Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

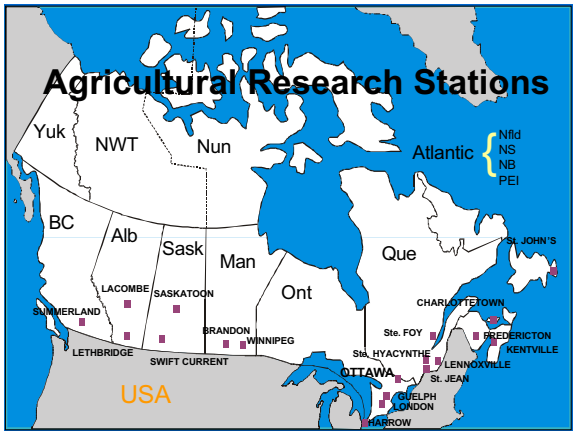
Soybean for Food and Feed

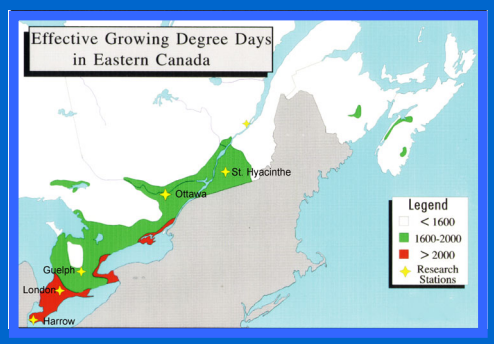
Dr. Malcolm Morrison,
Eastern Cereal and Oilseed Research Centre
Agriculture and Agri-Food Canada

Canada

Comparative Statistics

Item	Canada	Australia	Units
Land	9.98	7.68	km^2
Arable land	498,000	461,000	km^2
Population	32	19	million
Sheep	<2	119	million
Cattle	13.0	27.7	million
Hog	13.3	2.8	million
Poultry	1,092	662	kt
Soybean	1,059	33	000 ha
	2.5	2.1	t/ha
	2,699	70.4	000 t



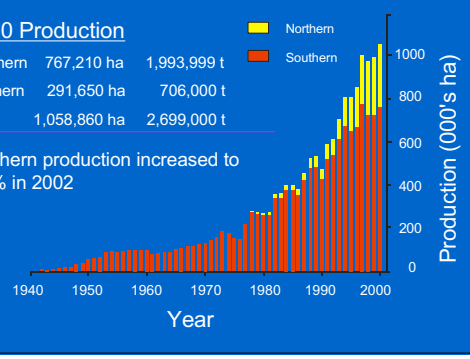


Soybean Production In Canada

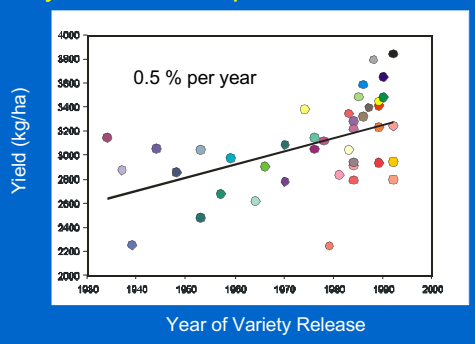
2000 Production

Southern	767,210 ha	1,993,999 t
Northern	291,650 ha	706,000 t
Total	1,058,860 ha	2,699,000 t

Northern production increased to 31 % in 2002

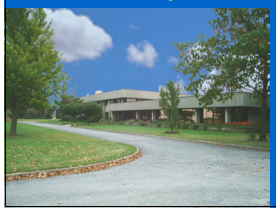


Soybean Yield Improvement in Canada



AAFC Research Centre, Harrow, Ont Southern Adaptation

Soybean Breeding	Vaino Poysa
Pathology	Terry Anderson
Soybean Cyst Nematode	Tom Welacky
Seed Quality	Lorna Woodrow



Breeding high yielding, white hilum, large seeded Tofu varieties.

Performance of Recent Tofu Lines

Cultivar	Yield (t/ha)	Maturity (days)	Seed Weight (g 100^{-1})	Seed Protein %	Seed Oil %	Seed Sugar %
Harovinton	3.67	114	27.6	47.6	18.5	10.3
AC Hime	3.87	114	26.7	46.1	18.4	10.7
AC X790P	3.77	115	27.6	48.6	18.4	10.2
AC Vin-Pro	3.84	113	26.4	46.4	19.5	10.7

Soymilk and Tofu Yield of Recent Lines.

