# SWITCHGRASS: Canada's emerging bioeconomy crop and strategies for improvement

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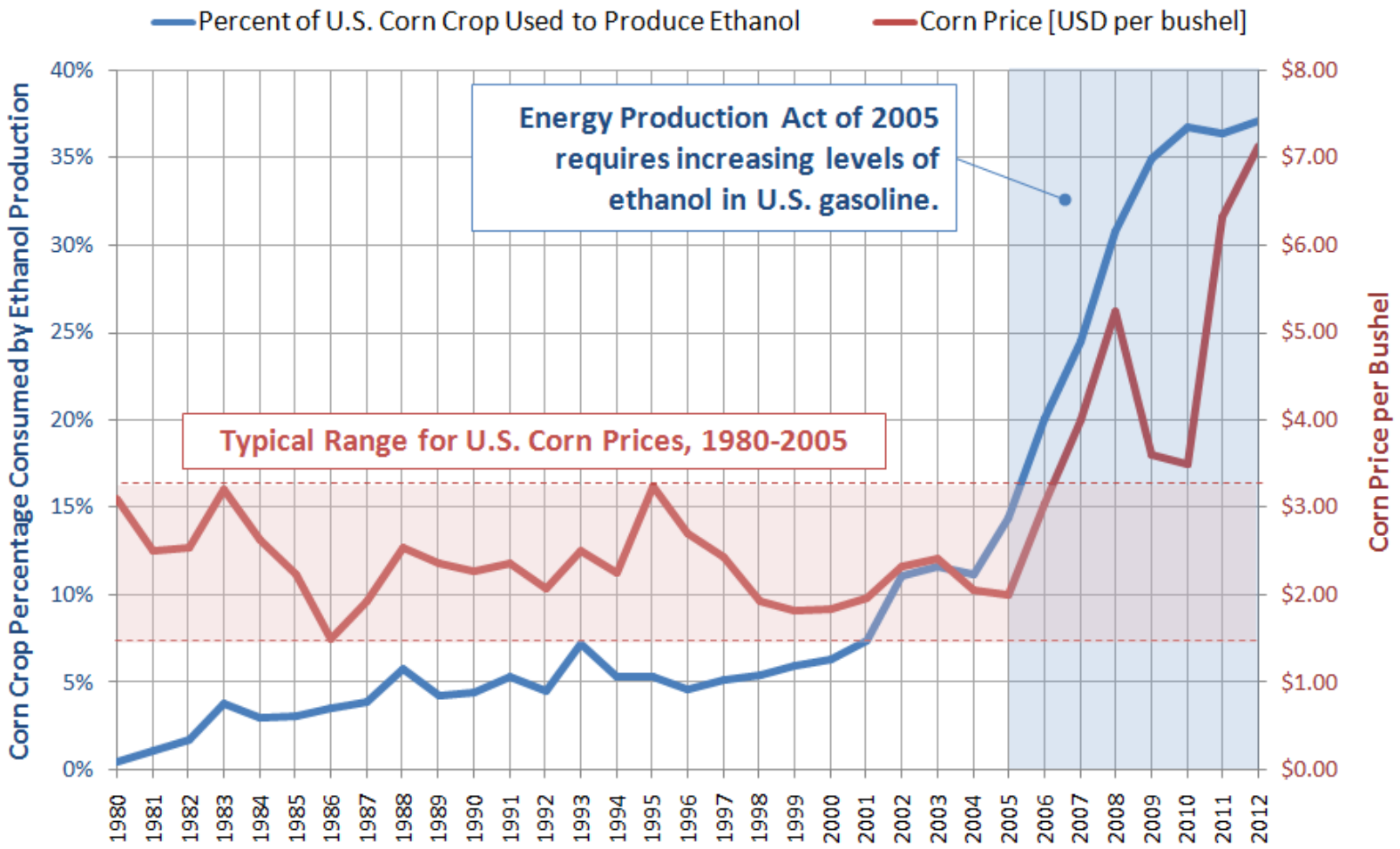
Presentation to AG BIOMASS DAY 2015
Guelph, Ontario, March 27 . 2015

