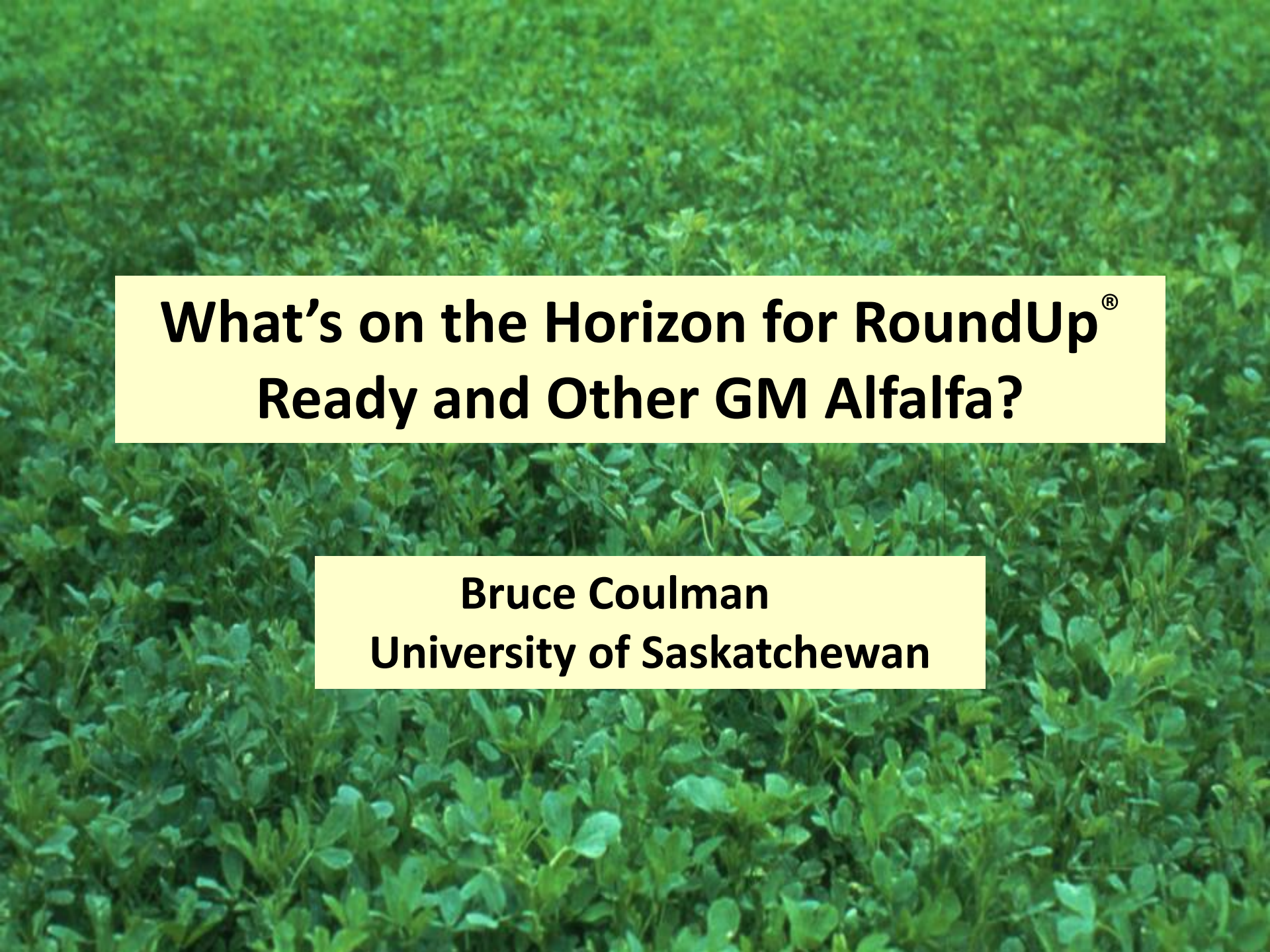


What's on the Horizon for RoundUp® Ready and Other GM Alfalfa?

Bruce Coulman
University of Saskatchewan

Crop Improvement

- “Traditional” plant breeding methods are used to improve many crop types
- Variation and improved traits introduced by
  - Crosses within a species
  - Crosses between closely related species
  - Mutagenesis

Crop Improvement

- In the 1980s, techniques were developed to transfer genes from one species or organism to another
- Permitted the transfer and expression of traits from one organism to another.

