Switchgrass Research at the WRRC

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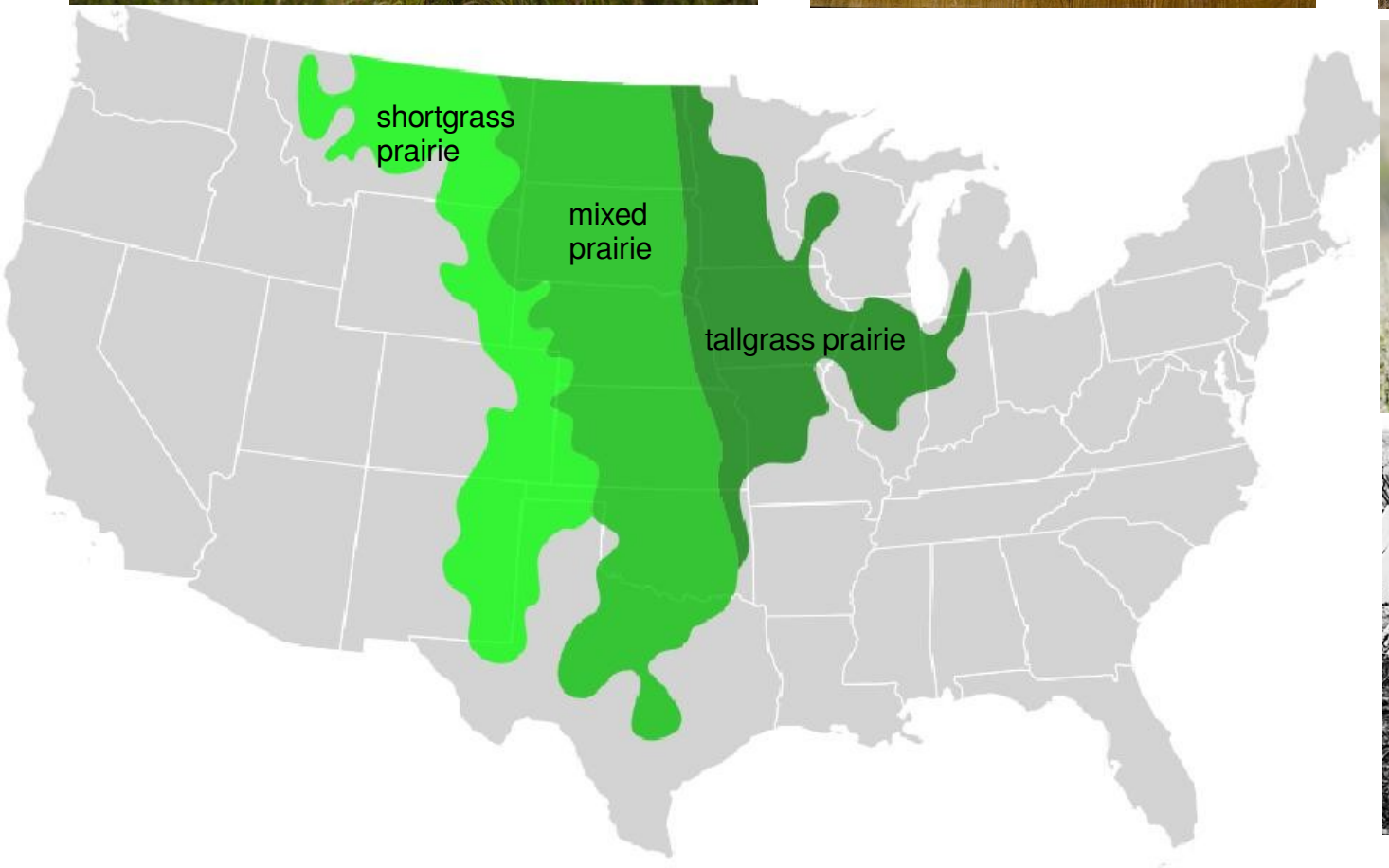
USDA Agricultural Research Service

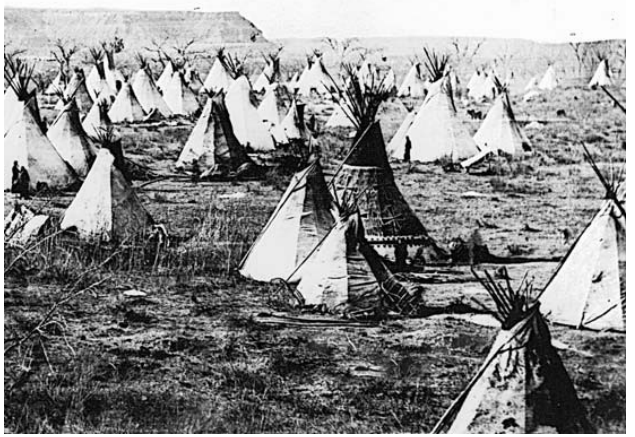
Western Regional Research Center

Grasslands are an Integral Part of American Identity

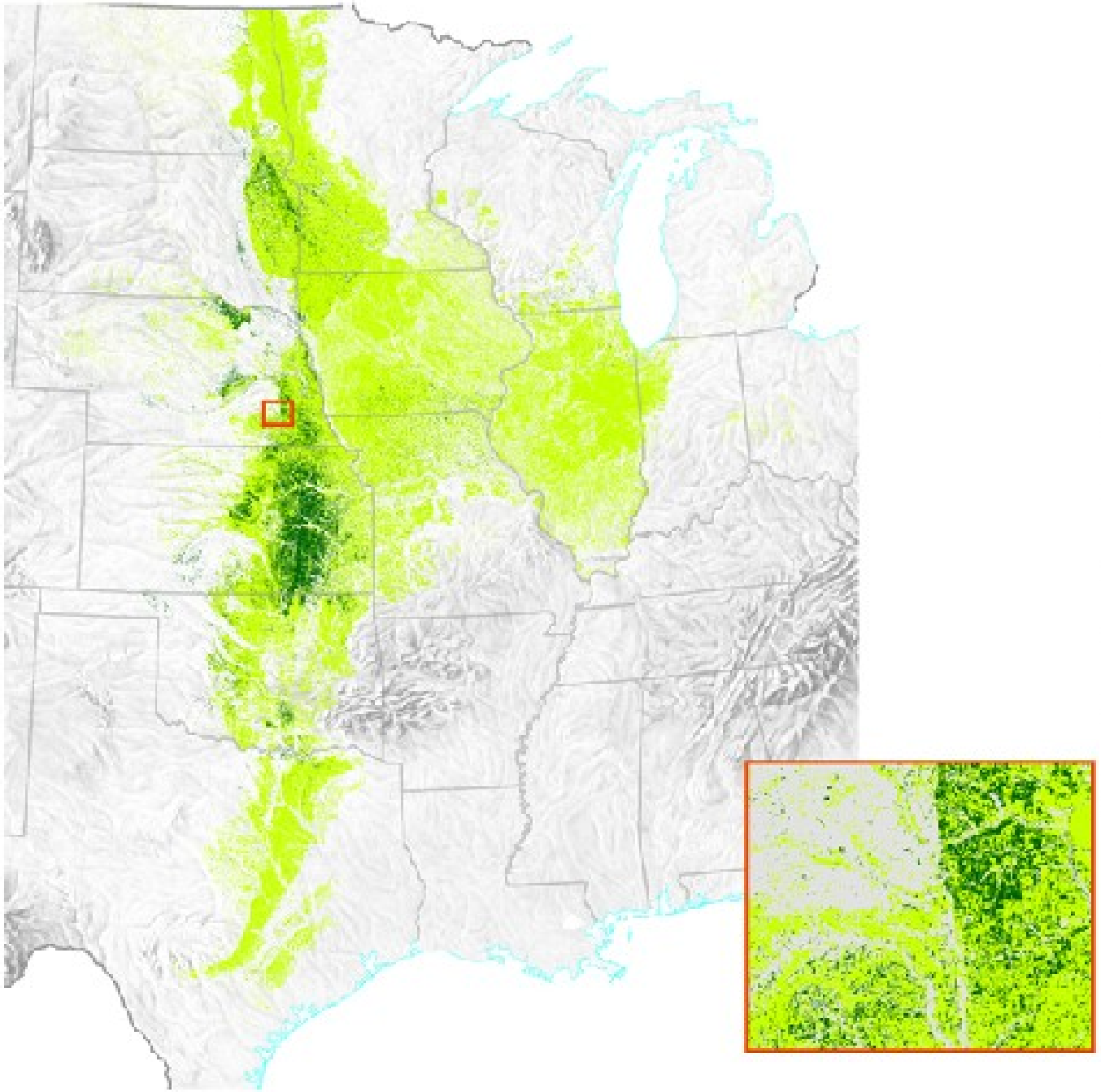
Banished from the thoroughfare and the field, it bides its time to return, and when vigilance is relaxed, or the dynasty has perished, it silently resumes the throne from which it has been expelled, but which it never abdicates.