REAP-Canada
Resource Efficient Agricultural Production

# Presentation overview

1) The urgency of demand enhancement for the farm sector
2) Status of switchgrass industry and rationale for development
3) Innovations in switchgrass plant breeding and establishment
4) REAP's innovative breeding protocol and advantages

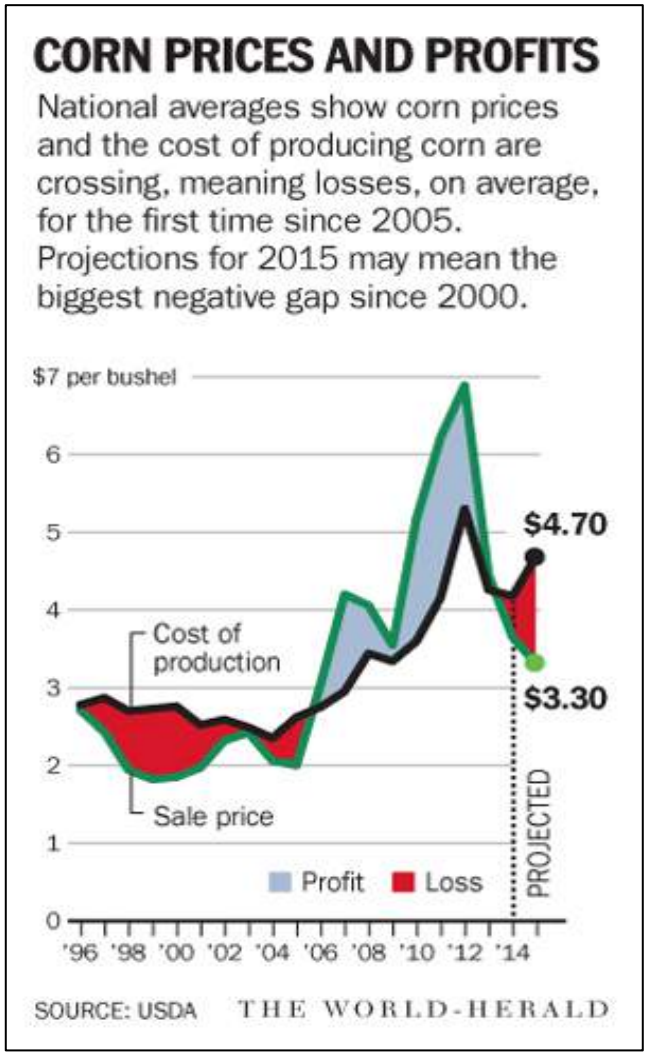
# Percentage of U.S. Corn Crop Consumed by Ethanol Production and Corn Price per Bushel, 1980-2012




Source: Iowa State University Agricultural Marketing Resource Center, Ethanol Usage Projections & Corn Balance Sheet and U.S.D.A. Agricultural Prices

# Current Challenges to Demand Enhancement

- Corn ethanol has reached ethanol blend wall of 10% and cellulosic ethanol 15 years late
- Corn yields increasing ~1.0%/year
- Return to commodity price collapse of the 1990's with stalled bioenergy demand and oil price collapse
- Need to create demand enhancement for the farm sector with fibre/biomaterial applications
- Annual food crops are a weak strategy to efficiently develop fibre -> need dedicated crops -> switchgrass



# REAP-Canada's Leadership in Switchgrass Development

**1991** - REAP becomes first Canadian agency to begin development work on the switchgrass bioeconomy to create demand enhancement

**1992** - Initiated first Canadian genetic improvement program on switchgrass for bioenergy and biofibre markets

**1995** - Initiated first work globally on pulp and paper applications with Domtar, Noranda and McGill and first commercial field plantings in Canada

