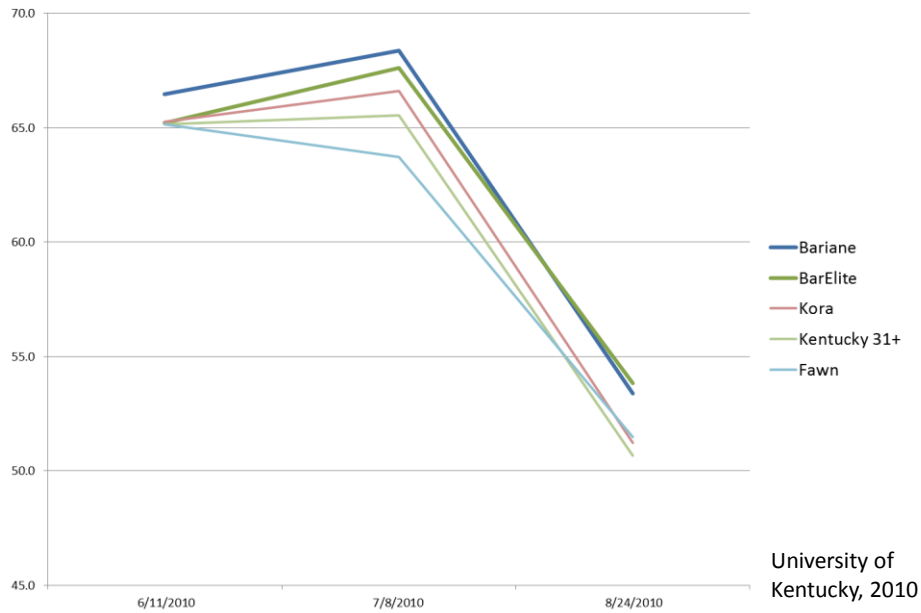
- Bred to have softer leaves
- Higher palatability fescue = higher intake
- Lower lignin content of leaves improves feeding value = higher energy value
- High stand density
- Larger bite size

Grazing Preference
(9 = completely consumed)



University of Kentucky, 2010

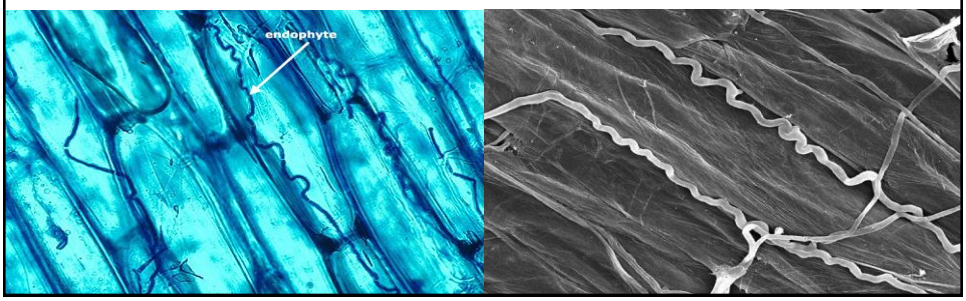
NDF Digestibility of Tall Fescue



University of Kentucky, 2010

Fescue Endophyte

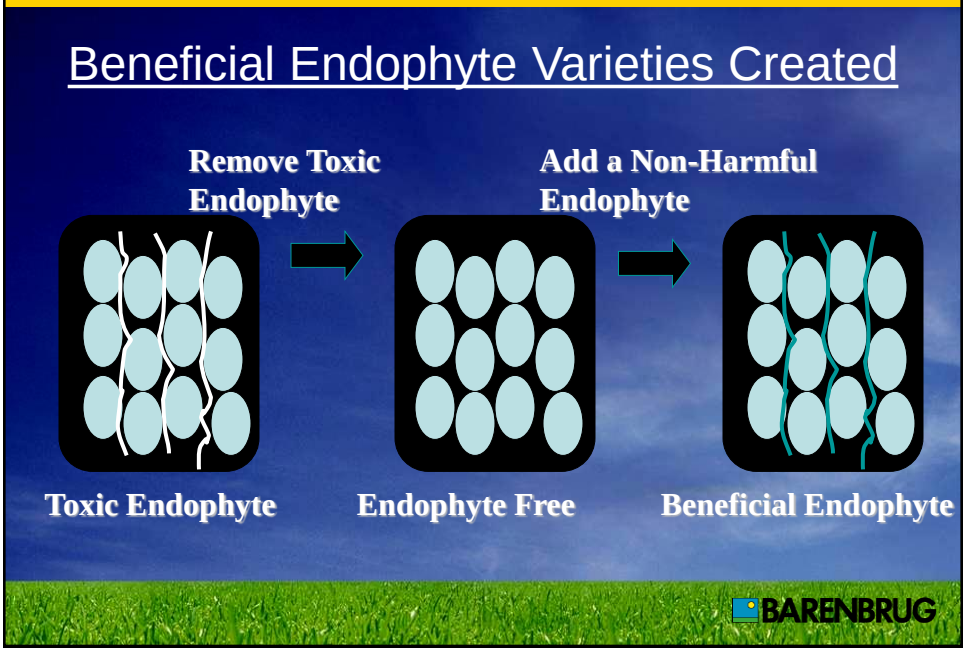
- Fungus that lives in stems, leaf sheaths, and seeds.
- Mutualistic relationship
  - Host plant provides water, nutrients, & structure
  - Fungus provides insect and nematode resistances & enviromental tolerances?



Tall Fescue Endophyte

- Produces two types of alkaloids
  - Lolines are non-toxic to livestock, but help protect the plant from insects and heat
  - Ergovalines are highly toxic to livestock, causing serious disease problems on pastures
- Native endophytes generally contain both types of alkaloids
- Researchers have traveled around the world and discovered a few very rare “friendly” endophytes that do not produce ergovalines.

Total Pasture Management



Do We Need the Endophyte in the Northern USA and Canada?

- Friendly or beneficial endophytes are critical for survival of tall fescue when
  - there is extreme heat in summer, as in the southern USA
  - there are serious insect pests, as in New Zealand and Australia.
- There is no evidence that friendly or beneficial endophytes have any impact on performance in cold-weather climates.
- One Wisconsin study shows no effect.