-John James Ingalls

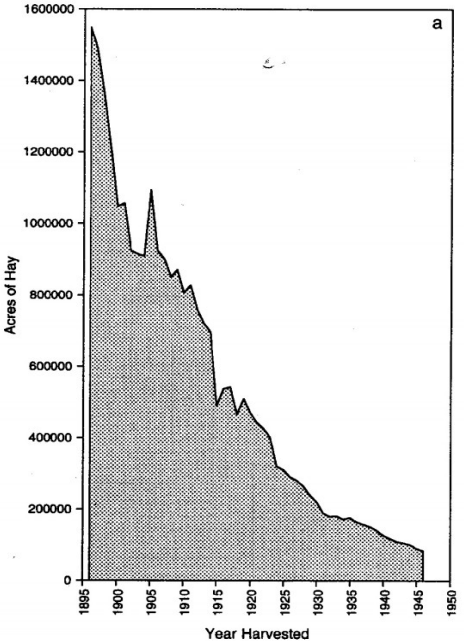




95% of the Great Plains Prairie Ecosystem is Gone



Iowa hay census data

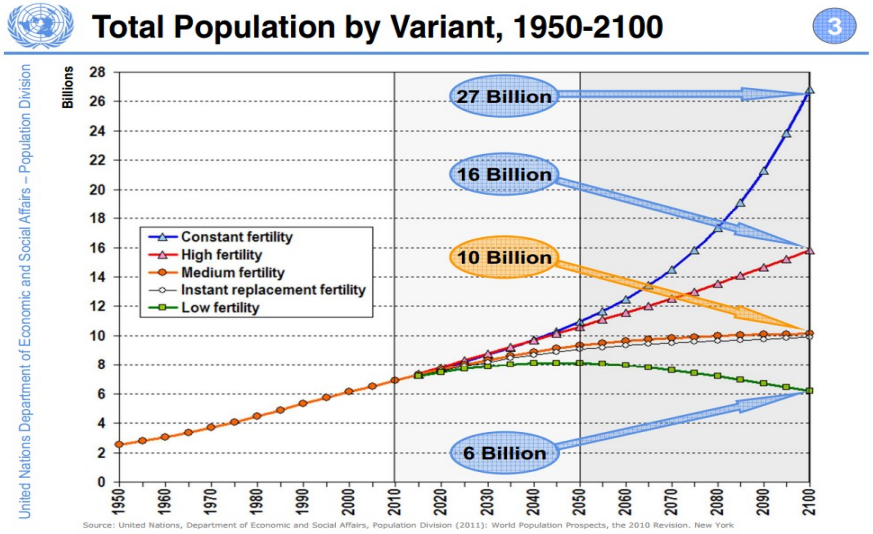


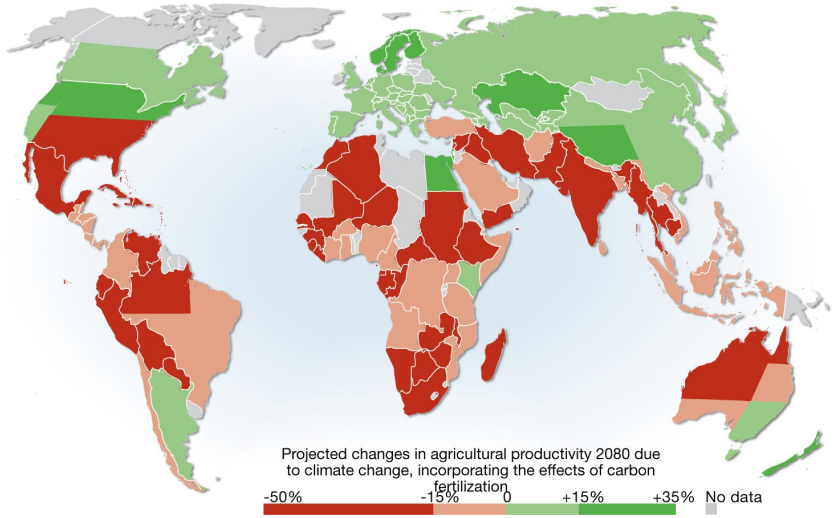
Smith, D.D. 1998 J. Iowa Acad. Sci.

Food Production Requirements

•Assuming no change in population growth, food consumption patterns and food waste management, the following production increases must take place by 2050:

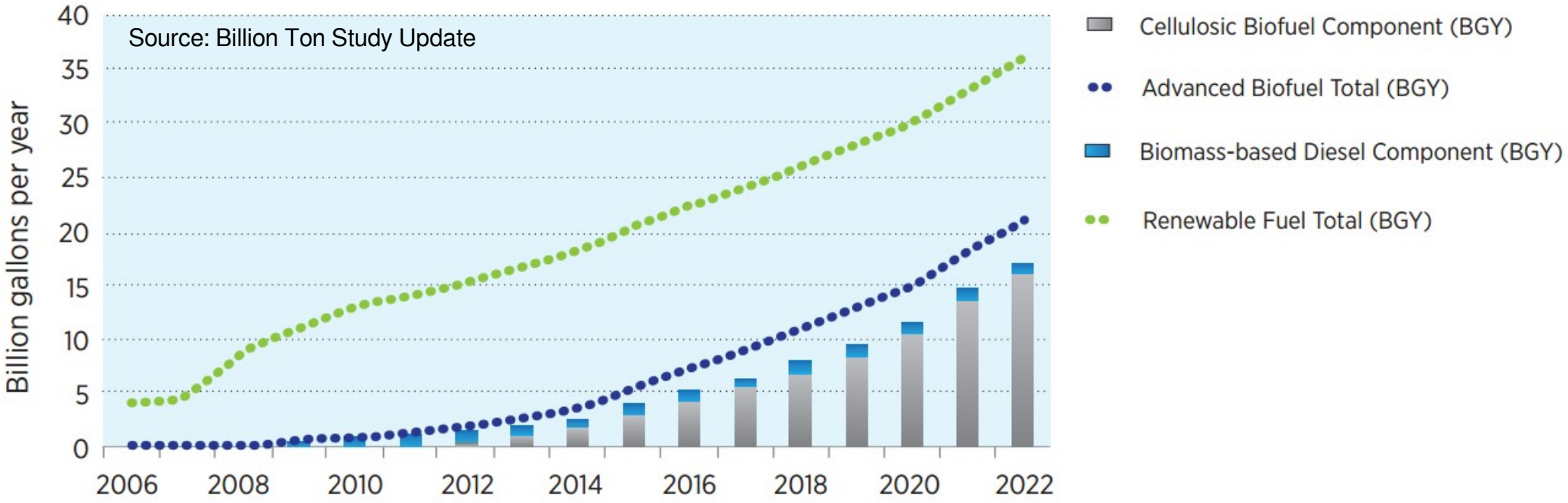
- •cereals production must increase by 940 million tonnes to reach 3 billion tonnes;
- •meat production must increase by 196 million tonnes to reach 455 million tonnes;
- •and oilcrops by must increase by 133 million tonnes to reach 282 million tonnes.





Renewable Energy Legislation/Mandates

Year	Milestone
2005	Billion Ton Study
	Energy Policy Act
2006	Advanced Energy Initiative
2007	Energy Independence and Security Act (EISA)
2008	Farm Bill Bioenergy Crop Assistance Program
2009	Establishment of BIWG
2010	USDA roadmap
	USDA Farm to Fly Partnership
2011	Billion Ton Study Update
2012	USDA Establishes Five Regional Biomass Research Centers
2013	USDA Farm to Fly 2.0 Partnership
2016	Billion Ton Update