	Harovinton	AC Hime	AC X790P	AC Vin-Pro
Soymilk				
Yield (L/kg beans)	7.5	7.3	7.8	7.3
Solid content (%)	9.9	10.1	9.6	10.3
Tofu ($CaSO_4$)				
Yield (kg kg^{-1})	6.3	6.0	6.5	6.1
Hardness (N)	1.6	1.3	1.7	1.4
Firmness (Newtons/mm)	0.3	0.2	0.3	0.3

AAFC Research Centre, Ottawa, Northern Adaptation

- Short Season Adaptation
  - Disease and Stress Resistance
  - Increasing the Zone of Adaptation
- Breeding for Feed and Food:
  - High Protein for food and feed
  - Natto,
  - Short Season Tofu

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Oilseed/Feed Soybean Breeding:

Short-season cultivars: (<2700 CHU)

- Develop cultivars with high yield, appropriate maturity, lodging resistance, and acceptable oil and protein.
- Develop cultivars with high seed protein content for on-farm feeding.
- Develop cultivars with white mold and phytophthora root rot tolerance and SCN resistance.
- Expand the range of cultivation and provide producers with an alternative livestock feed and cash crop.

Food-Grade Soybean Breeding

Natto Breeding:

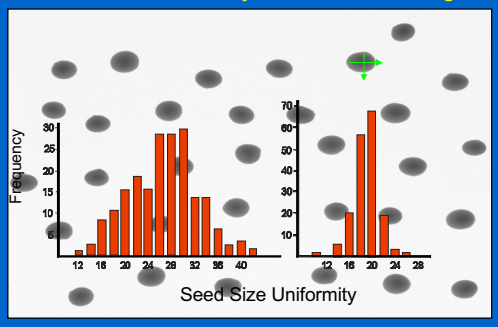
- Early lines came from small seeded crosses with high protein wild types.
- Nattawa, 1981, first Canadian variety.
- Lines selected to eliminate stone seed; for seed size and shape; water uptake, natto texture.
- Provide additional markets for soybean producers

Food-Grade Soybean Breeding

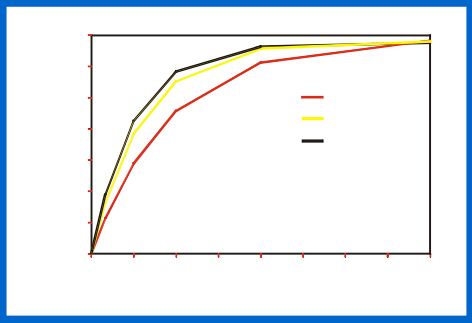
Short-Season Tofu Breeding:

- Crosses with Japanese Tofu types and high protein short-season parents, 1995
- Backcrossing to improve adaptation and agronomy
- Selection for Tofu quality, and texture.
- Provide additional markets for soybean producers

Image Analysis is used to Select for Seed Size Uniformity in Natto Breeding.



Water Uptake Rate 1999-2000

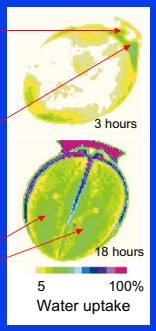


Water Uptake Rate 1999-2000

Variety	Time to 50% uptake (Min)	%Hard Seed (24 hrs)
Natto		
AC COLIBRI	125	0.1
AC PINSON	130	0.0
MICRON	132	0.0
FAUCON	132	0.1
HERON	152	0.2
ELECTRON	158	0.6
CANATTO	192	23.7
X3555-B-B-15	129	0.0
X3604-B-B-11-5	148	0.0

MRI Images of Water Uptake

- Magnetic Resonance Imaging (MRI) captures water movement into the seed through the micropile.
- Mucilage surrounding the rootlet rapidly expands
- Initially, water content is highest near the tip of the rootlet and the space between the cotyledon and the seed coat.
- Water moves from the rootlet through the vascular system of the cotyledon.