Meadow Fescue: Back to the Future

Charles Opitz Farm: Remnant Oak Savanna in 1990

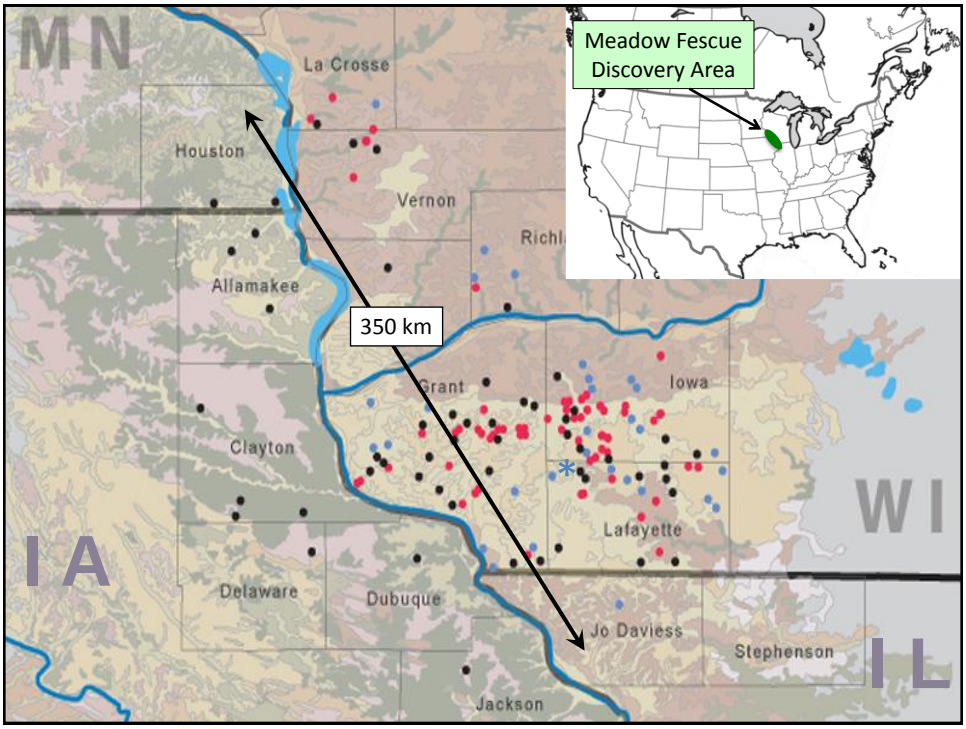
Isolated occurrence of an unknown grass

Idenfied as meadow fescue, based on DNA analyses

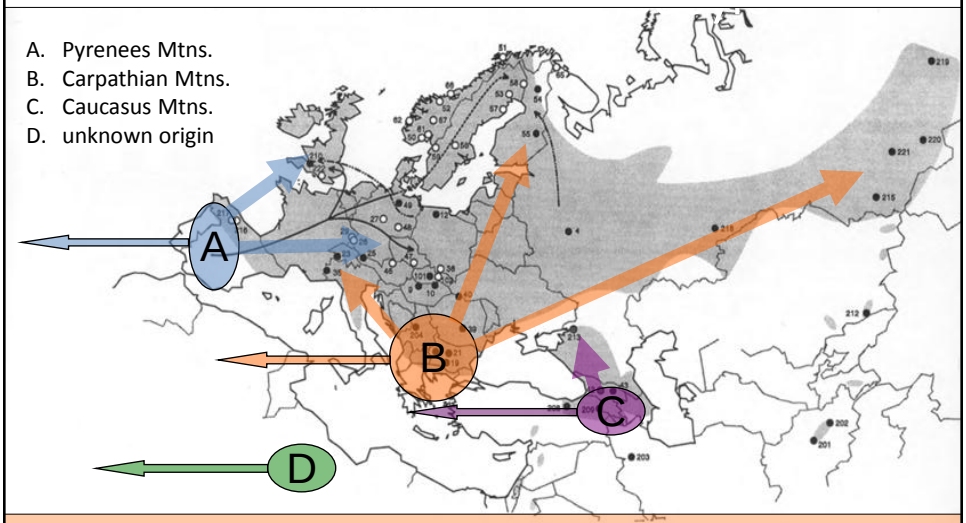
Cattle preferred this grass to all others on the 1000-ha farm


June 2000: ~1000 ha of Meadow Fescue


“History moves on the hooves of cows.”
(Anonymous)


MN
La Crosse
Houston
Vernon
Allamakee
350 km
Grant
Iowa
Clayton
Lafayette
WI
IA
Delaware
Dubuque
Jo Daviess
Stephenson
IL
Jackson
Meadow Fescue
Discovery Area

European Meadow Fescue: Post-Glacial Range Expansion: ~11,000 yrs ago



At least four introduction events are responsible for immigration of meadow fescue into the Upper Mississippi River Basin.

Meadow Fescue Endophyte

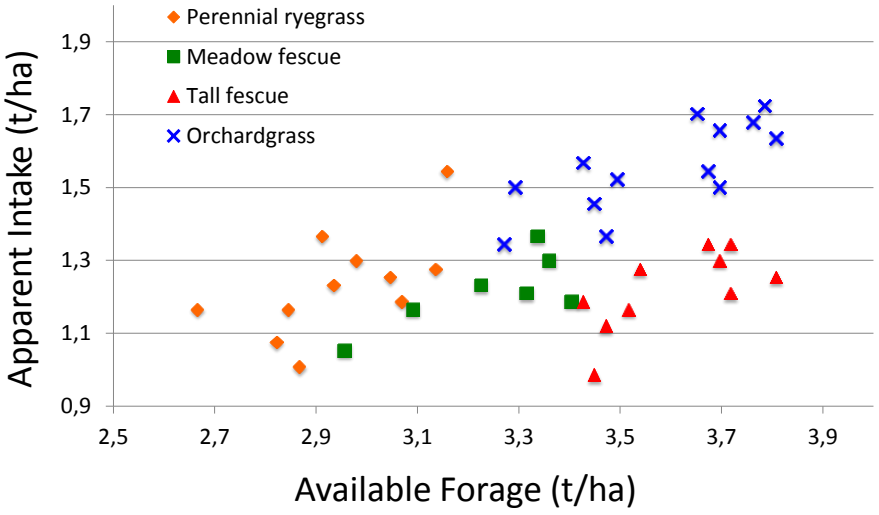
- *Neotyphodium uncinatum*
- Benign to livestock, does not produce ergovaline alkaloids
- We sampled 2800 plants for endophyte
  - 100 plants from the Opitz farm
  - 2700 plants from 27 other farms in the region
- Using ELISA and DNA tests, we have identified an infection rate of 99.7%!
- There MUST be some fitness advantage! But, we don't yet know what it is.