Second Generation Cellulosic Fuel Industry is Viable but Growing Slowly

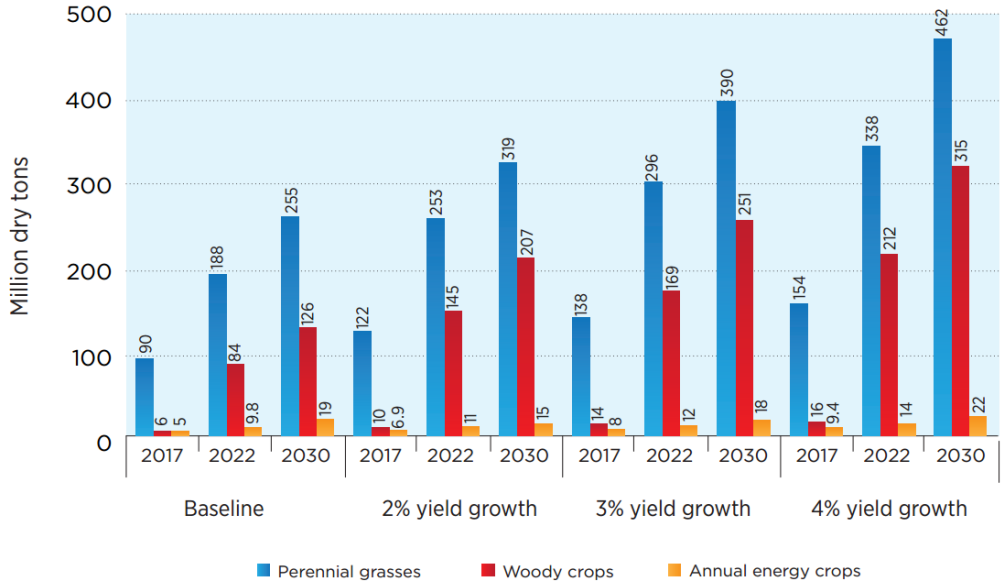
• Hugoton KS	25-30 Mga/yr	Ethanol	wheat straw
• Alpena MI	1 Mga/yr	Ethanol	wood residues
• Galva IA	3.75 Mga/yr	Ethanol	corn kernel fiber
• Emmetsberg IA	20-25Mga/yr	Ethanol	corn stover
Crescentino IT	13 Mga/yr	Ethanol	wheat straw, Arundo
• Nevada IA	25 Mga/yr	Ethanol	corn stover
• Fulton MS	(19 Mga/yr)*	Ethanol	multiple sources
• Reno, NV	(11 Mga/yr)	JetFuel/Diesel	MSW
• Alagoas BZ	(22 Mga/yr)	Ethanol	sugarcane straw
• Las Cruces NM	(~7 Mga/yr)	Green Crude	Algae

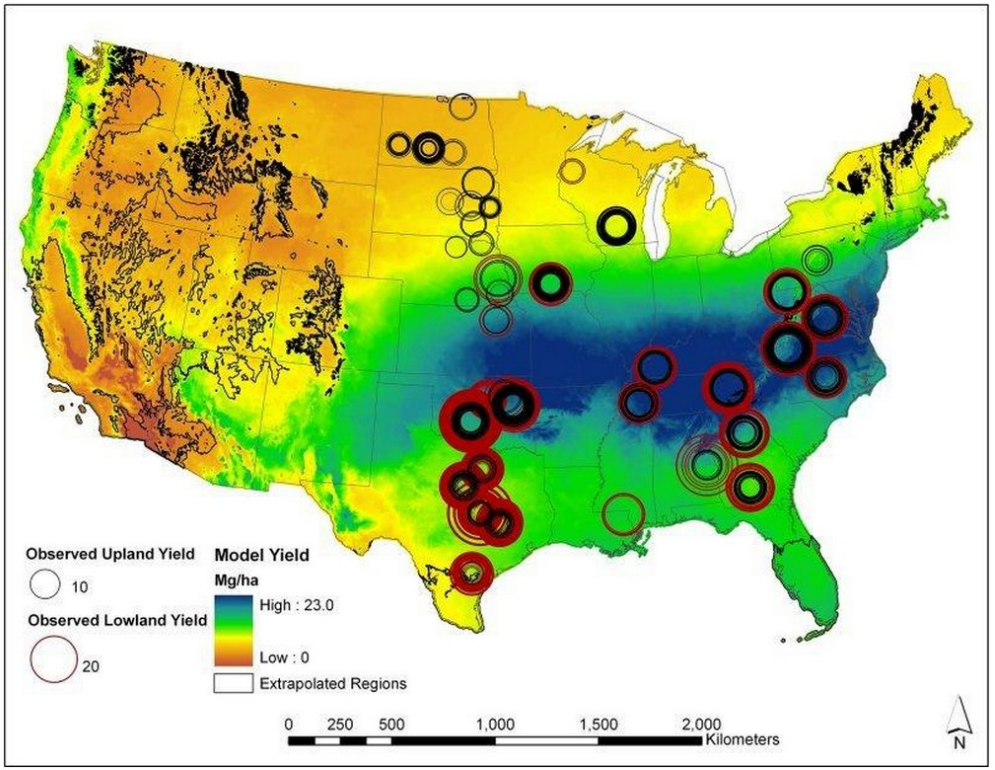
US Cellulosic Biofuel Production (Mgal): EPA RFS data

Year	All Cellulosic	Ethanol	EISA target
2014	33.3	0.7	2500
2015	140	2.2	3000
2016 (to 7.1)	78.8	2.0	4000

*Plants under construction

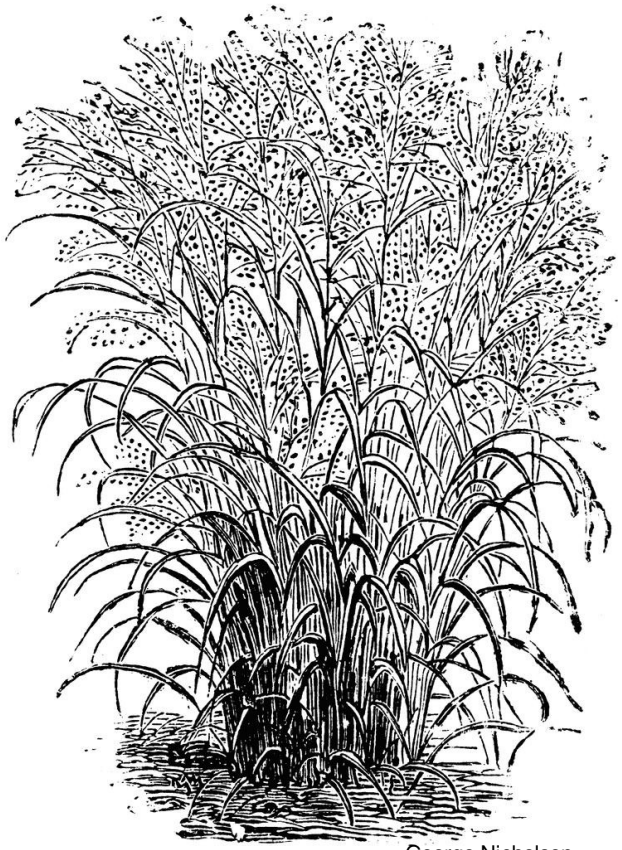
Herbaceous Perennials are a Significant Source of Available Biomass