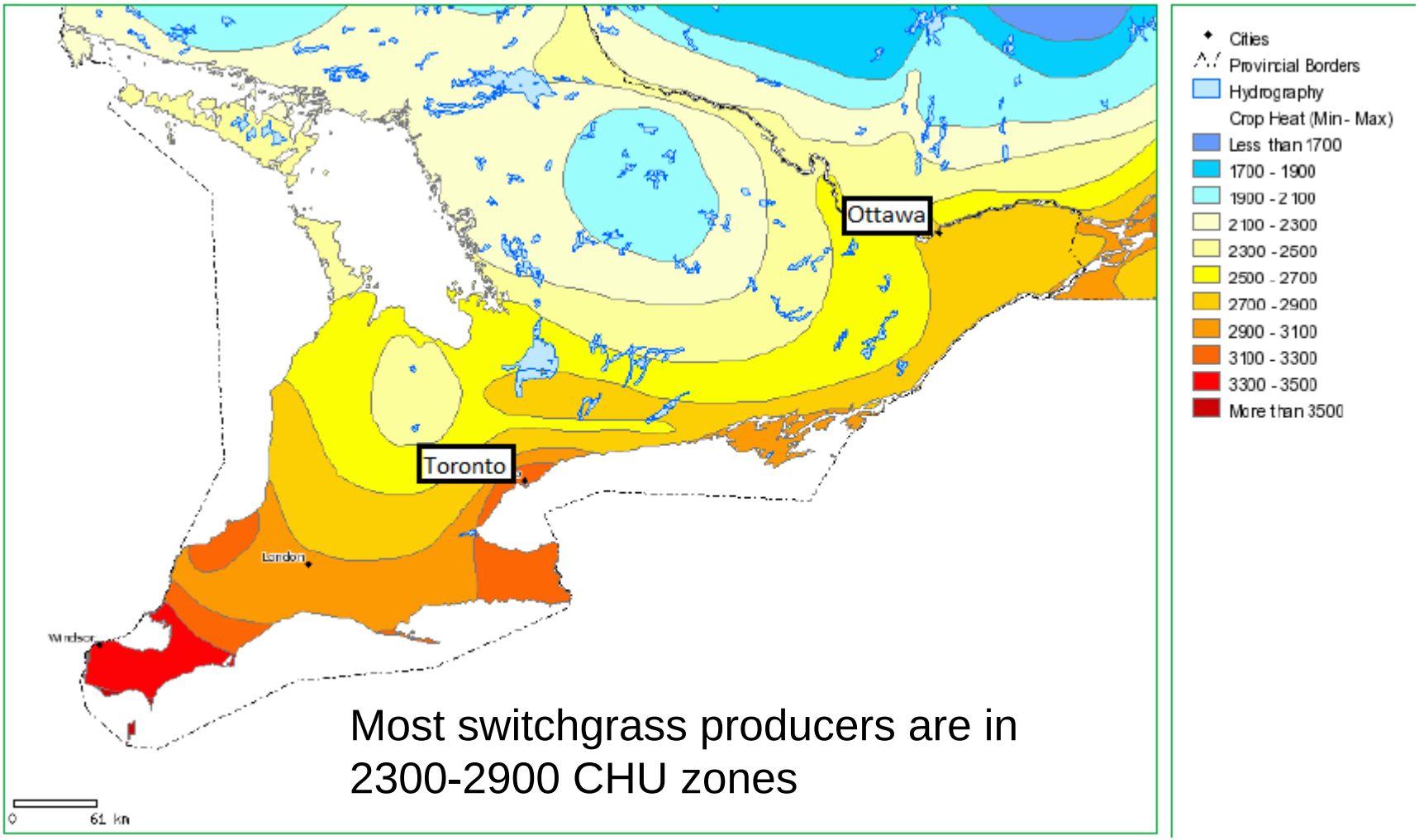
**1999** - Initiated first commercial pelleting of switchgrass and first successful combustion trials with switchgrass (NRCAN/Dellpoint Corp.)