What is the agronomic value of meadow fescue for management-intensive grazing?

- How productive is it?
- Does it persist?
- How do livestock respond to it?

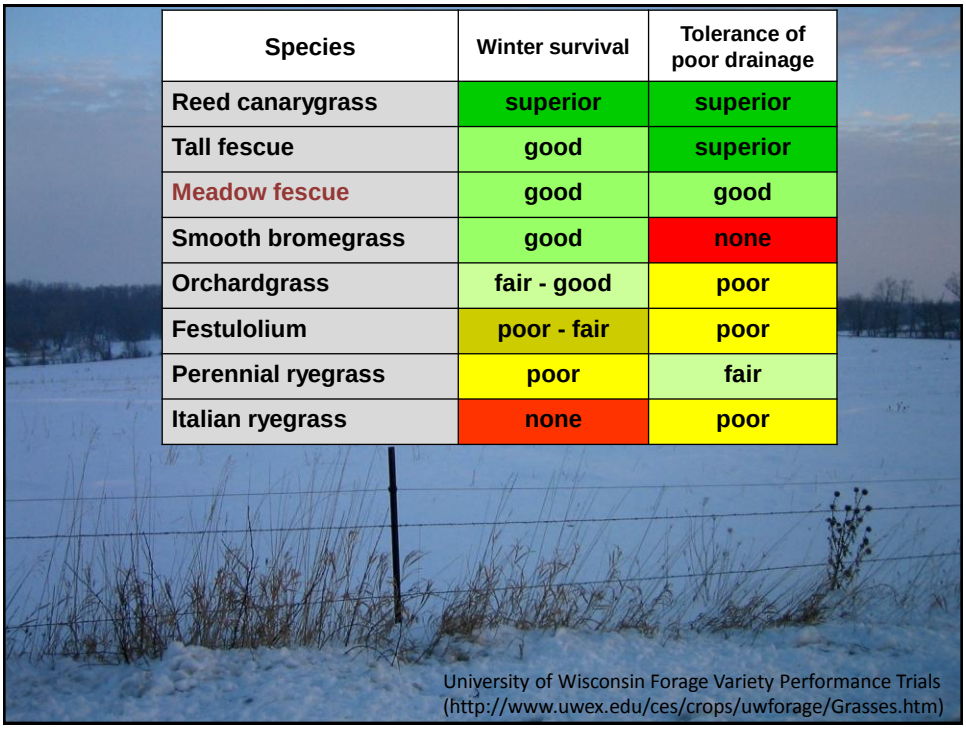
Performance of Meadow Fescue in On-farm Grazing Trials (Dairy Cattle)

Averages across 11 grazing events in 2 years (May through October)



Forage Yield Loss with Meadow Fescue

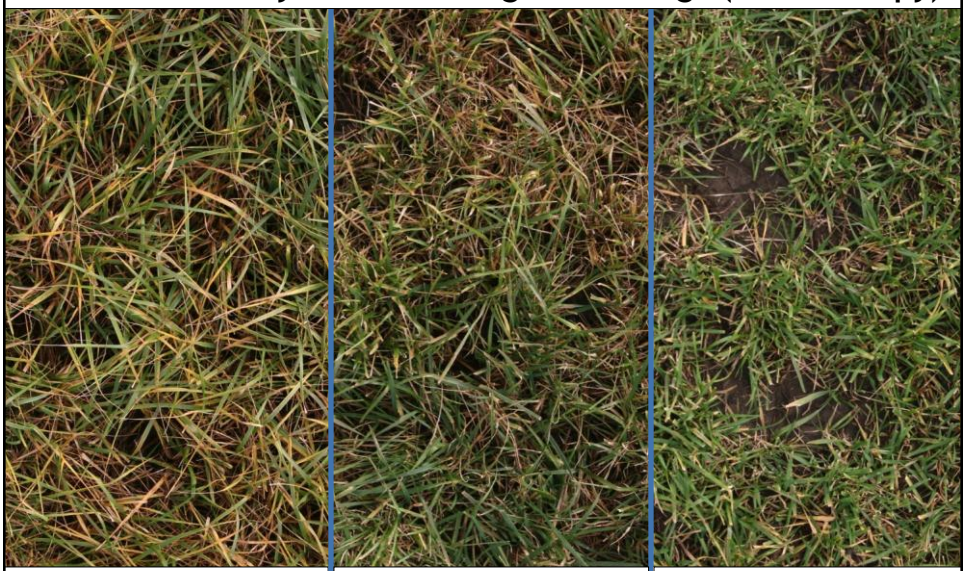
Variety and Species	Forage yield (t/ha): Wisconsin grazing	Forage yield (t/ha): Wisconsin hay	Forage yield (t/ha): New York hay
Hidden Valley meadow fescue	5.11 (-7.3%)	6.37 (-8.8%)	10.15 (-5.0%)
Tall fescue	5.49	7.07	10.67
Orchardgrass	5.54	6.90	-