Wullschleger, S.D., et al. (2010) Agronomy J. and Billion Ton Study Update

The Big Three: Dominant Grasses of the Tallgrass Prairie



George Nicholson

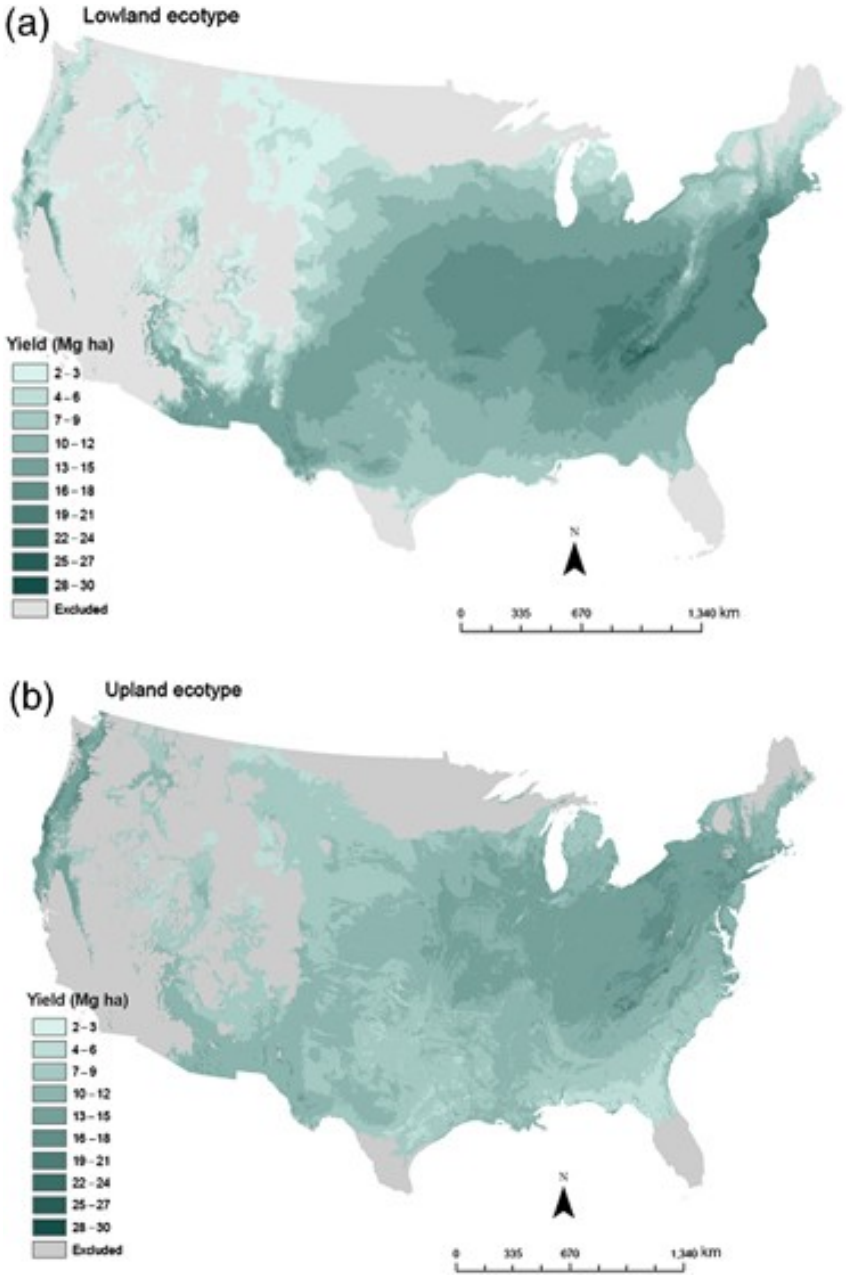
Hitchcock, A.S

Switchgrass
Panicum virgatum

Indiangrass
Sorghastrum nutans

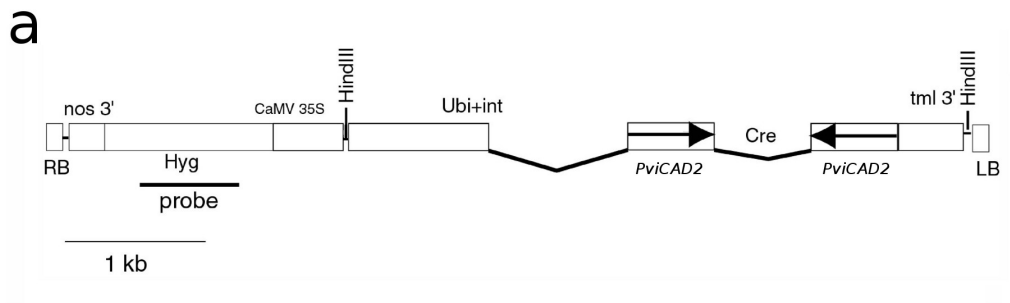
Big Bluestem
Andropogon gerardi

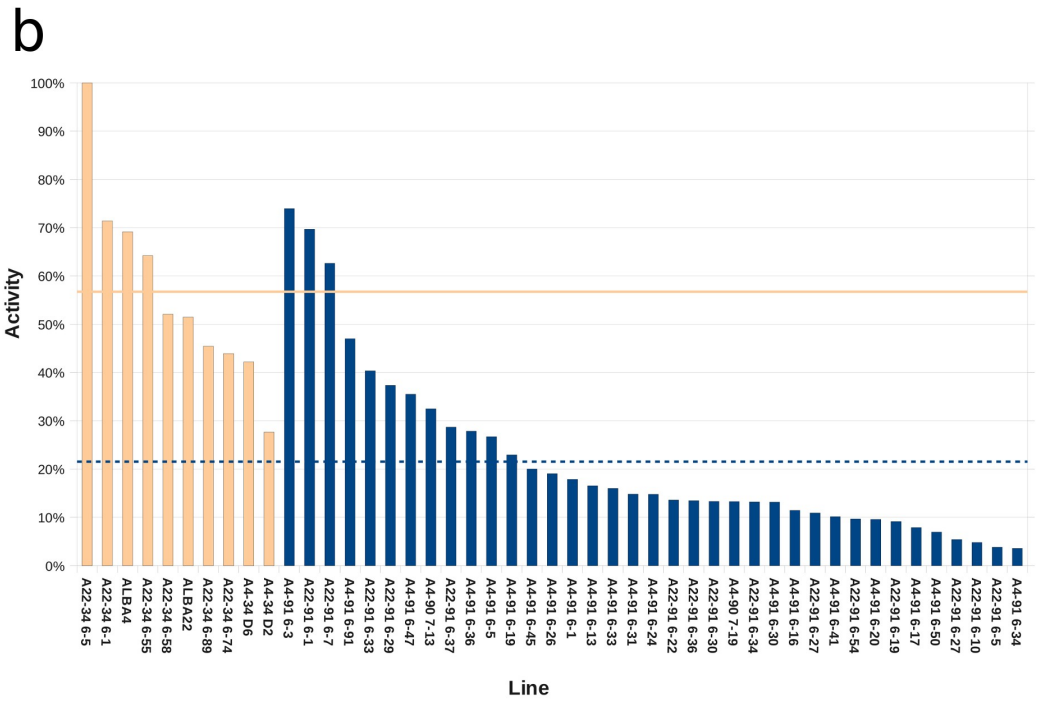
- **Switchgrass as a feedstock is ready to hit the road in terms of it's utilization for renewable biofuels.**
- **Outcrossing and Polyploidy complicate genetics**
- **Upland/Lowland 8x/4x cytotypes**
- **It is amenable to transformation and molecular approaches**
- **It is highly variable and there is high potential for yield improvements however biotechnological approaches remain unproven but with high potential.**

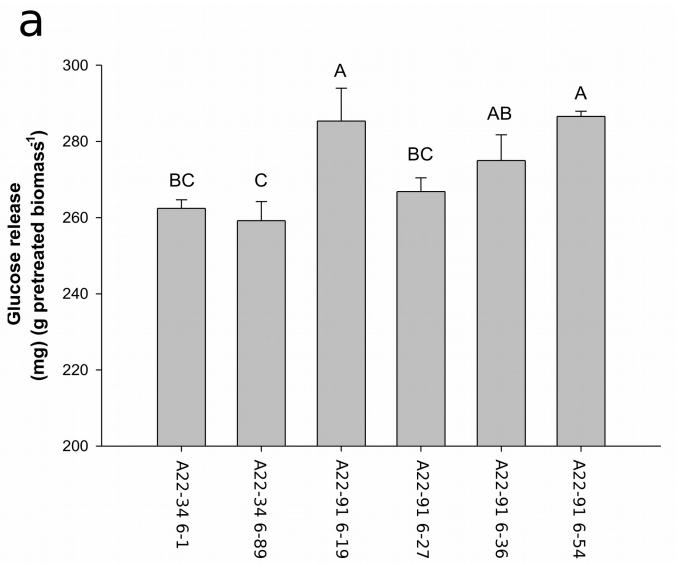


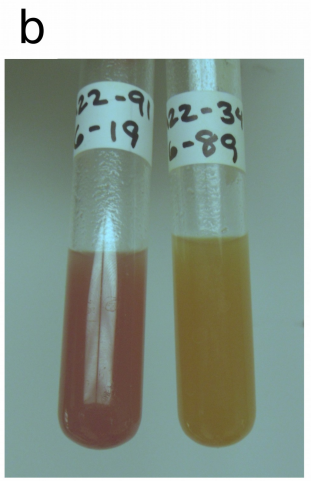
Jager et al. 2010

Silencing of a Switchgrass Gene Involved in Lignin Formation Results in Greater Digestbility