Specialty Soybean Trial

Mean from 13 locations, 1999 and 2000.

Variety	Yield Kg/ha	Seed Wt g/100	Protein %	Oil %	Sucrose	Stach Raff (%)
High Protein						
AC HERCULE	2758	19.0	46.3	18.8	4.5	4.4
AC PROTEINA	2839	16.5	46.7	18.0	4.3	4.5
RD714	3103	20.3	48.8	17.2	4.6	3.9
Natto						
AC COLIBRI	2042	7.5	40.0	19.8	6.0	4.7
AC PINSON	2215	7.4	40.7	19.7	5.4	4.6
MICRON	2434	7.5	39.8	20.1	6.2	4.5
FAUCON	2134	7.2	41.8	19.0	5.9	4.5
HERON	2629	7.7	40.9	20.7	5.4	4.0
ELECTRON	2569	8.2	44.8	18.6	4.7	4.6
Tofu						
KAMICHIS	2946	19.7	46.8	18.0		
OHGATA	2931	26.0	43.7	19.8		

Recent Varieties

Electron Faucon Heron

Future Soybean Breeding for Food Quality Traits, North and South

- High protein, yellow hilum.
- High sugar content.
- Low linolenic Acid content improved soymilk flavor and stability
- Lipoxygenase triple null lines for better soymilk taste
- A4 null lines Nigari tofu
- Edamame types

Soybean Quality

- Quantify seed quality characteristics for soy-food products (take the *art* out of soyfood making)
- Develop fast, reliable, and inexpensive screening tools for quality characteristics, ensuring variety suitability for end-users.

Dr. J. Frégeau-Reid
FregeauJA@agr.gc.ca

Quality Traits & Tools: Seeds

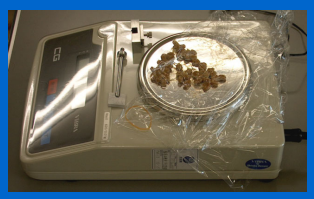
- Size — fi Image Analysis
- Color — fi Colorimeter (Hunter Lab)
- Protein content — fi NIR whole grain
- Soluble sugar content — fi Megazyme protocol
- Protein quality (specialty soybean) — fi Electrophoresis (A_4 null) & lipoxygenase
- Water uptake — fi Total uptake
- Rate of water uptake — fi Uptake at $T_{0.5}$
- Water Holding capacity — fi Carver press

Taking the *art* out of Natto making

Natto soybean quality testing in Japan involves slicing 20 steamed and fermented natto soybean on a balance with a knife and recording the combined weight.

The results are dependent on the technicians skill and experience.

We have very little experience making or eating natto in Canada.



Natto Quality Characteristics

Potential natto lines tested for texture in the Instron Analyser following 30 minutes of steaming in an autoclave (120 psi).

Maximum Load in Newtons

	94-95	2000
Minnatto		161
Ibaragi	147	
Hartz	125	
Micron	118	128
Suzumaru	117	
Hokkaido	111	
AC Colibri	107	125
AC Pinson		117
Faucon		121
Electron		114
Heron		127

The test is mechanized, standardized and repeatable.

Protocol for Soymilk and Tofu

- Use of constant protein: water ratio of 18:1 to emphasize protein quality, not quantity.
- Tofu is silken.
- GDL, and $CaSO_4$
- NIR Analyzer to evaluate soymilk composition.
- Colourimeter for soymilk and tofu colour.
- Instron Texture Measuring System for tofu firmness.

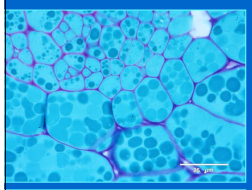
Mullen,W.J and J.E. Frégeau-Reid et al. 2001 Food Research International 34:669-677

Test Tube Tofu for Early Generation Selection

- Protein content on whole seeds, NIR
- 10 to 20g of seeds soaked for 22hrs at 13°C
- Soymilk = 18:1 water to dry matter protein (soymilk protein conc. 4% to 5%).
- Tofu Yield measured on DW basis after centrifugation.
- 20 lines/day/tech; duplicate readings and 2 coagulants (GDL and $CaSO_4$).

