The Apple Context

- Apples are produced in most provinces
  - Concentration in ON, QC, BC, NS and NB
  - Largest tree fruit crop - volume and value
  - 2nd most valuable fruit crop after blueberries

- The market is variety-driven
  - Variety used up to 100 years, but now reduced
  - Domestic market share decreasing over the last decade

- Key innovations to regain our domestic share*
  - Innovativeness
  - Introduction of new varieties

*Horticulture Value Chain Roundtable Benchmarking Study for Canadian Apples, 2012
Genetic Improvement...

...the beginning of the Value Chain Model
AAFC’s Research Centres Supporting Apple Horticulture

Coastal Region
Prairie Region
Ontario-Quebec Region
Current Apple Breeding Work...

Stage 1

- Cross between two parents
- Screening for disease resistance (e.g. scab) + 3 years juvenile seedling growth
- Budding + 3 years select for disease resistance (e.g. powdery mildew) and post-harvest traits

Years 8-14: 2nd Selection in Replicated Trial

- Budding + 3 years of juvenile growth
- Deblossom to prevent stunting
- 3 years of selection for yield and quality traits

Stage 2

Years 15-20: On-Farm Testing (SVC)

- Budding + 3 years of juvenile growth
- 2+ year evaluation for regional climate adaptation, yield and quality

Stage 3

- AAFC generates final varieties
  - Focused on quality and yield
  - Little germplasm development and new breeding technologies
- Provinces/grower organizations, arms-length organizations in some places test regional adaptability
- Universities are not typically involved
- Nurseries sell trees and pay royalties
The Challenge

• AAFC is a national, publicly funded entity;

• In all our sector strategies we consider:
  • Productivity +
  • Environmental sustainability +
  • Attributes +
  • Threats to the value chain;

• It is important that we:
  • Ensure results of a national program reach all regions where the crop is significant
  • Reflect an emphasis on the “public good” (e.g. sustainability, adaptation to climate change)
  • Work collaboratively and appropriately distribute risks between the public and private sectors
## The four phases along the breeding continuum

<table>
<thead>
<tr>
<th>Phases</th>
<th>Steps in breeding continuum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Precursors to breeding</strong></td>
<td>Training in plant breeding&lt;br&gt;Germplasm Collections and Maintenance</td>
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<tr>
<td><strong>2. Genetic research</strong></td>
<td>Dev. of new knowledge and enabling tools for crop improvement (genomics, inheritance, genotyping, phenotyping, DH etc.)</td>
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<td><strong>3. Germplasm development</strong></td>
<td>Identification and characterisation of new traits&lt;br&gt;Germplasm enhancement for new traits, development of early generation material (pre-breed)</td>
</tr>
<tr>
<td><strong>4. Cultivar development</strong></td>
<td>Finishing cultivars and evaluation trials for adaptation&lt;br&gt;Licensing and release of genetic material&lt;br&gt;Commercialization, distribution of cultivars, and adoption</td>
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</tbody>
</table>
Who are the key players along the value chain breeding continuum?

- **Genetic research & germplasm development**
- **AAFC**
  - Collection of germplasm
- **Universities**
  - Education of HQP
- **Private breeders**
  - Enhanced germplasm to include in Elite cultivars
- **Seed distributors & nurseries**
  - Improved cultivars
- **Farmers**
  - Reduced fertilizers and pesticides
  - Adaptation to climate change
  - Emerging crops
- **Food processors**
  - Improved processing quality
  - Attributes and safety
- **End-users**
  - Commodity/Partnership levy
  - Research priorities
  - Public good & knowledge
  - Accelerated adoption
- **Consumers**
  - Improved food security and quality
  - Local food, reduced imports
# An apple research and innovation capacity map

<table>
<thead>
<tr>
<th>Performer</th>
<th>BC</th>
<th>Prairies</th>
<th>ON</th>
<th>QC</th>
<th>Maritimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAFC</td>
<td><em>Summerland</em> - Breeding</td>
<td></td>
<td>Harrow - Canadian Clonal Genebank</td>
<td></td>
<td>Kentville</td>
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<tr>
<td><strong>Germplasm</strong></td>
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<tr>
<td><strong>Development and Genomics</strong></td>
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<td>Universities</td>
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<tr>
<td><strong>Provinces</strong></td>
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<tr>
<td>Private Sector</td>
<td></td>
<td></td>
<td>VRIC - start breeding and applied genomics</td>
<td>Les pommes de demain</td>
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<tr>
<td><strong>Variety Evaluation &amp; Finishing</strong></td>
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<td>AAFC</td>
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<td>Kentville</td>
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<tr>
<td>Universities</td>
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<tr>
<td>Private Sector</td>
<td>SVC licencing</td>
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<td>VRIC - scouting of new varieties</td>
<td>RECUPOM</td>
<td>NS Fruit Grower’s Association</td>
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<tr>
<td><strong>Production Protection &amp; Post-Harvest</strong></td>
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<tr>
<td>Universities</td>
<td><em>U. of BC</em>: Biocontrol for postharvest diseases</td>
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<td>Guelph</td>
<td>Western U.: IPM&amp;genomics</td>
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<td><strong>Provinces</strong></td>
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<tr>
<td>Private Sector</td>
<td></td>
<td></td>
<td>OMAF/MRA: post-harvest, Invasive pest (BMSB)</td>
<td>IRDA: DT in IPM</td>
<td>Advisory clubs, CRAAQ: extension</td>
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## A National Apple Innovation System