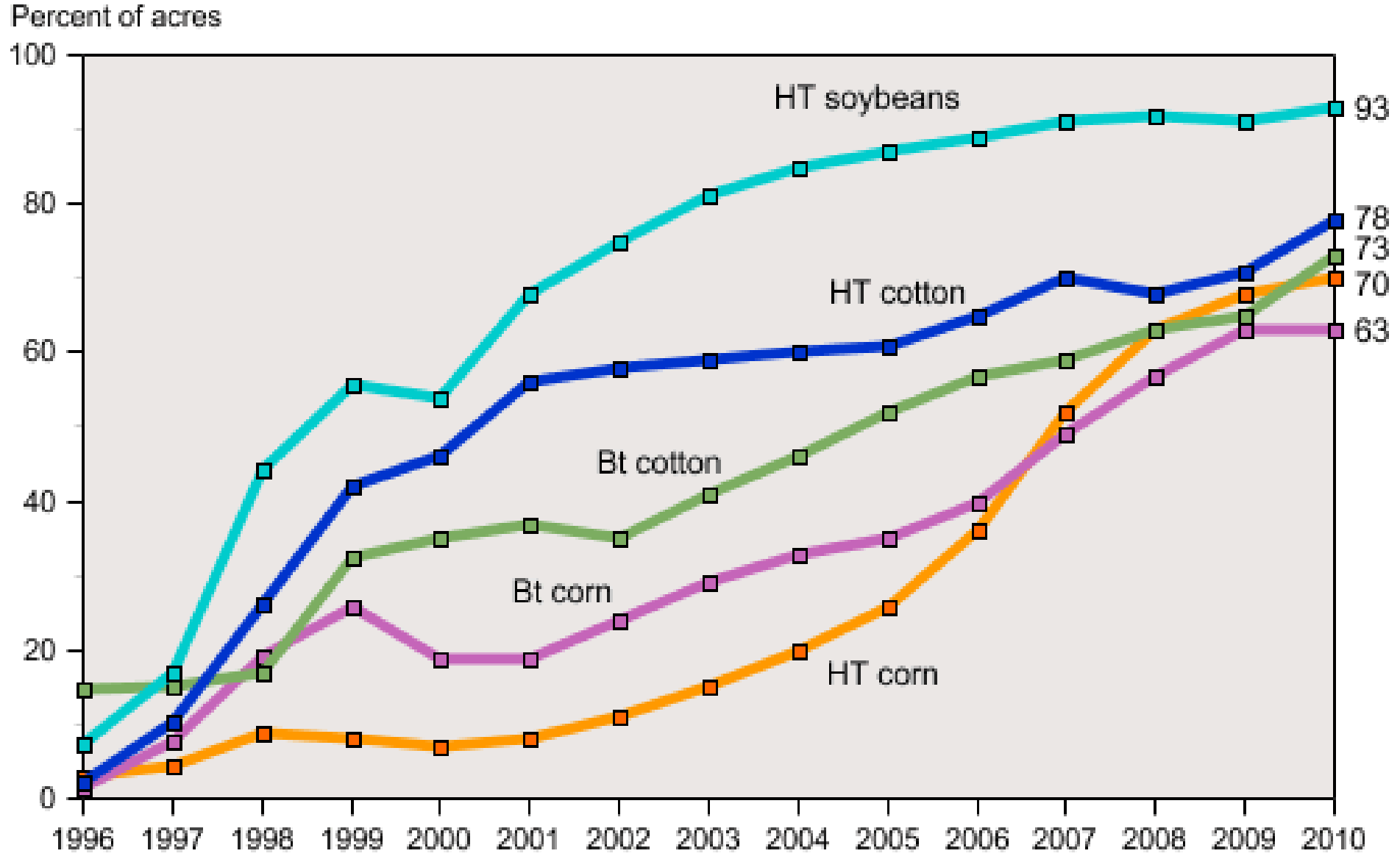
Genetically Modified (GM) Crops

- GM, GMO, Transgenic
  - Transfer of a gene or genes to a crop from another species or organism
  - Provides a new trait to the crop which could likely not have been developed by “traditional” plant breeding techniques
- First GM varieties were released in the mid-1990s