Soil fertility characteristics associated with meadow fescue

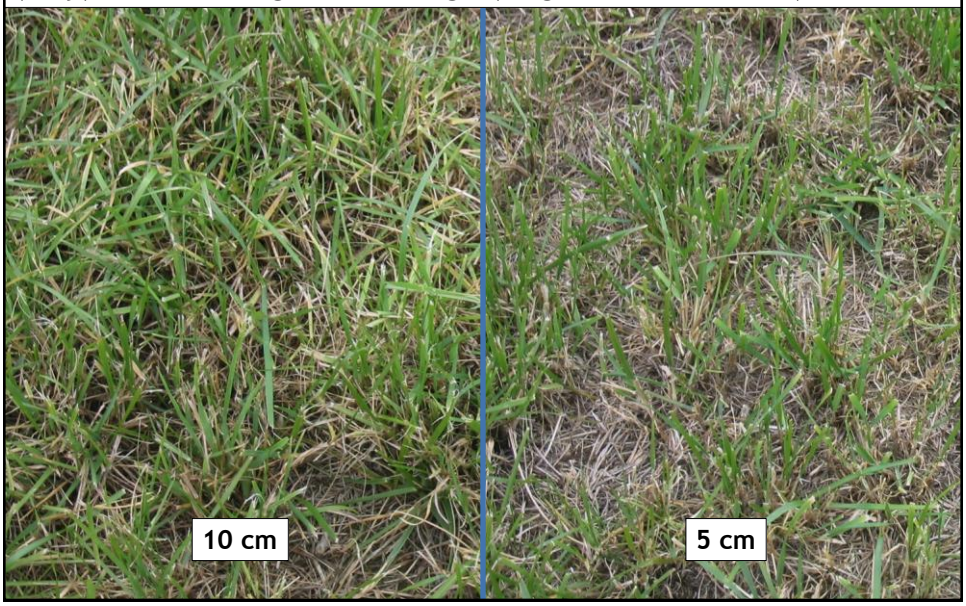
	Minimum	Maximum
Clay content (%)	7	40
pH	5.5	8.2
Potassium (ppm)	160	530
Phosphorus (ppm)	5	50

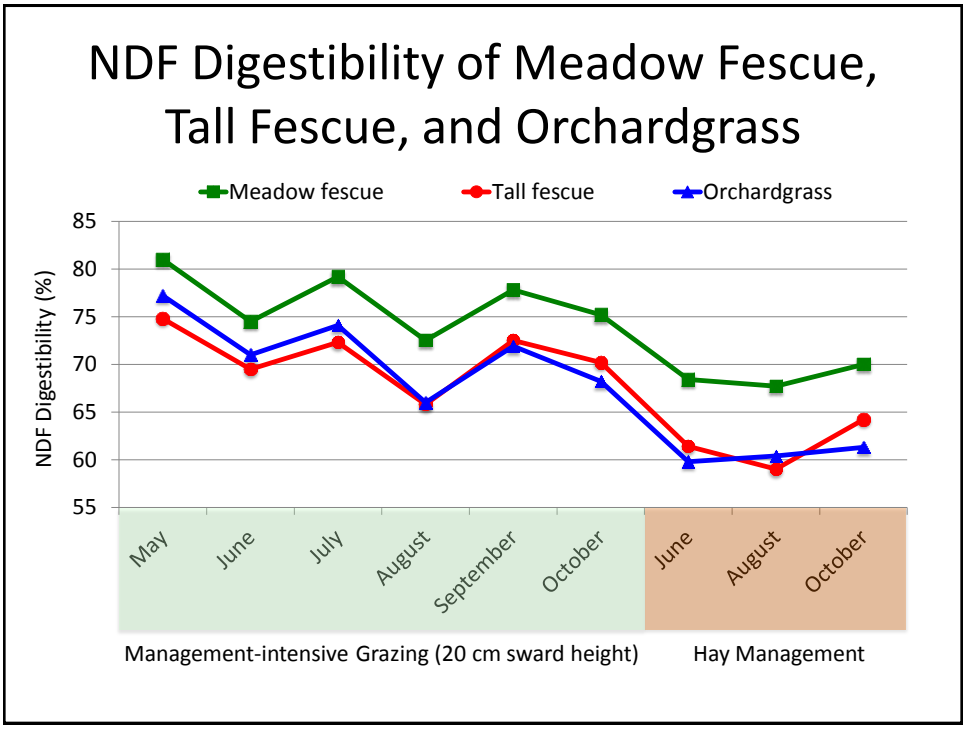
Residual Sward Height (RSH) after grazing: effects on meadow fescue rotationally stocked at vegetative stage (25cm canopy)



16 cm RSH; 6 grazing events per year	8 cm RSH; 5 grazing events per year	2 cm RSH; 4 grazing events per year

Residual Sward Height (RSH) after grazing: effects on meadow fescue managed for hay production; harvested at boot stage (May) and late vegetative stage (August and October).



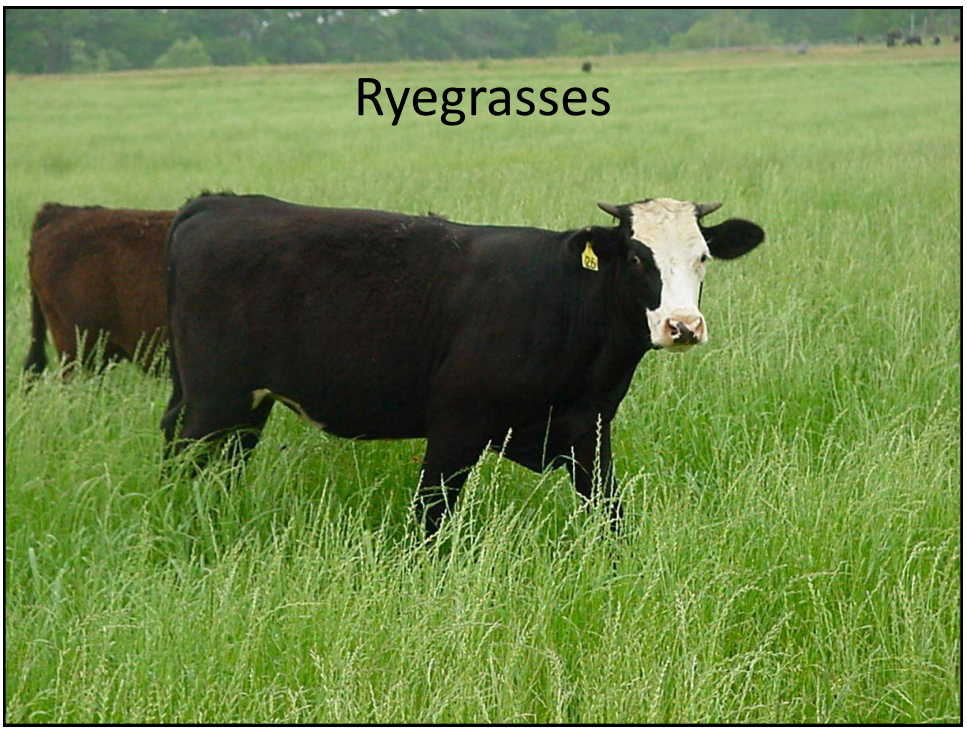


Potential milk production based on diets of three grasses defoliated at vegetative stage.