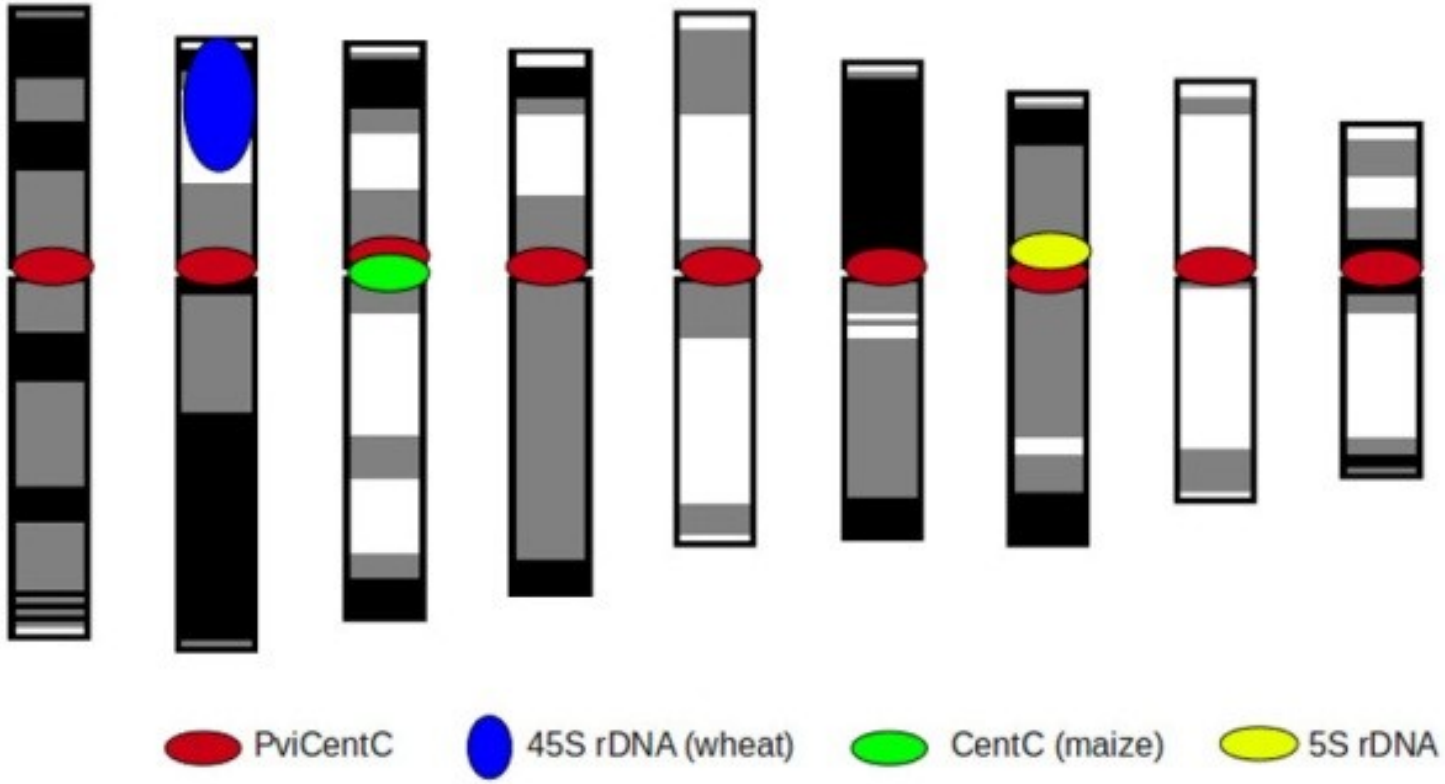






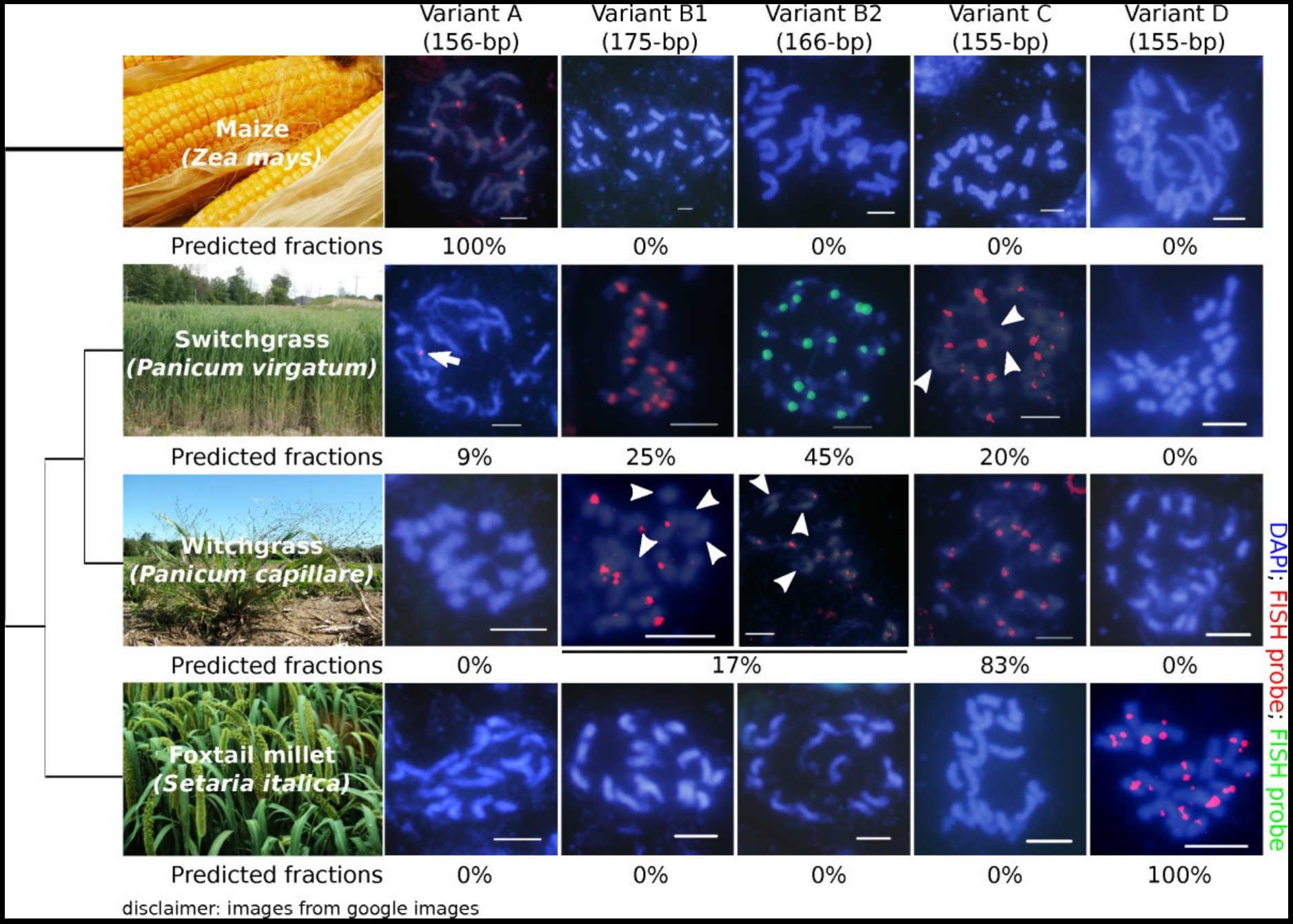
Saathoff et al. PloS One, 2010

Cytogenetic Features Reveal Structural Differences Between Subgenomes and Switchgrass Ecotypes