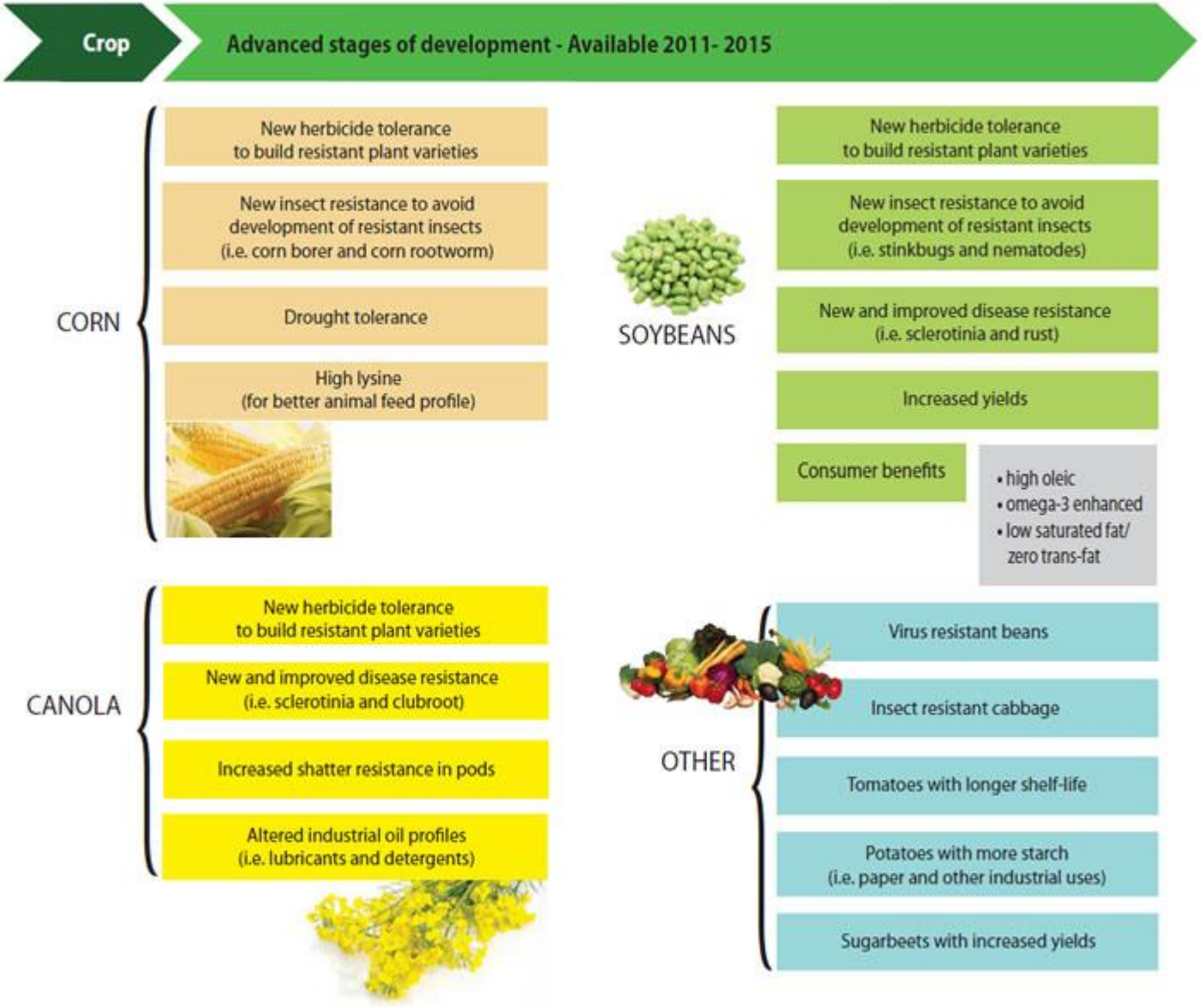
Use of GM crops in Canada (2010)

- Corn – 65%
  - Herbicide and insect tolerance
- Soybeans – 65%
  - Herbicide tolerance
- Canola - > 80%
  - Herbicide tolerance

Rapid growth in adoption of genetically engineered crops continues in the U.S.