	NDFD	NDF	DM intake	NE_L intake	Milk
	--------- % ---------		kg/day	Mcal/day	kg/day
Meadow fescue	76.5	46.0	15.4	26.0	24.5
Tall fescue	70.9	49.2	14.1	23.1	20.4
Orchardgrass	71.4	48.5	14.5	23.6	20.9

Brink et al. 2008. Forage and Grazinglands doi:10.1094.

Experiments are underway to verify these values using dairy cows.



What are the Ryegrasses?

- Perennial ryegrass (*Lolium perenne*) – the common perennial type of ryegrass.
- Italian ryegrass (*Lolium multiflorum*) – this is a specialized version created in Italy about 1000 years ago; tall, early flowering, hay type.
- Annual ryegrass (*Lolium multiflorum*) – a specialized form of Italian ryegrass created for winter growth in the southern USA.
- Hybrid ryegrass (*Lolium hybridum*) – an intermediate type.
- Festulolium (*Festulolium braunii*) – these are fescue x ryegrass hybrids; there are many types.

Breeding Ryegrass Varieties

- There is very little ryegrass breeding conducted in North America.
- Nearly all varieties available were bred in Europe. Ryegrass varieties should be chosen after inspecting performance trial results from your local extension or outreach service.
- Annual ryegrasses are bred for the southern USA – winter overseeding of bermudagrass pastures.
- Festulolium breeding is ongoing in both Europe and the USA.

What is “Festulolium”?

- Fescue x Ryegrass hybrids
- Fescue parent
  - Tall fescue
  - Meadow fescue
- Ryegrass parent
  - Perennial ryegrass
  - Italian ryegrass
- Final result of breeding and selection can look exactly like ryegrass or fescue, depending on the breeding goals and methods.

Characteristics of Ryegrasses and Fescues for Eastern Canada and USA

(+ is favorable; - is unfavorable)

Plant trait	Italian ryegrass	Perennial ryegrass	Meadow fescue	Tall fescue
Rapid establishment	+++	++	+	+
Early spring growth	-	-	++	+
Summer growth	+++	++	++	++
Forage quality	+++	+++	++	+
Winter hardiness	- - -	--	+++	+
Drought tolerance	- -	- -	++	+++
Persistency	- - -	+	+++	++
Grazing tolerance	- -	+++	++	++
Conservation harvests	+++	-	-	+

Tall fescue x Perennial ryegrass

Controlled cross made in the glasshouse

F1 hybrid is then backcrossed to either the fescue or ryegrass parent

Selection for "fescue" type with one or more ryegrass "traits"

Selection for "ryegrass" type with one or more fescue "traits"

Tall fescue x Perennial ryegrass

- Selection for "fescue" type is most common
- Most recent tall fescue cultivars are products of fescue x ryegrass crosses, e.g. Kenhy, Johnstone
- Cultivars retain all the benefits of tall fescue (persistency, grazing tolerance, heat tolerance)
- Improved forage quality or nutritional value (digestibility) is added from the ryegrass parent.

Meadow fescue x Italian ryegrass

Controlled cross made in the glasshouse

↓

F1 hybrid is backcrossed to ryegrass

↓

Many generations of selection and breeding

- Need to have stable and uniform variety
- Morphology is similar to ryegrass
- Traits transferred from fescue
  - Cold tolerance
  - Drought tolerance

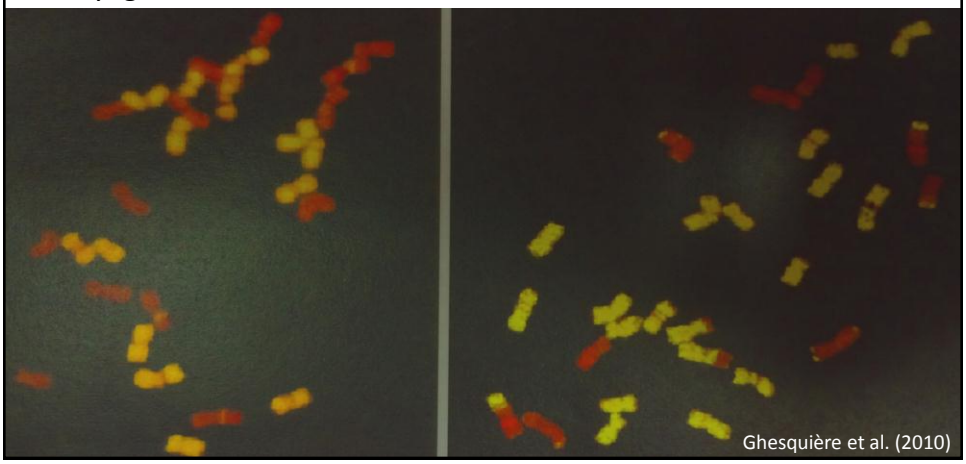
Six Generations of Selection for the Ryegrass "type"

Original F1 Cross:

- 14 fescue chromosomes
- 14 ryegrass chromosomes

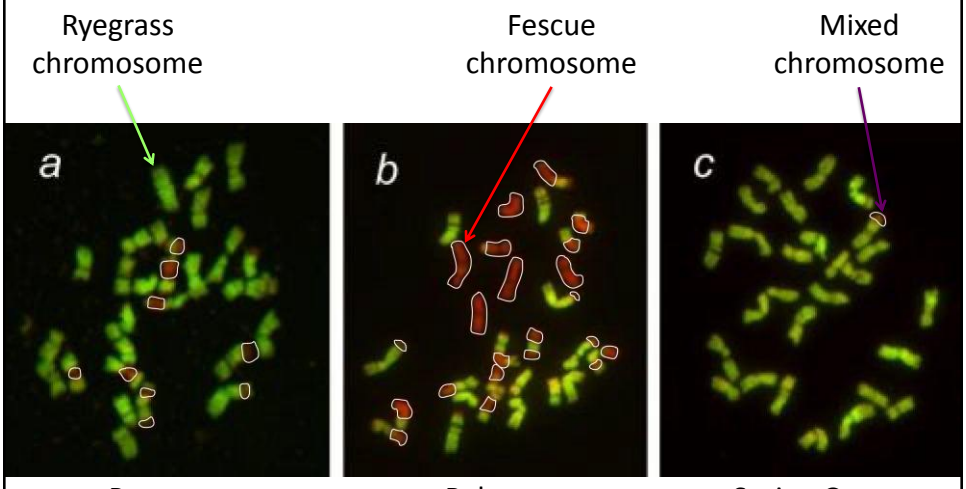
F6 Generation:

- 9 fescue chromosomes
- 19 ryegrass chromosomes



Ghesquière et al. (2010)

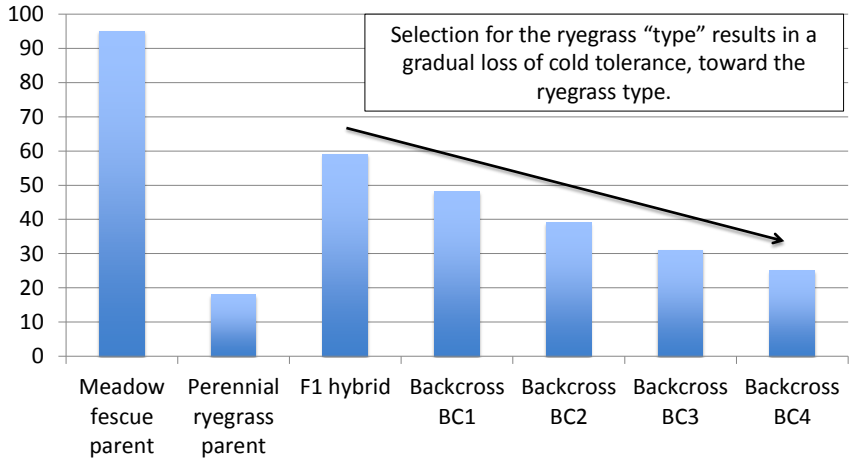
Chromosomes of Three Festulolium Varieties (Red = fescue; Yellow = Ryegrass)



Ghesquière et al. (2010)

Breeding Festulolium – Change in Cold Tolerance During Selection and Breeding

Survival following 24 hr at -14°C



Pitts et al., 2005

Spring Green *Festulolium*: Selection for Winter Survival Under Harsh Winters

Festulolium Variety	Growth chamber survival at -11°C (%)	Field survival in the northern USA (%)	Forage yield (t/ha)
Spring Green	**63**	**45**	**4.27**
Elmet	33	17	3.15
Kemal	3	25	4.08
Prior	34	27	3.99
Tandem	11	9	2.56

Spring Green *Festulolium*

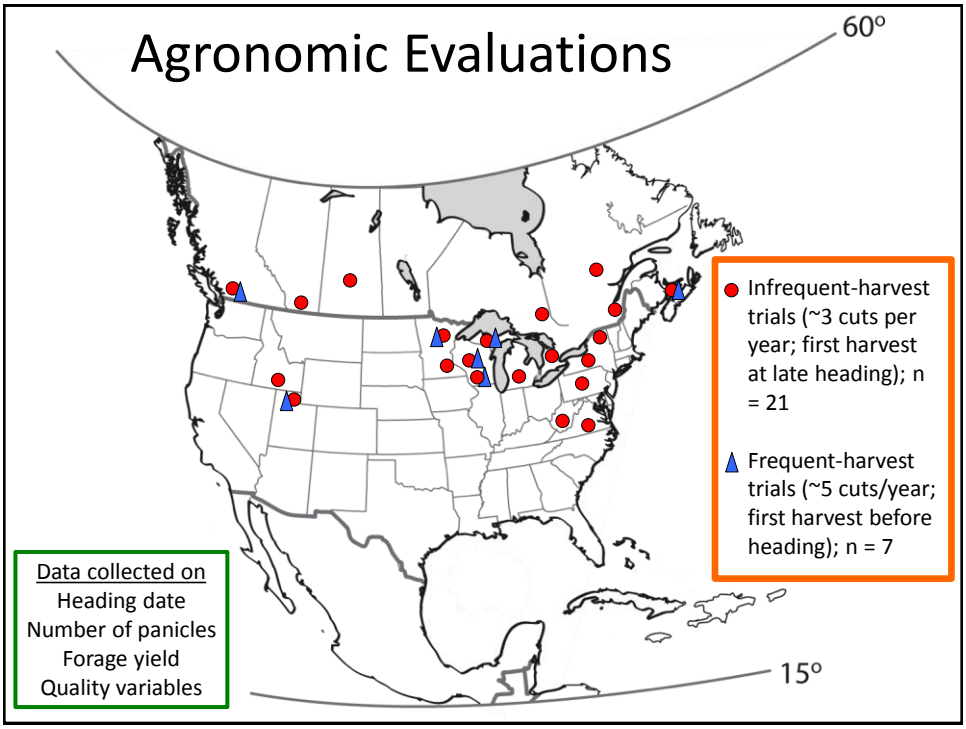
- Seed sales are licensed through numerous seed dealers
- Information is available through internet searches
- Can be purchased as a pure variety or as a component of forage blends/mixtures
- Probably planted on over 25,000 ha/year in USA

Non-flowering Orchardgrass

Overall Objectives

- Develop a non-flowering or sparse-flowering orchardgrass to simplify spring management in rotational grazing applications.
- Identify the environmental conditions under which flowering is normally or abnormally expressed in sparse-flowering orchardgrass.
- Determine if we can effectively combine seed production with the sparse-flowering trait for forage production.