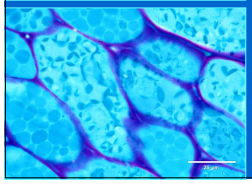
Microscopy

Dr. S Miller



OX951 – Normal seed

-protein bodies well developed and absorb stain.



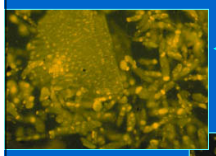
OX951 – Stone seed

-protein bodies in some cells fragmented and miss-shapened
-variable staining of protein bodies

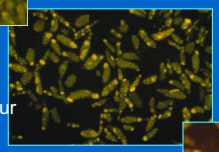
Microscopy

Miso Structure

Dr. J. Mullin



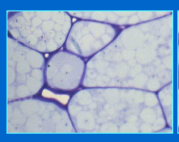
Experimental miso
-granular texture
-less complex flavour

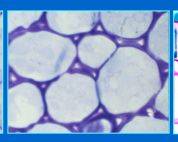


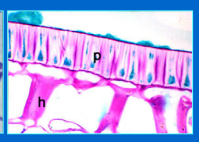
Commercial miso
-smoother texture
-more complex flavour

Commercial miso
-aged longer
-more free and oxidised lipids (flavour development)

Microscopy and Carbohydrate Analysis







Ontario Japanese Seed Coat

- Survey of several Ontario and Japanese varieties showed differences in cell wall thickness.
- Japanese varieties have lower levels of xylan hemicellulose in the palisade layer of the seed coat, resulting in better water uptake.

VALUE-ADDED TECHNOLOGIES

Dr. F. W. Collins

Separation Technology:

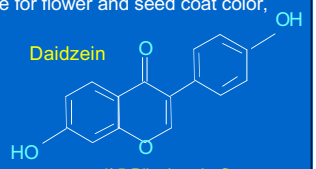
- Develop new methods to extract natural compounds from soybean.

Use of "Designer Gels", organic solvents and patented extraction techniques for the purification of isoflavones and soyasaponins

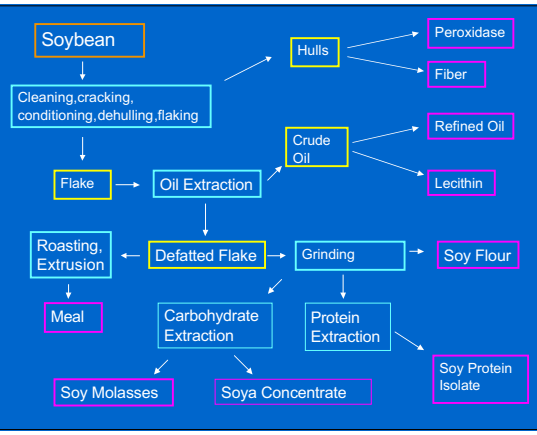
Isoflavones: Properties

- USA FDA claim: Diets low in fat that include 25 g of soyprotein per day may reduce the risk of heart disease.
- 1 cup of soymilk = 8 grams of soyprotein ~ 100 to 200 mg of total isoflavones -- antioxidants, free radical scavengers, LDL oxidants, anti-carcinogenic, plant estrogens: daidzein and genistein.
- Compounds responsible for flower and seed coat color, mitosis, nodulation.

	U$/g
Daidzein	71
Genistein	75
Soyasaponin B_b	???

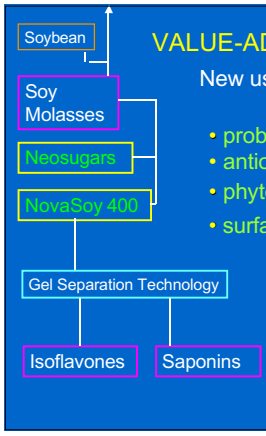


4',5-Dihydroxyisoflavone

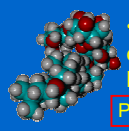


VALUE-ADDED TECHNOLOGIES

New uses for soy isolates.



- probiotic sugars, raffinose, stachiose
- antioxidants: food ingredients
- phytoestrogen therapy
- surfactants: personal care



- therapeutic compounds for kidney disease

PKD Treatment

Soyasaponin B_b

Physiology, Ottawa

Plant characteristics that promote stress tolerance and ensure high yield, seed quality and marketability.