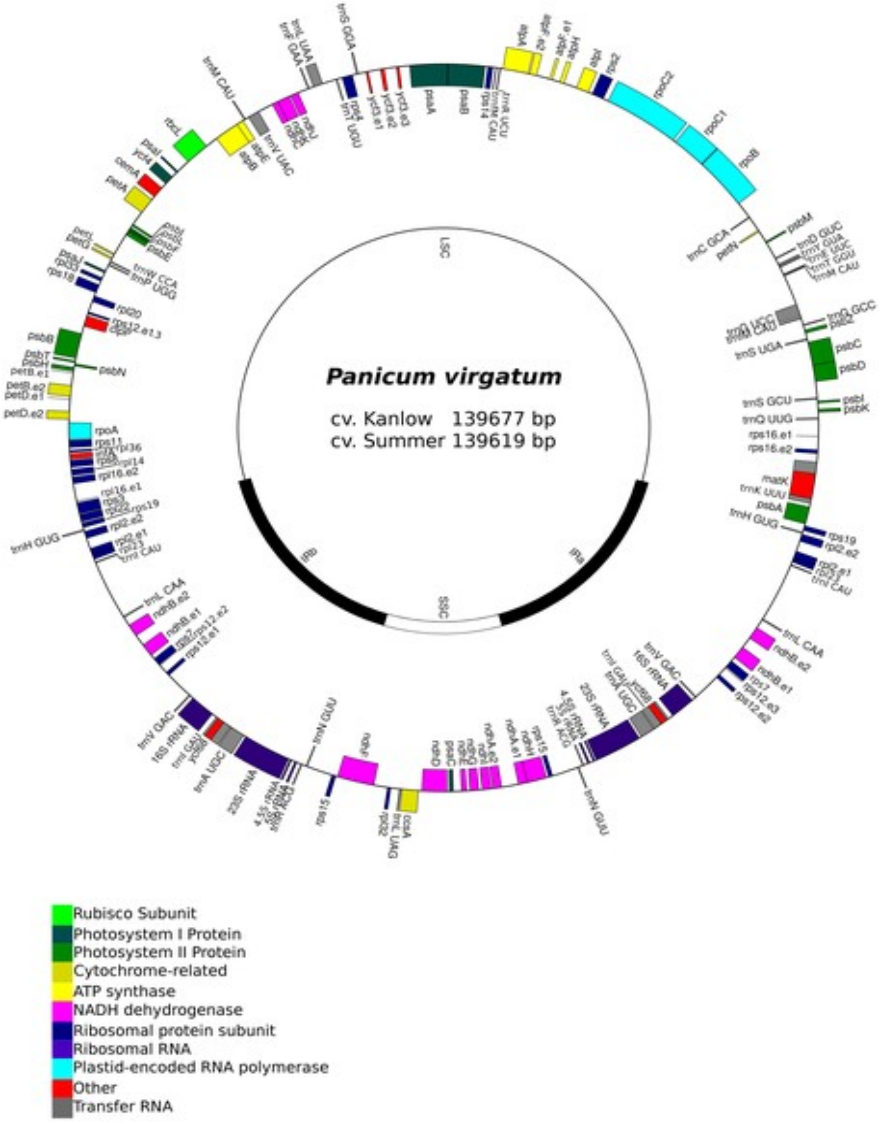


Chromosome	1	2	3	4	5	6	7	8	9
Length[a] (μm ± SE)	4.10 ± 0.25	3.73 ± 0.30	3.38 ± 0.18	3.26 ± 0.16	3.05 ± 0.18	2.82 ± 0.16	2.61 ± 0.17	2.35 ± 0.11	2.05 ± 0.16
Arm Ratio[b] (r ± SE)	1.30 ± 0.09	1.31 ± 0.06	1.15 ± 0.07	1.28 ± 0.13	1.22 ± 0.16	1.21 ± 0.06	1.30 ± 0.08	1.18 ± 0.06	1.21 ± 0.04

[a]Average value of 10 chromosome pairs (μm); [b]Arm ratio r (long/short); SE = standard error

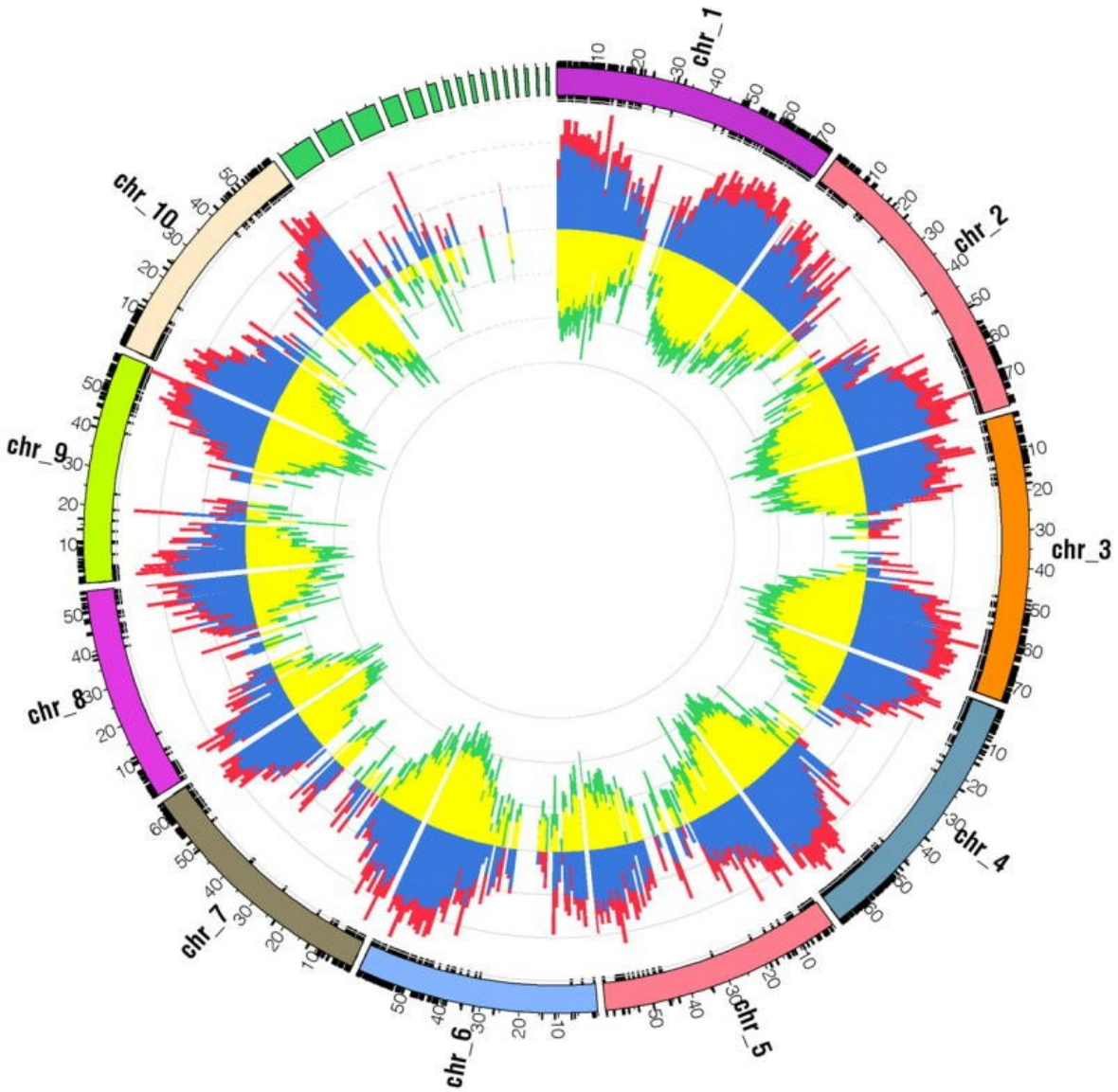

Variant A (156-bp)
Variant B1 (175-bp)
Variant B2 (166-bp)
Variant C (155-bp)
Variant D (155-bp)
Maize (Zea mays)
Predicted fractions
100%
0%
0%
0%
0%
Switchgrass (Panicum virgatum)
Predicted fractions
9%
25%
45%
20%
0%
Witchgrass (Panicum capillare)
Predicted fractions
0%
17%
83%
0%
Foxtail millet (Setaria italica)
Predicted fractions
0%
0%
0%
0%
100%
DAPI; FISH probe; FISH probe
disclaimer: images from google images

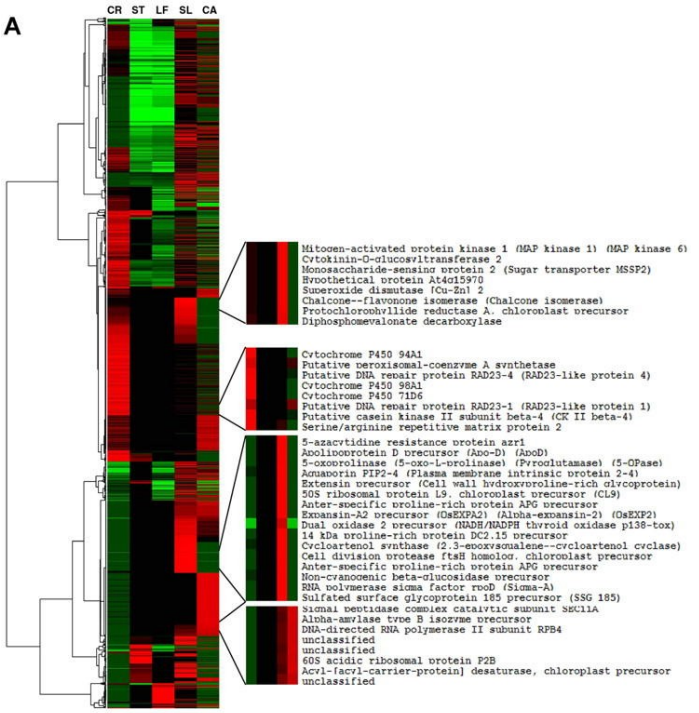
Map of the Chloroplast Genome of *P. virgatum* cv. Kanlow