Agronomic Evaluations



Infrequent-harvest Means

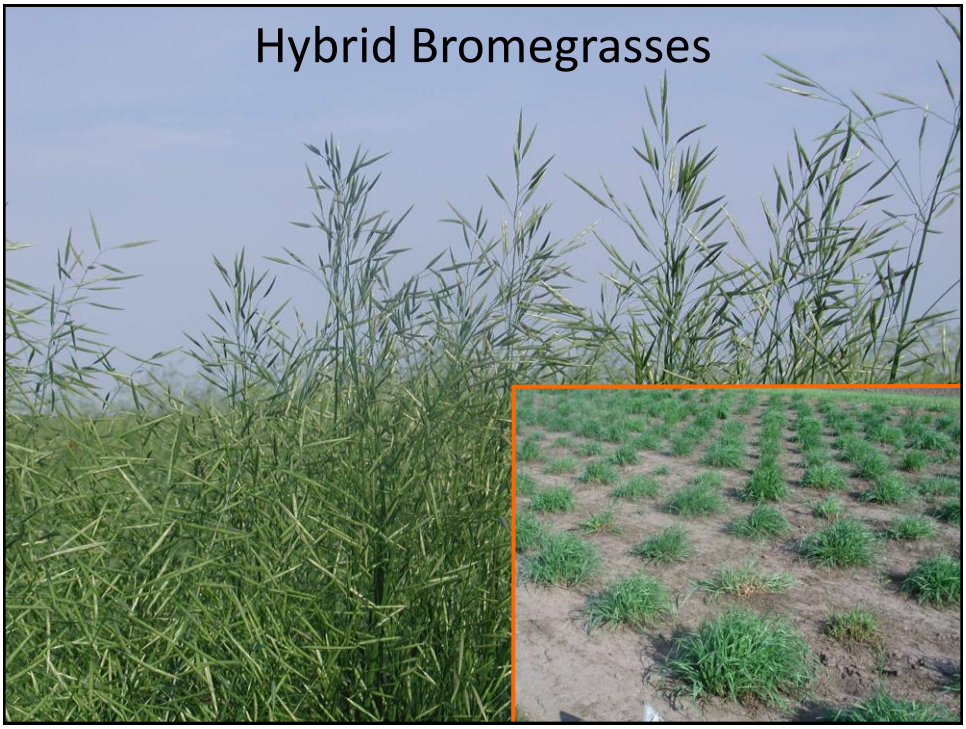
Cultivar	Heading Date	Panicle Density	Cut-1 Yield	Regr. Yield	Total Yield
	May	#/m^2	Mg/ha	Mg/ha	Mg/ha
WO5-ARL	**30**	**53**	**3.36**	**4.86**	**8.17**
WO5-ASH	**29**	**56**	**3.38**	**4.66**	**7.99**
WO5-PEI	**30**	**74**	**3.67**	**4.88**	**8.48**
Benchmark	24	128	4.54	5.28	9.75
Albert	26	168	4.89	4.97	9.80
Icon	26	128	4.24	4.90	9.08
% Change	**8**	**-57**	**-24**	**-5**	**-14**
LSD(0.01)	1	13	0.26	0.36	0.41

Frequent-harvest Means

Cultivar	Cut-1 Yield	Regrowth yield	Total Yield
	Mg/ha	Mg/ha	Mg/ha
WO5-ARL	**1.44**	**5.82**	**7.25**
WO5-ASH	**1.35**	**5.74**	**7.09**
WO5-PEI	**1.51**	**6.24**	**7.75**
Benchmark	2.17	6.92	9.09
Albert	2.11	6.39	8.51
Icon	2.00	6.27	8.27
% Change	**-32**	**-9**	**-15**
LSD(0.01)	0.25	0.48	0.54

Forage Quality Traits

	CP	NDF	NDFD	IVDMD
	g/kg	g/kg	g/kg	g/kg
First harvest				
Normal	118	607	597	760
Sparse	130	593	616	777
% Change	**10**	**-2**	**3**	**2**
LSD(0.01)	6	8	13	11
Regrowth				
Normal	147	581	644	795
Sparse	152	585	635	788
% Change	**4**	**1**	**-2**	**-1**
LSD(0.01)	**NS**	**NS**	**NS**	**NS**



Hybrid bromegrass breeding at University of Saskatchewan

- Meadow X smooth bromegrass hybrid populations
  - Original crosses made in late 1970s
- Dual purpose type of grass
  - High first cut yield like smooth
  - Fast regrowth like meadow brome
- Cultivars released
  - AC Knowles (2000)
  - AC Success (2003)

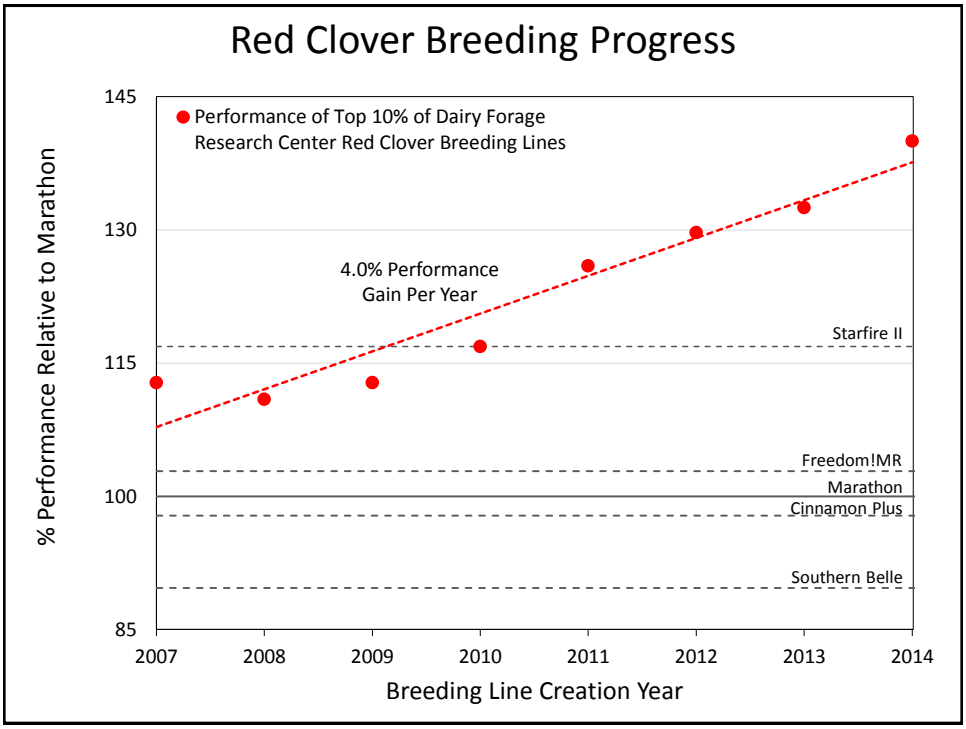
Present hybrid bromegrass breeding activities