### Area of work

<table>
<thead>
<tr>
<th>Innovation continuum</th>
<th>Research</th>
<th>Development</th>
<th>Technology transfer</th>
<th>Extension</th>
<th>Commercialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Germplasm Development and Genetics</strong></td>
<td>AAFC Harrow: Canadian Clonal Genebank; AAFC Kentville: Apple Biodiversity Collection; AAFC Summerland: breeding</td>
<td>Dalhousie U.: Apple Genomics</td>
<td>SVC (BC): licensing; RECPOM (QC), OAG/VRIC (ON), NSFGA/SG (NS)</td>
<td>Provinces: CHC (BCFGA, OAG, FPPQ, NSFGA etc.), advisory clubs, Annual meetings, field demonstrations etc.</td>
<td>Industry stakeholders</td>
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<tr>
<td><strong>Variety Evaluation and Finishing</strong></td>
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### Colour Legend
- National public
- Regional public
- Sector organisations
Some inspiring models

• An international consortium (2011-2015) EU-funded
  • 24 participants (4 outside EU)
  • To bridge the gap between genomics and fruit breeding

http://www.fruitbreedomics.com/
a USDA-SCRI awarded project
- RosBREED (2009-2014) $14M
- RosBREED2 (2014-2019) $10M
- A national team of 35 scientists

14 U.S. universities and agencies
- Combining Disease Resistance with Horticultural Quality delivering new CVs in 22 U.S. breeding programs

Crop | Common Name
---|---
apples | apple scab, fire blight, and blue mold
pears | fire blight
peaches | brown rot, bacterial spot, and Armillaria root rot
sweet cherries | powdery mildew
tart cherries | cherry leaf spot
strawberries | angular leaf spot and root and crown rots
roses | black spot

National Apple Breeding Framework

Monday 29 February 2016
OUR BUSINESS

- Budwood Orchard
- Variety Rights Management
- Variety Development
  - Grower Testing
  - Commercialization
- Extension Services
- Research and Development
A Vineland Approach

Consumers matter

- Sensory analysis
- Consumer likes-dislikes
- Stakeholders

Apple Breeding

- Parent selection
- DNA markers
- Quality
- Performance
- Disease Resistance

On-farm testing
- Business model
- Marketing
- Consumer testing

Cultivar release

Consumer Preference
• Mission – Sean Myles
  – To develop genomics tools to accelerate food improvement
  – To gain fundamental insights into plant biology

• Nature of work
  – Genetic mapping
  – DNA sequencing and analysis
  – High-throughput phenotyping
An integrated apple breeding program

- A single program
- Stage 1 at 2 sites (Summerland, VRIC)
  - Complete sharing of genetic material
- SVC as agent of commercialization
- Pre-breeding work depending on trait
  - e.g. powdery mildew in Summerland, apple scab at VRIC
- Genomic, genome editing work at Dalhousie U./VRIC
- Stage 2 in multiple sites (how many? for GxE)
  - Site with technical expertise and method standardization
  - e.g. RECUPOM, Kentville
- IP framework is required
- Need to be endorsed and transparent to growers associations
- Goal is international in scope for sustainability
Funding models

• AAFC: A-base (Vote 1), GF3 (Vote 1/10), Genomic RD Initiative (Vote 1-interdepartmental)

• Universities: NSERC, research Chairs, CFI (Canada Foundation Innovation), Genome Canada (Vote 10)

• Genome Canada: GAPP (Genomic Application Partnership Program), GIN (Genomic Innovation Network), regional genome center programs

• Industry stakeholders*: provincial sources, cash, commercialization revenues, levy/check-off, Industrial Research Assistance Program (IRAP)

• Coordinated funding strategy

* Producers associations, food processors, SVC, VRIC, marketers, retailers, nurseries (possibility to have a consortium ?)
Thank you!

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