**1999** - First large scale switchgrass acreage planting of 500 acres with Iogen Corporation in Ottawa

**1997-2014** - Performance trials performed on RC switchgrass germplasm in Ontario, Quebec, New York and EU.

**2014** - Seed fields planted of RC TECUMSEH and RC HIAWATHA with Nott Farms in Ontario

# Corn Heat Unit Map of Ontario




Most switchgrass producers are in 2300-2900 CHU zones

# Rationale for switchgrass as a model bioeconomy crop for Eastern Canada

**1)** Moderate to high biomass yields as it is a perennial C4 grass

**2)** Low cost to produce $/tonne and well adapted to marginal farmlands (land rent is a major cost driver)

**3)** Amongst perennial biomass crops has excellent traits for both energy conversion processes and fiber traits

**4)** Inexpensive to establish and grow, and requires no specialized equipment investments

**5)** Diverse market opportunities: biomaterials, bioenergy, and agri-food (feed, bedding, and a straw substitute, eg. mushroom cultivation).

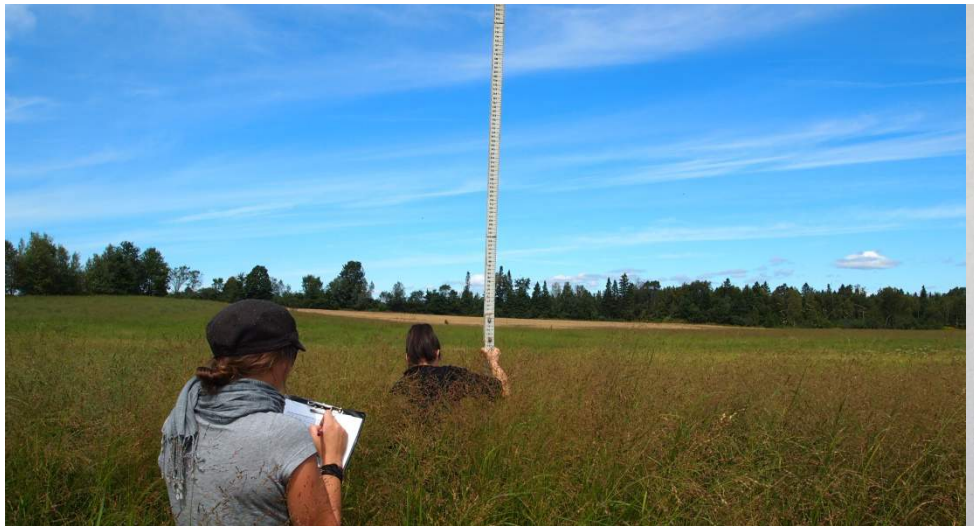
**6)** Large potential for genetic progress to increase yields and fiber quality

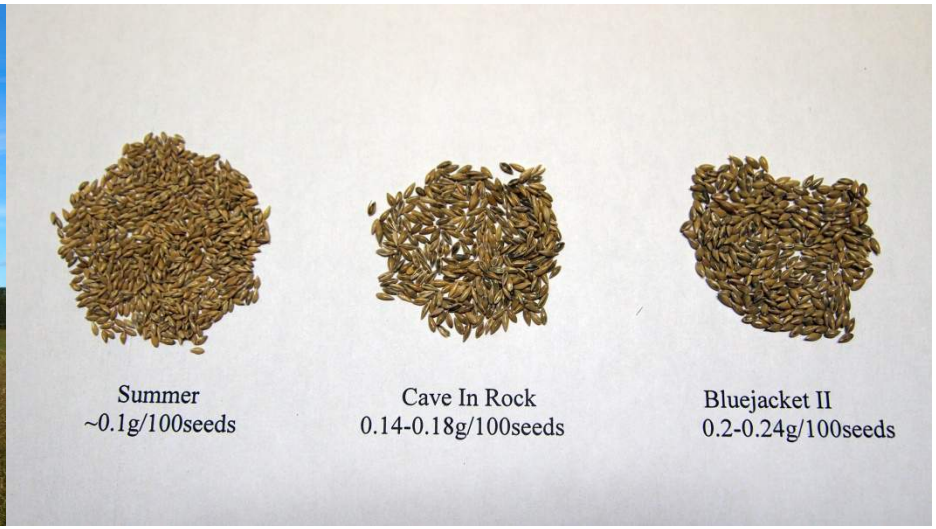
# Switchgrass Breeding in North America

- Currently 12 programs scattered throughout the US
- Main germplasm gaps:

  **1)** lack of improved upland switchgrass cultivars for the Great Lakes region and establishment issues

  **2)** need to improve fiber quality to more effectively compete with woody and non-woody plants (Jute, bamboo, straw) in biomaterial applications





# REAP-Canada's Unique Position

- Ste Anne de Bellevue QC location enables strong collaboration with McGill University on warm season grass research since 1992
- Long season location (2950 CHU) readily allows all upland germplasm to reach seed maturity reliably
- Well located for developing upland switchgrass germplasm for Ontario, Quebec and US Great Lake State markets

# REAP-Canada Breeding Objectives

## To reduce

- Seed dormancy
- Tiller number
- Lodging
- Length and cost of breeding cycles

## To increase

- Seed size and seedling vigor
- Yield (Increase reproductive tiller % and weight, height, upright leaves in the top of the canopy)
- Fiber strength and cellulose content

# Stop Tiller mortality!

- Shade-killed decomposing plant material at the bottom of the canopy is lost solar energy
- Excess vegetative tillers
- Selecting for single-tillers in the seedling stage reduces tiller mortality, increases % reproductive tillers, and optimizes plant resource allocation

# Photos from Sept 11, 2013
# Ste Anne de Bellevue Quebec

Sunburst
(Parent germplasm)

Blue Jacket II
(selection made in 2009)

# Ideotype Breeding of Native Grasses

- For the original collection, seed harvested from 30-50 superior plants chosen from 10+ year old switchgrass fields
- Seed collected and largest seed derived through air-column separation of parent seed (Boe and Johnson, 1987)

# Breeding Methods - Steps

- ~15 seeds planted in each cell of a 38-cell tray with 1000 cells per population (15000 seeds)
- Each cell thinned to the three fastest seedlings to emerge after 5-10 days to reduce dormancy
  (3000 plants)
- After 3 weeks, thinned to single strongest plant of the three left (1000 plants)
- After 6 weeks, population undergoes single tiller selection to reduce tiller number in mature plants(210 plants)

# Breeding Methods - Steps

- Single-tiller Selection:
  - Less tillers overall
  - Aim for less tiller mortality and greater % reproductive tillers
- At 6 weeks:
  - transplanted into larger pots to allow rapid greenhouse growth, creating bigger plants and reducing field transplant shock (210 plants)
- At 8 weeks:
  - field planting best 200 plants

Precise holes are dug with a motorized post-hole digger to minimize transplant shock to ¾ gallon pot transplants

# Spaced-Plant Nurseries for RRPS

- 200 plants of each population are then planted in spatially isolated nurseries
- Recycling the best ~10% of plants from each generation back into the next cycle
- Collect seed to repeat cycle annually
- Planting at 40 cm spacing in row and 55 cm between rows to enhance competition