Data for each crop category include varieties with both HT and Bt (stacked) traits.
Sources: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-10 are available in the ERS data product, Adoption of Genetically Engineered Crops in the U.S., tables 1-3.



Source: Crop Life Canada www.croplife.ca

GM Crop Concerns

- Contamination of non-GM varieties with transgenes
  - Impact on organic industry which has 0 tolerance
- Effect on markets which have 0 tolerance for GM
  - European Union etc
- Perception of risk by public with no apparent benefit

GM Forage Crops

- Development of GM crops is expensive
- To date, GM varieties have been in major crop kinds
- Most forage species do not have a large enough market to justify the expense
- Alfalfa is the most widely used forage crop
  - Active programs on a number of GM traits
  - Roundup Ready® alfalfa is first release

North American Alfalfa Breeding Programs

- Canada
  - AAFC Lethbridge
  - Ste-Foy, Québec

- U.S.
  - Private companies
    - Largest breeding effort
  - Universities and USDA
  - Private, non-profit – Noble Foundation

Improvements from “Conventional” Alfalfa Breeding Programs

- New varieties of all dormancy classes
- Multiple disease resistance
- Grazing tolerance
- Leafhopper resistance
- Slightly lower fiber content
- Increased forage yield
- Improved winter hardiness
- Reduced bloat incidence

Present Alfalfa Genetics Research

- Noble Foundation – Oklahoma
  - Leaders in genomics research
- AAFC, Ste-Foy
  - Cold tolerance, forage quality, molecular genetics
- AAFC, Saskatoon
  - Condensed tannins to eliminate bloat
- USDA stations and U.S. universities
  - Molecular genetics and genomics
- University of Guelph
  - Evaluation of transgenic lines – stress tolerance etc.
- U.S. Private Companies – FGI etc.
- Molecular genetic research in other countries

Roundup Ready® Alfalfa

- Developed by Forage Genetics International (FGI) and Monsanto
- Gene from bacteria introduced into alfalfa which gives tolerance to glyphosate
  - Same gene used in corn, soybean, canola
- U.S. regulatory approval – June, 2005
- Canadian regulatory approval – Sept., 2005
  - CFIA and Heath Canada
  - novel plant safe for food, feed and environment

Roundup Ready® Alfalfa in the U.S.

- Planted in U.S. in fall, 2005 and spring and fall, 2006
- 2.5 million lbs seed planted in 2006
  - 5% of total U.S. market
  - 50% of market in Kansas
- Were predicting 20-25% of market in 2008
- $125-$150 technology use fee per 50lb bag
- Varieties available in fall dormancies 3-8

Roundup Ready® Alfalfa in the U.S.

- California U.S. District Court decision on Feb. 13, 2007
  - Court ruled that the US Animal and Plant Health Inspection Service (APHIS) should have prepared an environmental impact statement should have been prepared rather than an environmental assessment
    - Violated the National Environmental Policy Act
- Further sales of RR alfalfa were prohibited

Roundup Ready® Alfalfa in the U.S.

- APHIS provided provisions for RR alfalfa already planted
  - Procedures for cleaning forage and seed harvesting equipment used for RR alfalfa
  - Provisions for segregating and labelling RR hay and seed
- APHIS prepared Environmental Impact Statement and released final version in late 2010
- RR Ready alfalfa re-granted non-regulated status in Feb, 2011
  - Plantings resumed in spring, 2011

Roundup Ready® Alfalfa in Canada

- Although approved for cultivation and production, RR Ready alfalfa is not grown in Canada
- Roundup ® not currently approved for use on alfalfa
  - Trials have been done to obtain minor use label
- RR Ready varieties currently not registered for sale in Canada
  - Field trials underway in 2011 in Ontario and Quebec
- No apparent present interest in using in western Canada
  - Alfalfa most often seeded in mixtures with grasses

Assessing the Potential Impact of Roundup Ready® Alfalfa on Canada's Forage Industry

Workshop – Saskatoon Dec. 2011

Douglas Yungblut, Ph.D., P.Ag.

Jacques Jalbert, M.Sc., Agr.