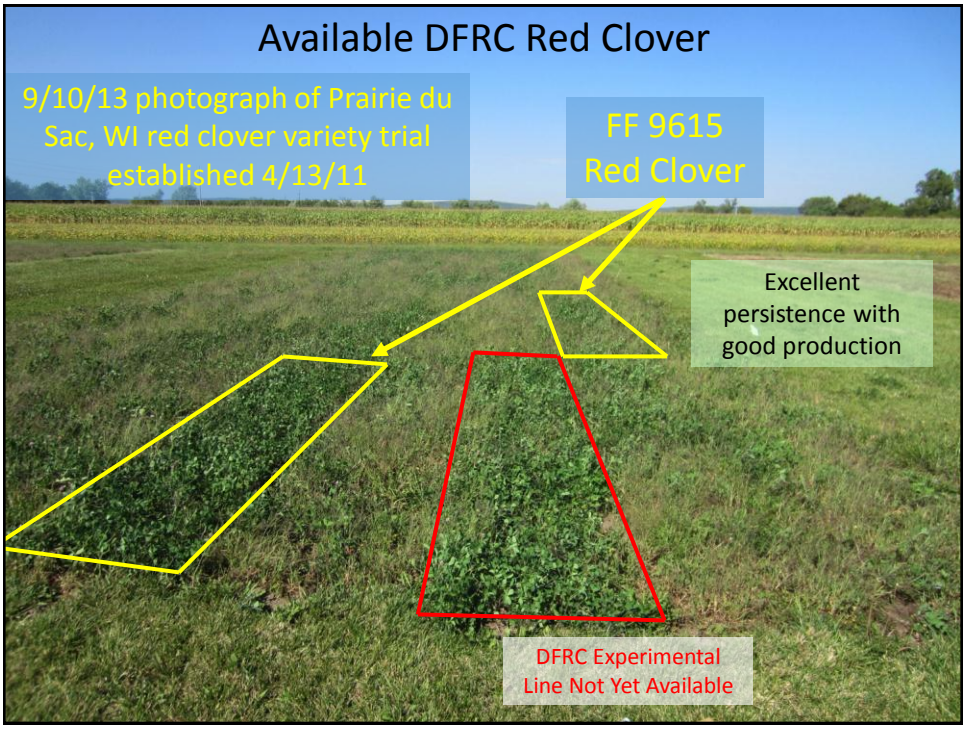
- Continue selection in existing populations
- Expand adaptation to more humid regions
  - New population (S9478) from crosses using "southern" type smooth brome parents
- Improved seed yield
- Improved regrowth
  - Backcrosses to meadow brome

Red Clover Breeding Program

- Red Clover
  - Excellent forage quality
  - Fixes nitrogen
  - Excellent establishment versatility
  - Competitive in mixtures
- Breeding Targets
  - Increasing persistence (4 production years)
  - Increasing forage yield
  - Selecting in grass mixtures


Plants exposed to many different conditions


Red Clover Breeding Progress
% Performance Relative to Marathon
145
130
115
100
85
Performance of Top 10% of Dairy Forage Research Center Red Clover Breeding Lines
4.0% Performance Gain Per Year
Starfire II
Freedom!MR
Marathon
Cinnamon Plus
Southern Belle
2007
2008
2009
2010
2011
2012
2013
2014
Breeding Line Creation Year


Available DFRC Red Clover
9/10/13 photograph of Prairie du Sac, WI red clover variety trial established 4/13/11
FF 9615 Red Clover
Excellent persistence with good production
DFRC Experimental Line Not Yet Available

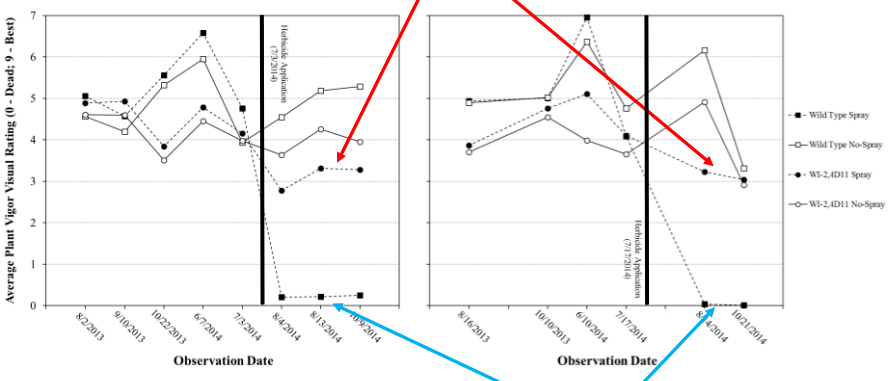

Non-GMO 2,4-D Tolerant Red Clover
KUBOTA

2,4-D Tolerant Red Clover

Resistant plants survive
2,4-D application

Test Site 1 Prairie du Sac, WI

Test Site 2 Arlington, WI



Regular plants die under
2,4-D application

Breeding Improvements in Alfalfa by Traditional and GMO Methods

- GMO methods
  - Roundup resistance
  - Reduced lignin = increased digestibility
  - Protected protein & tannins
- Traditional breeding methods
  - Multiple disease resistances
  - Multiple insect resistances
  - New used for bioproducts (feed, energy, chemicals, adhesives)
  - Standability (lodging resistance)

UW Extension

Standability (lodging resistance)

alfalfa 36 days growth Wisconsin

Questions?