1st year transplant of 6th cycle selection from sunburst, Sept 2013

# RC Tecumseh-(Centre plots)


RC HIAWATHA

# REAP's Unique Breeding Cycle

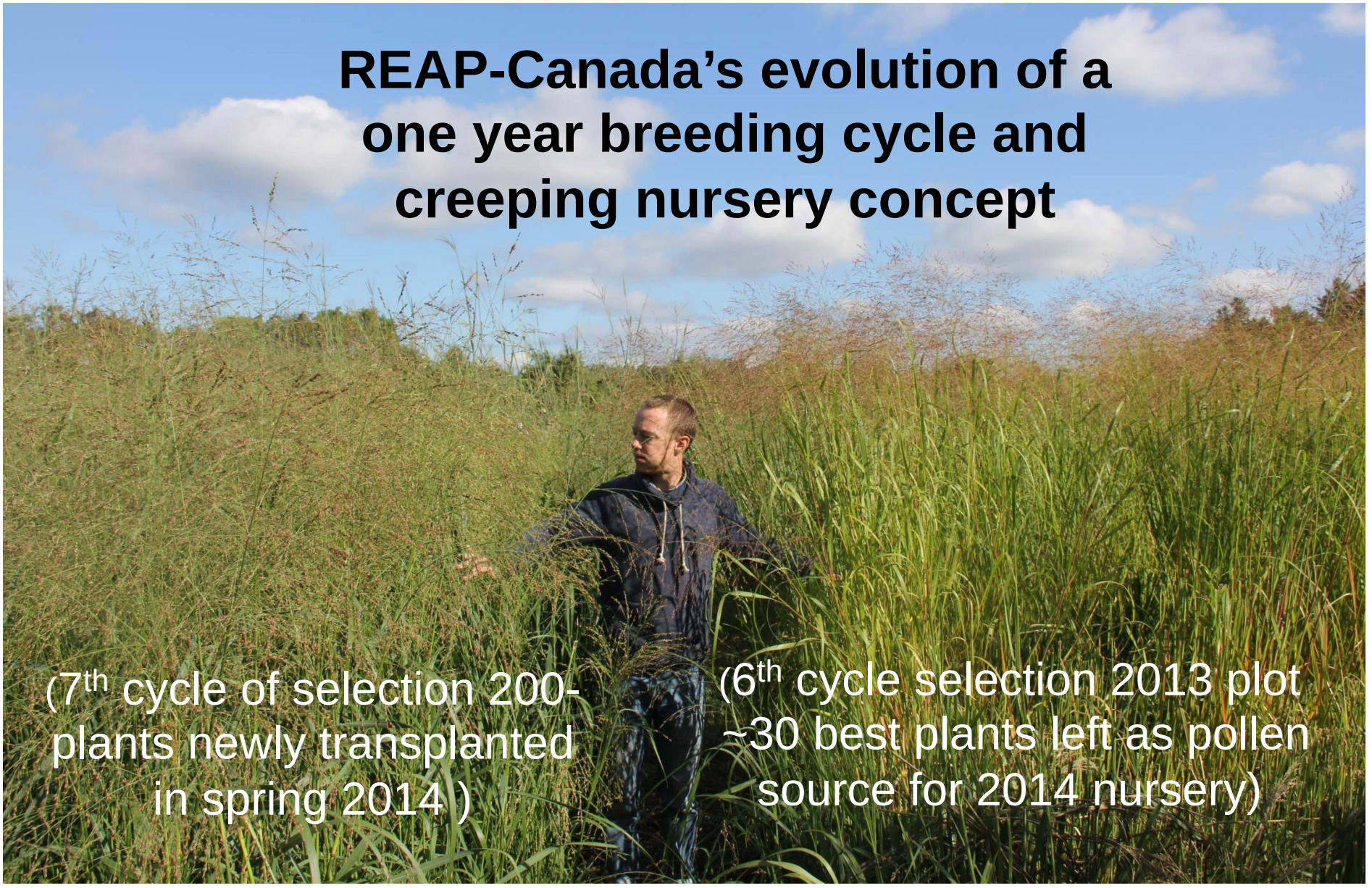
- Allows for 1-year breeding cycle; typical cycle is 3-7 years in this perennial crop
- Key to rapid success: multi-point selection stages within a single cycle. Simultaneous selection for:
  - Increased seed size
  - Reduced dormancy
  - Fast emergence
  - Increased yield (Reduced tillering and erect leaf architecture)

- This process allows REAP to make rapid gains in plant genetic quality related to increased yield, biomass quality and more

# 8 Distinct Selection Points in the 1 Year Cycle

1. Heavy seeds selected from seed lot and sown into 1000 cells
2. Seed dormancy improved by leaving 3 most rapid to emerge seeds per cell (~1 week)
3. At ~3 weeks, best competing seedling of the three is left per cell
4. At ~4 weeks, seeds with longest 2nd leaf are marked (good indicator of seedling vigor)
5. At 6 weeks, ~210 plants with tallest single tiller selected and transplanted into ¾ gallon pot
6. At 8 weeks best of 200 plants (most vigorous and least tillering) taken to field for transplanting
7. Prior to pollination, inferior plants cut and prevented to pollinate (~2-5%)
8. At seed harvest, seed from inferior plants will not be collected (~5-10%)