Canadian Forage & Grassland Association
Association Canadienne pour les Plantes Fourragères

Sask Forage Council

Regulatory status around the world

As of November, 2011 the following is the regulatory status of RRA:

- Cultivation/Production Approval: US and Canada
- Import Approval: Australia/New Zealand, Japan, Korea, Mexico, Philippines
- Pending Import Approval: China

Potential Impacts (Pros)

- Alfalfa growers would gain an effective, relatively low cost herbicide option.
- RR alfalfa could be used in a rotation to get rid of problem weeds like quackgrass and Canada Thistle,
- Alfalfa quality would be increased due to the better weed control.
- Stand life might also be improved.

Potential Impacts (Cons)

- An additional RR Ready crop would increase risk of RR resistant weeds
- The RR gene could spread to feral or non GMO alfalfa creating unintended resistant plants.
- Producers would lose the option of using Roundup to take out alfalfa stands at the end of their productive cycle.

Potential Impacts (Cons)

- Some producers would resent having to pay a technology fee and sign a usage agreement.
- Organic producers might experience undesired contamination of their alfalfa fields.
- Unintentional or adventitious contamination of seed or forage could hurt certain export markets.

Other GM Traits Under Development in Alfalfa

- Low lignin
- Bloat safe
- Improved protein utilization
- Tolerance to stress – drought, salt , cold
- Delayed flowering
- Delayed senescence (Stay-green)

Low Lignin Alfalfa

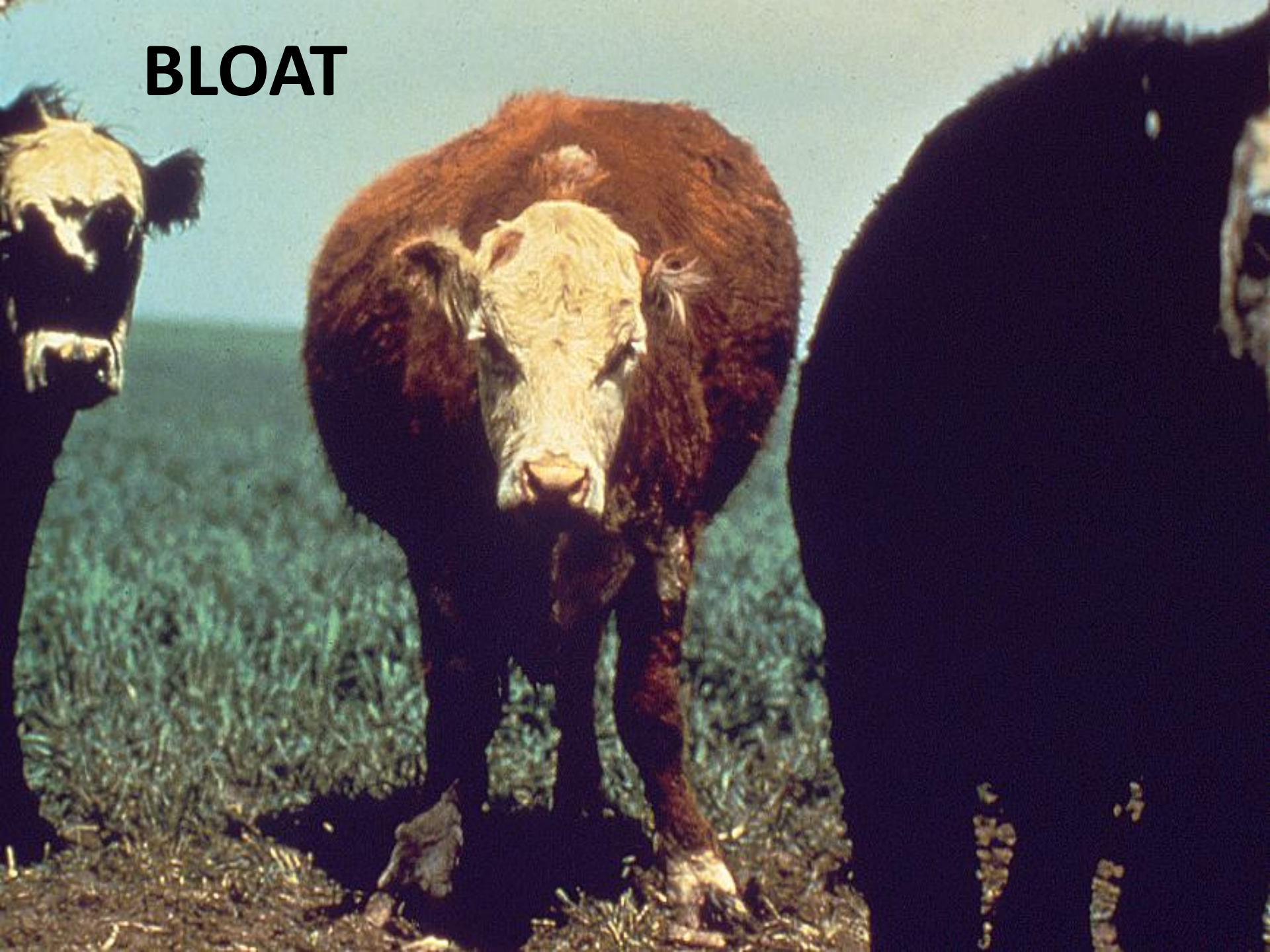
- Lignin is an indigestible component that also makes cellulose less digestible
- Reduced lignin increases forage digestibility and provides more available carbohydrates
- Reduced lignin lines available through “knocking out” activity of certain enzymes involved in lignin biosynthesis
  - Produced by Noble Foundation and Forage Genetics International