Grey Tawny

Tawny

I, T =

i, T =

i-j, T =

Grey

I, t =

i, t =

i-j

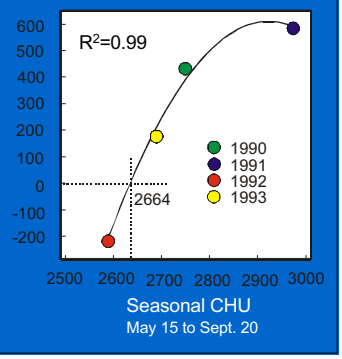
, t =

Grey – Tawny Yield (kg/ha) Differential

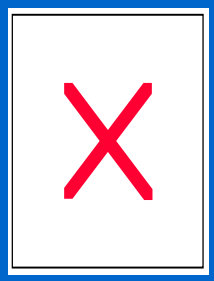
8 sets of F2-derived isolines with either tawny (T) or grey (t) pubescence.

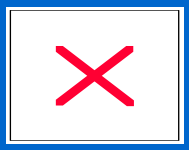
Grey lines yield more then tawny lines in warm years (>2664).
But in cold years Tawny yields more then grey.
WHY?

Conclusion: Grow Tawny lines with white hilum and seed coat.



Canopy Temperature Differences Between Grey and Tawny Colored Pubescence





Infrared sensors
Three replications
Tawny and grey isolines
Two years data.

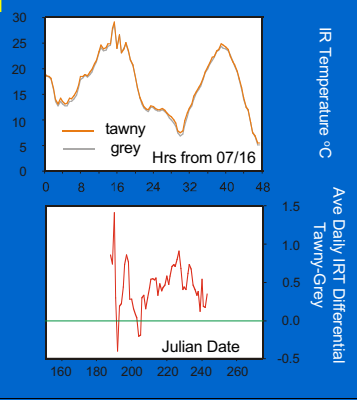
Results from 2001 Field Season IR Thermometer.

Average daily IRT differential 2001 = 0.43°C.

Two year ave = 0.37 °C

In warm years, tawny matures 6 to 10 days sooner than grey.

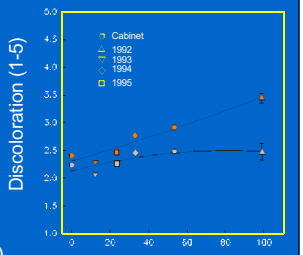
Grow tawny varieties BUT



Seed Coat Discoloration

Grey Tawny

Temperature <15°C during seed development (R4 to R6) increase the expression of pigment in the seed coat in tawny lines.



Pubescence Color and Seed Coat Discoloration

Summary:
Tawny colored lines perform better in cool regions (<2600 CHU) because of warmer canopies (0.37C)

But, Tawny colored lines with yellow seed coat and hila discolor with cool temperatures (<15C) during seed development.

Solution: ??? (i) Convince the buyers that discoloration does not matter. (ii) Grow grey lines and accept the yield loss. (iii) Find a new way to shut of seed pigment production.

High Protein Soybean

Objective: determine the physiological differences among closely related lines differing in seed protein content.

Goal: produce lines with high yield and protein.

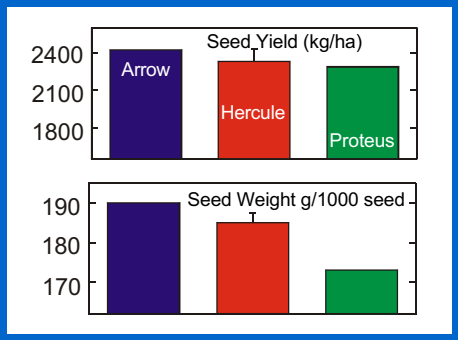
Maple Arrow = normal protein (40%).

Hercule = medium high protein (45%).

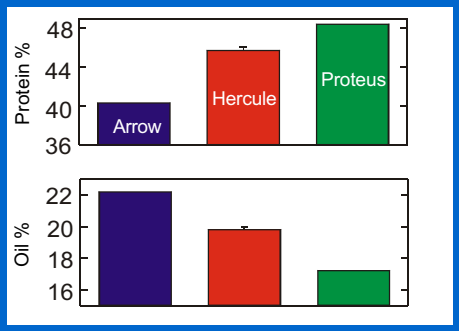
AC Proteus = high protein (48%).