# REAP-Canada's evolution of a one year breeding cycle and creeping nursery concept

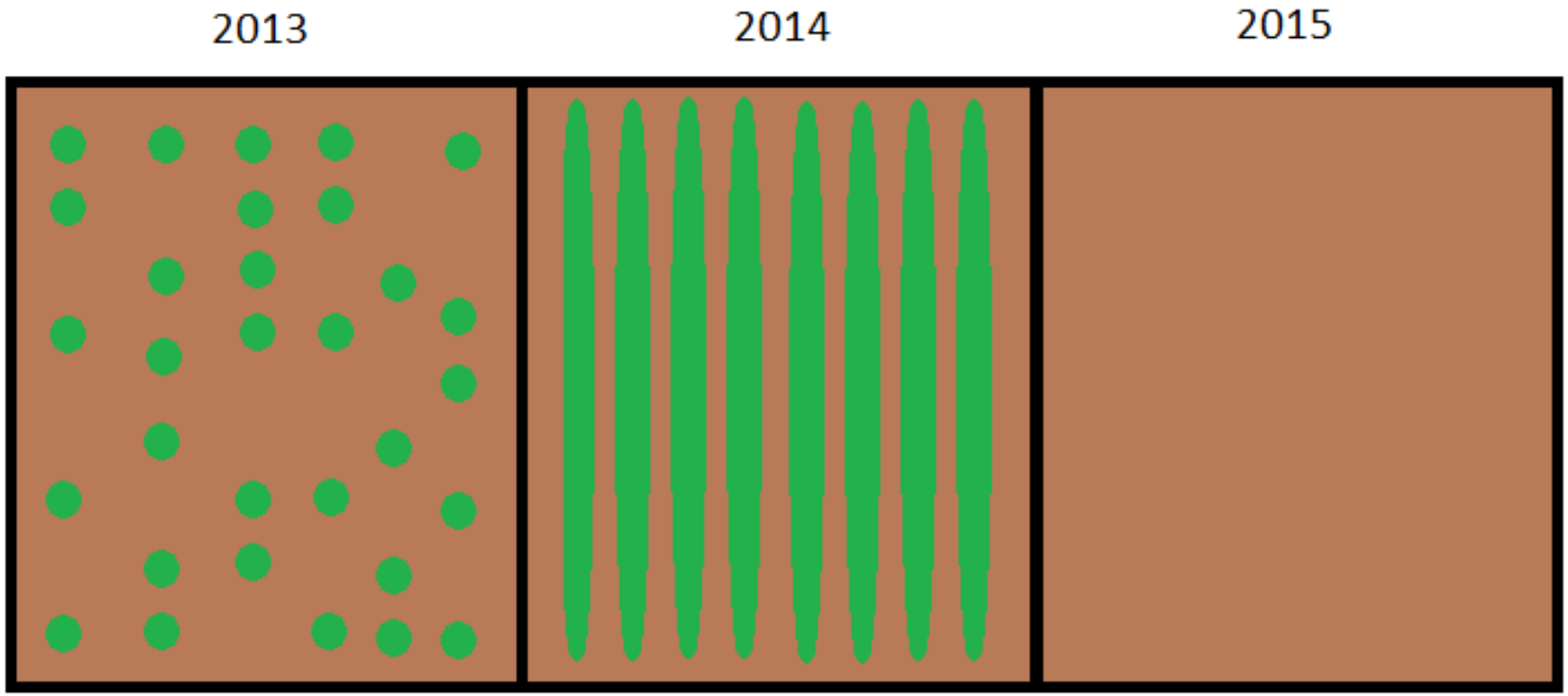


(7th cycle of selection 200-plants newly transplanted in spring 2014 )

(6th cycle selection 2013 plot ~30 best plants left as pollen source for 2014 nursery)