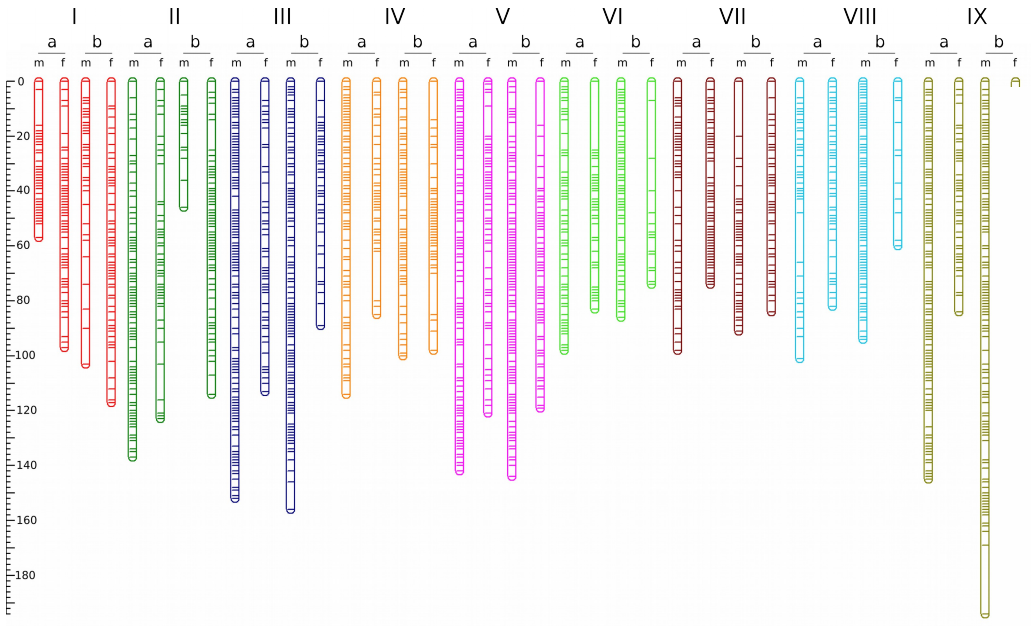
Young HA, Lanzatella CL, Sarath G, Tobias CM (2011) Chloroplast Genome Variation in Upland and Lowland Switchgrass. PLoS ONE 6(8): e23980. doi:10.1371/journal.pone.0023980
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0023980

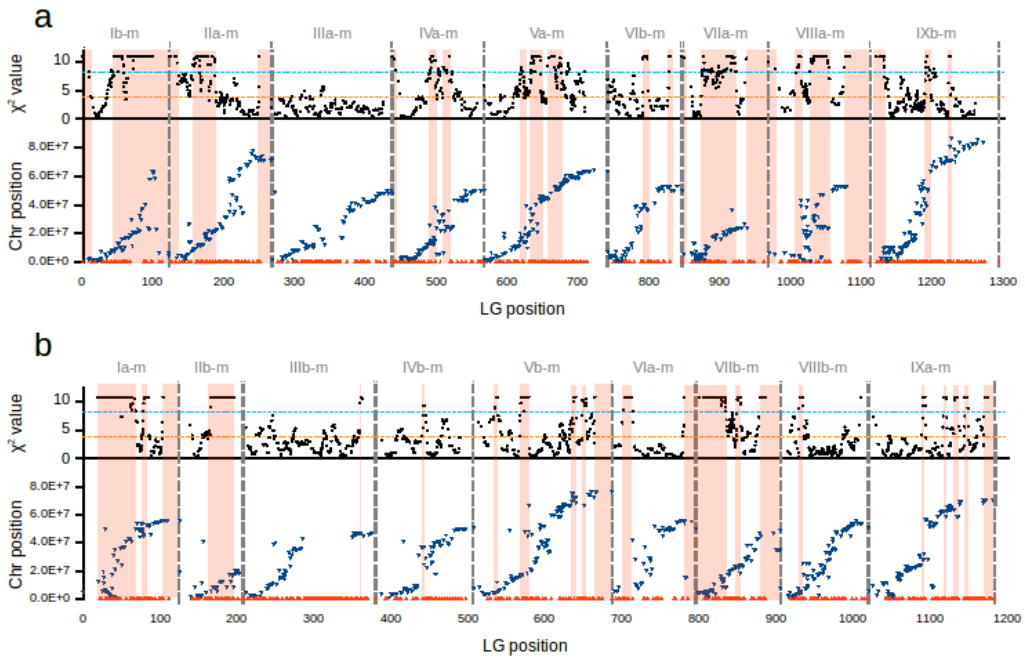
Sequencing of the Switchgrass Transcriptome Polymorphism, Duplication, and Conservation

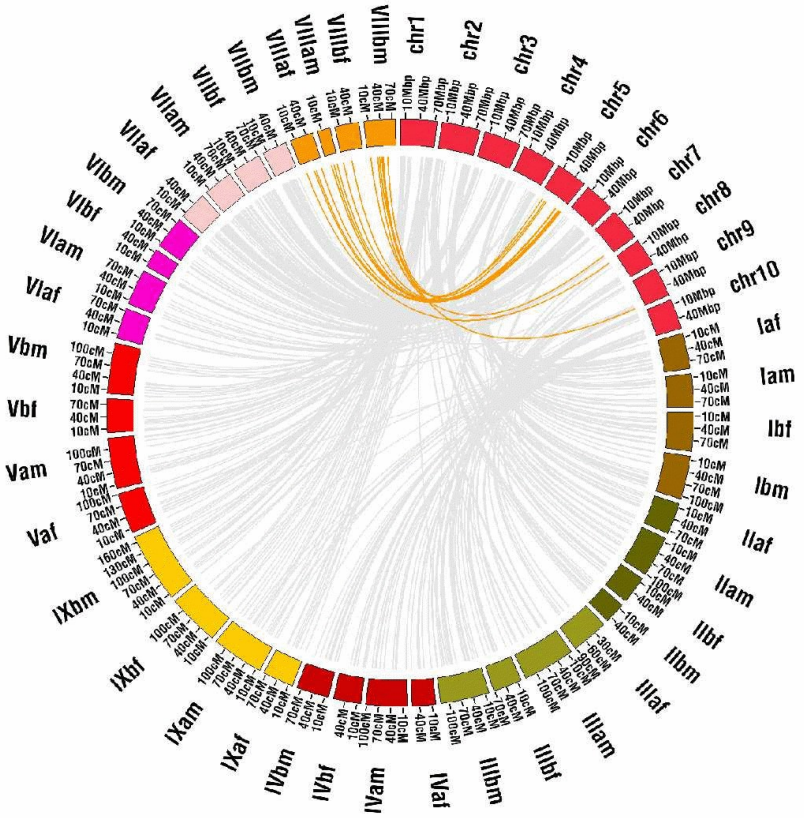




Linkage Mapping has Allowed Comparisons Among Grasses, Across Subgenomes and Has Facilitated Genome Assembly