Lines grown for 4 years; 4 replications per year; standard growth analysis techniques, LAI; photosynthesis and SPAD; seed combine harvested and NIR used for protein and oil analysis;

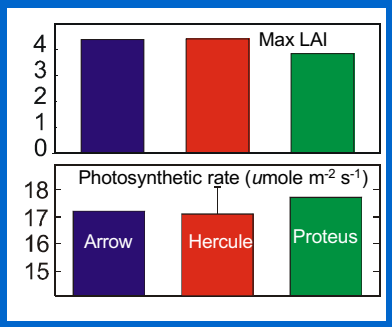
High Protein Soybean



High Protein Soybean

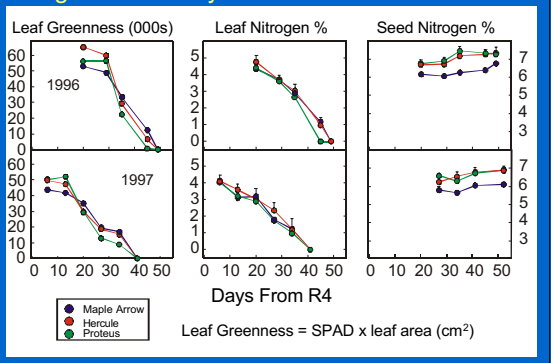


High Protein Soybean



No Significant differences among cultivars for max LAI or photosynthetic rates (ave of 3 readings; V3, R1 and R4 and two years).

High Protein Soybean



High Protein Soybean: Summary

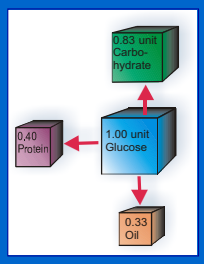
- High seed protein is associated with lower total seed yield. Physical reasons hard to find.
- In the high protein lines the demand for protein causes a rapid canopy senescence -- resulting in less photosynthate being produced towards the end of seed filling and lower yield.
- Protein occupies less storage space then oil, high protein seeds are smaller, with lower yield.

Soybean for Food and Feed: Summary

- Southern region concentrates on food-type soybeans for soymilk and tofu.
- Northern region breeds for Food, (natto and tofu), Feed (high protein) and oilseed types.
- Breeding is supported by Quality, Physiology, Pathology Genetics and Value Added Research Programs.
- Goal: to develop varieties and practices that result in a soybean product of consistent end-use quality for domestic use and export.

High Protein Soybean

Yield Composition and Glucose units



	Maple Arrow	AC Hercule	AC Proteus
		Grams m-2	
Yield	243	233	229
Protein	98	107	111
Oil	54	46	40
M.F.A	41	40	39
Carbo	50	40	39
		Glucose units	
Protein	245	267	277
Oil	164	140	120
Carbo	60	48	47
Total	469	455	446

Bahtai and Rabson, 1976, Science 19:1418.

Arrow significantly greater than Proteus

Isoflavones: Health claims

- USA FDA claim: Diets low in fat that include 25 g of soyprotein per day may reduce the risk of heart disease.
- 1 cup of soymilk = 8 grams of soyprotein ~ 100 to 200 mg of total isoflavones.
- In the US only 20% of post-menopausal women prescribed estrogen replacement therapy actively use it.

Why? Fear of breast cancer and associated health risks.

- There are two estrogen receptors in the body. ER alpha and ER beta. Genistein and Daidzein conform 80% to ER beta, 20% to ER alpha. Effectiveness of soy-protein depends on the estrogen receptor.
- http://www.nal.usda.gov/fnic/foodcomp/Data/isoflav/isoflav.html

Isoflavones:
Summary of 30 years of study on the consumption of soyprotein isolate in primates

Dr. T.B. Clarkson, Wake Forest U.

Brain Function: improves cognition, memory.

Hot Flashes: only moderate decrease

Cardiovascular: indirect effect due to reduction in fat. Increase in Apo A1 and lipoprotein profile. Reduction in LDL cholesterol. Reduce risk of stroke.

Cancer: may decrease estrogen induced cell proliferation and reduce breast and endometrial cancer

Osteoporosis: No direct effect on humans