# The CREEPING NURSERY CONCEPT

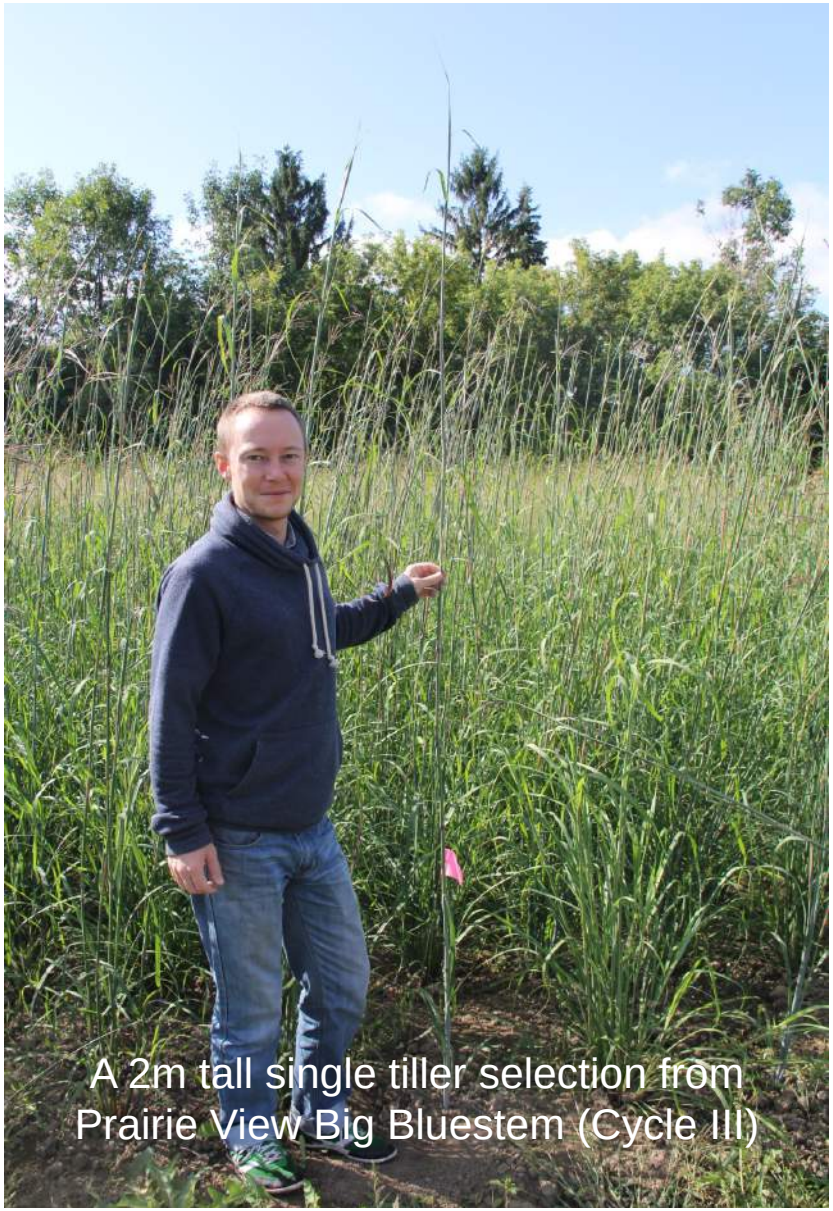
- By planning neighbouring space for subsequent years, the best plants can continue to contribute



# RC Tecumseh Underseeded in Spring Wheat for Seed Multiplication by Nott Farms

Outstanding seedling vigor makes RC switchgrass more suitable for crop rotations

# 1 Year Breeding Cycle in Big bluestem



A 2m tall single tiller selection from Prairie View Big Bluestem (Cycle III)

# Need for a Competitive Canadian Breeding Program

- 12 existing breeding programs in the USA, extensive investment through DOE
- Canadian potential, especially in marginal zones is very significant if appropriate research investments are directed at the issue
- With its research history, location and expertise REAP-Canada is in a unique position to contribute to this field

REAP-Canada

Resource Efficient Agricultural Production

# Partners in Switchgrass Germplasm Research

ERNST SEEDS

ONTARIO BIOMASS PRODUCERS CO-OP

for a cleaner tomorrow

SWITCH ENERGY CORP

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