Feeding trials with Low Lignin Alfalfa

- Lambs
  - Improved digestibility of NDF and dry matter
- Dairy cattle
  - Improved NDF digestibility
  - Improved milk yield (3.5%) with one line

Other Advantages of Low Lignin Alfalfa

- Can delay harvest and get same forage quality as non-LL alfalfa cut 8-12 days earlier (in Wisconsin)
- In warmer areas, could take fewer cuts – get higher yields and same quality
- Release date ????


BLOAT

AC Grazeland Br Alfalfa

- 60 - 65% reduction in bloat
- Seed available since 2000
- Similar variety in Argentina

Alfalfa: Bloat and Protein Utilization

- Development of alfalfa expresssing condensed tannins (CTs) in the leaves
  - CTs bind to soluble proteins in the rumen
  - Alfalfa produces CTs in the seed coat but not in the leaves
  - Would be bloat-safe and higher in rumen undegradable protein
  - AAFC Saskatoon, Forage Genetics and Noble Foundation

Alfalfa : Bloat and Protein Utilization

- Regulatory gene from corn transferred to alfalfa
- First lines which express condensed tannins in leaves
  - Very low concentrations
- Digestibility experiments – Lethbridge
  - Lower initial rate of overall digestion
  - Lower initial rate of nitrogen digestion

Alfalfa: Bloat and Protein Utilization

- More winter hardy alfalfa lines produced which contained corn regulatory gene
- Nutritional and chemicals profiles on new lines done by graduate student at U. of S., Arjan Jonker
  - Contained anthocyanidins, compounds closely related to condensed tannins
  - Very low levels of condensed tannins
  - Improved (lower) N to carbohydrate ratio
  - Reduced foam volume

Alfalfa: Bloat and Protein Utilization

- The lines transformed with corn regulatory gene have slightly improved nutritional and digestion characteristics
- Condensed tannin concentration must be much higher to have significant effects on bloat prevention and protein utilization
- Improved varieties will take time

Alfalfa : Other GM characters in pipeline

- Work by research group in Italy
- Delayed senescence (leaf death and loss)
  - A group of senescence associated genes identified
  - A gene transferred to alfalfa from a bacteria
    - Delayed leaf senescence (“stay green”)
- Larger seed size
  - Gene from Arabidopsis transferred to alfalfa
  - Plants presently being evaluated

Alfalfa research: Genomics

- Determine the DNA sequence of model legume species *Medicago truncatula*
  - International effort led by Noble Foundation in U.S.
- The genome has now been sequenced
  - Genes identified for many important characteristics
- These genes can be related to genes in alfalfa
  - Can identify and select for these genes

Summary

- Round Up Ready® alfalfa is the first available GM alfalfa
  - Not being sold or cultivated in Canada yet
- Low lignin alfalfa will likely be the next GM alfalfa available
- Other GM alfalfas under development
  - "Tannin alfalfa – bloat-safe and improved protein utilization
  - "Stay-green" alfalfa