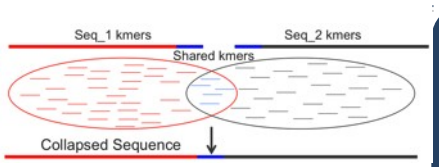


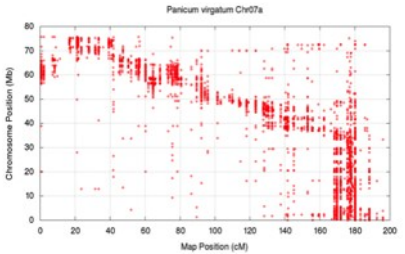
Switchgrass Genome

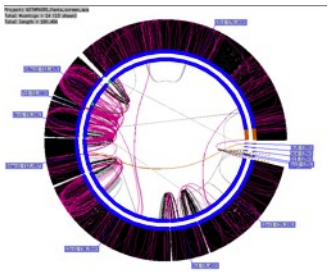
Switchgrass
Panicum virgatum

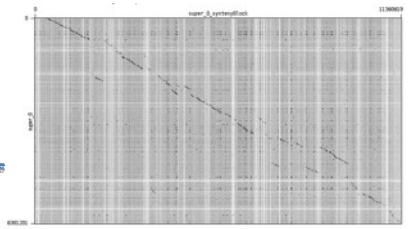
Outbred tetraploid
1.4 Gb genome

Advanced Custom Assembly & Integration









Whole genome shotgun – 454, Illumina

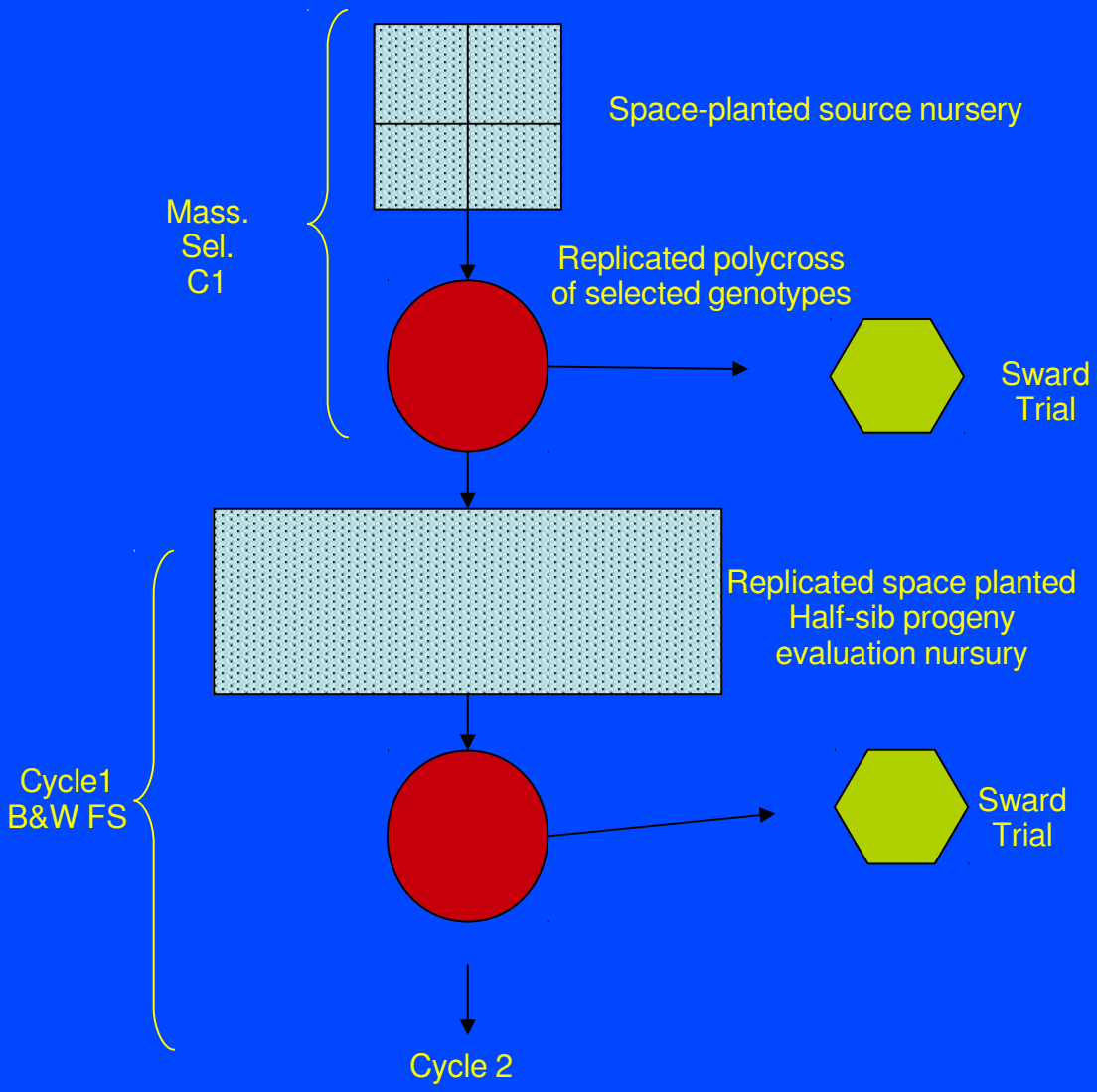
POP-SEQ Map ~1.9 M Markers

Single haplotyped clones 734 MB

Synteny with diploid panicum

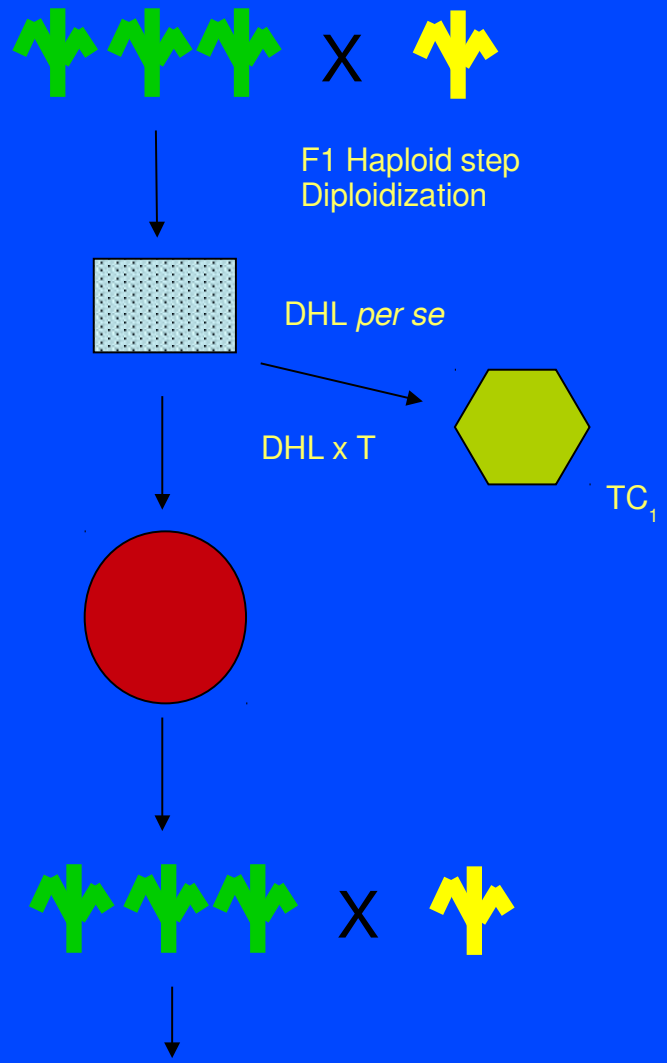
	V1.0	V2.0
Chromosome Bases	636.1 Mb	1.031 Gb
Chromosome Contig N50	9.2 Kb	33.1 Kb
Unassigned	48.0%	**11.7%**

Phenotypic selection



2 generations
6 years

DH Breeding

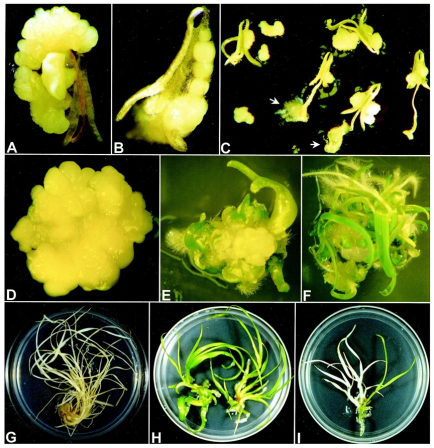


2 generations
6 years
2x genetic variance

Adapted from Pederson & Vogel, ; Geiger, 2009

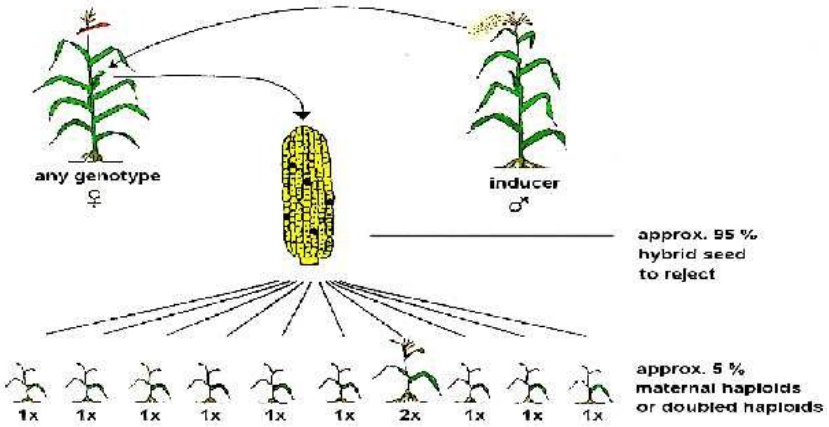
Uniparental Genome Elimination

Gametopyte culture

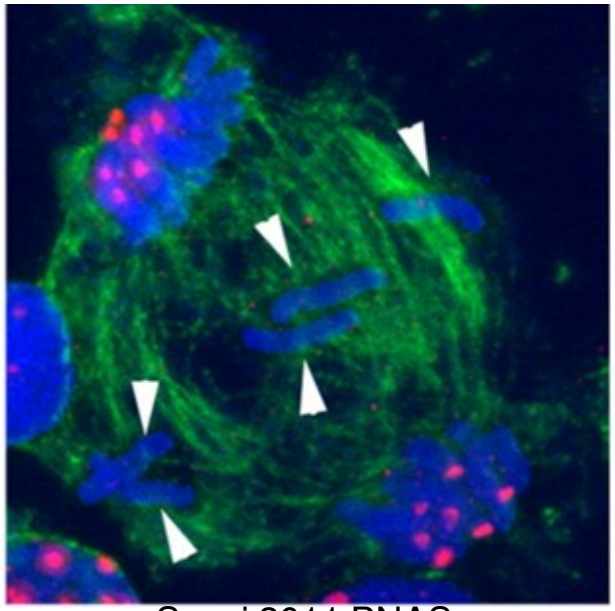


canola/barley

Inducer lines



CMCE (Arabidopsis only)



Sanei 2011 PNAS

Interspecific crossing

Hordeum bulbosum

Masu salmon

Nasonia

Acknowledgements

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Miki Okada (Mapping)

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