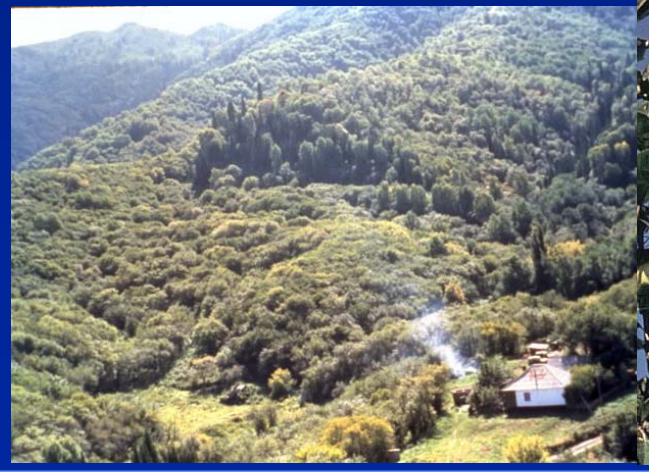
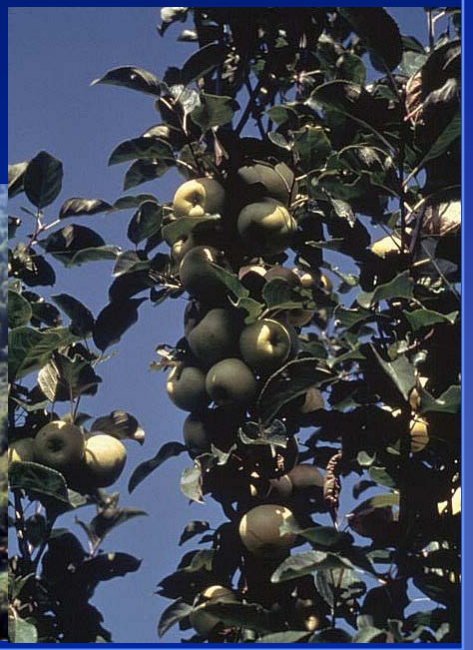
The REAL Origin of the Apple

"Genetic Treasures from Apple's Ancestral Home"

Phil Forsline, Horticulturist and Retired Fruit Crops Curator, USDA-ARS, Plant Genetic Resources Unit (PGRU), Cornell University, Geneva, NY

HOS-NAFEX-CRFG Conference: August 6, 2014



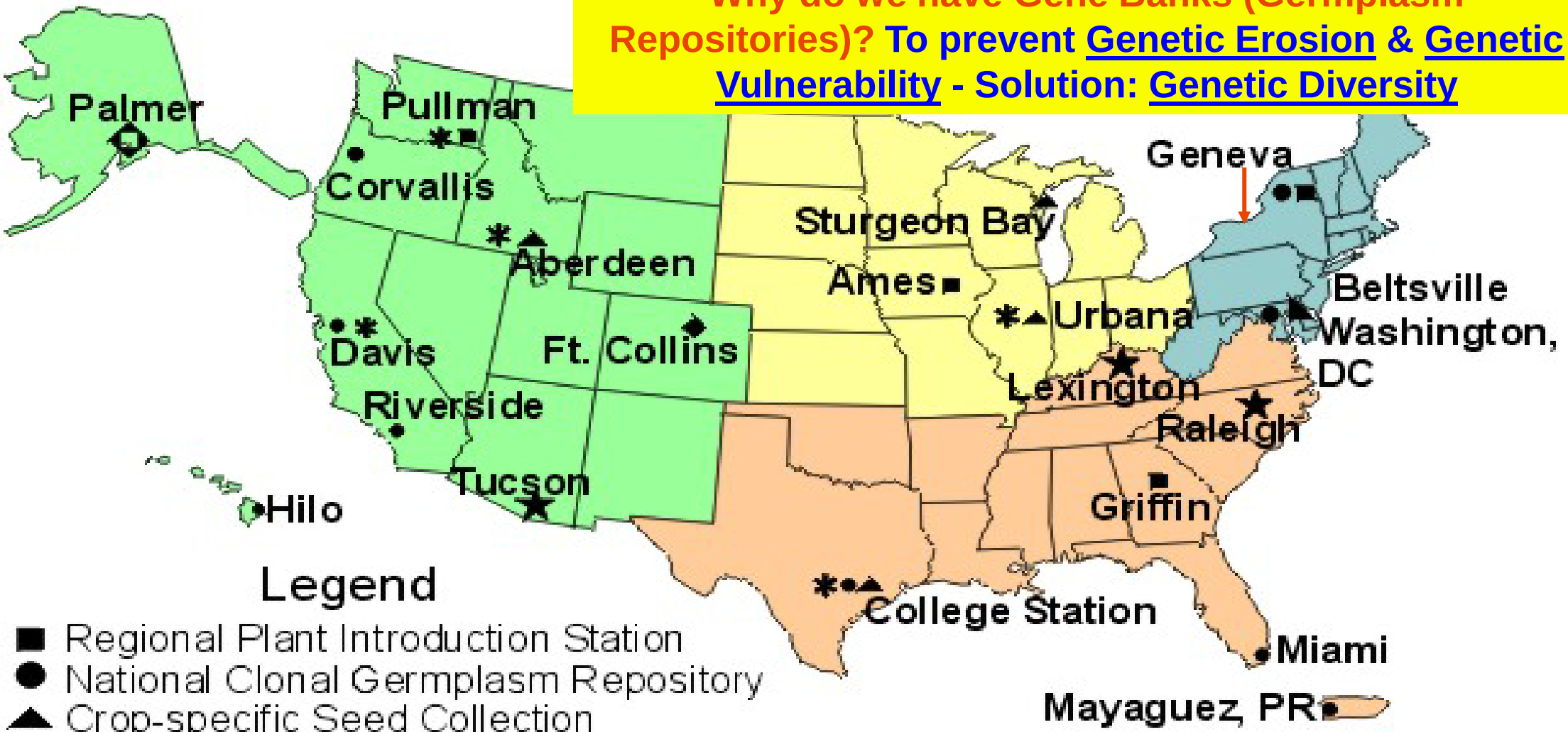
Plant Genetic Resources Unit (PGRU) located at Cornell University, Geneva, New York

Cornell's New York State Agric. Expt. Station Established in 1882

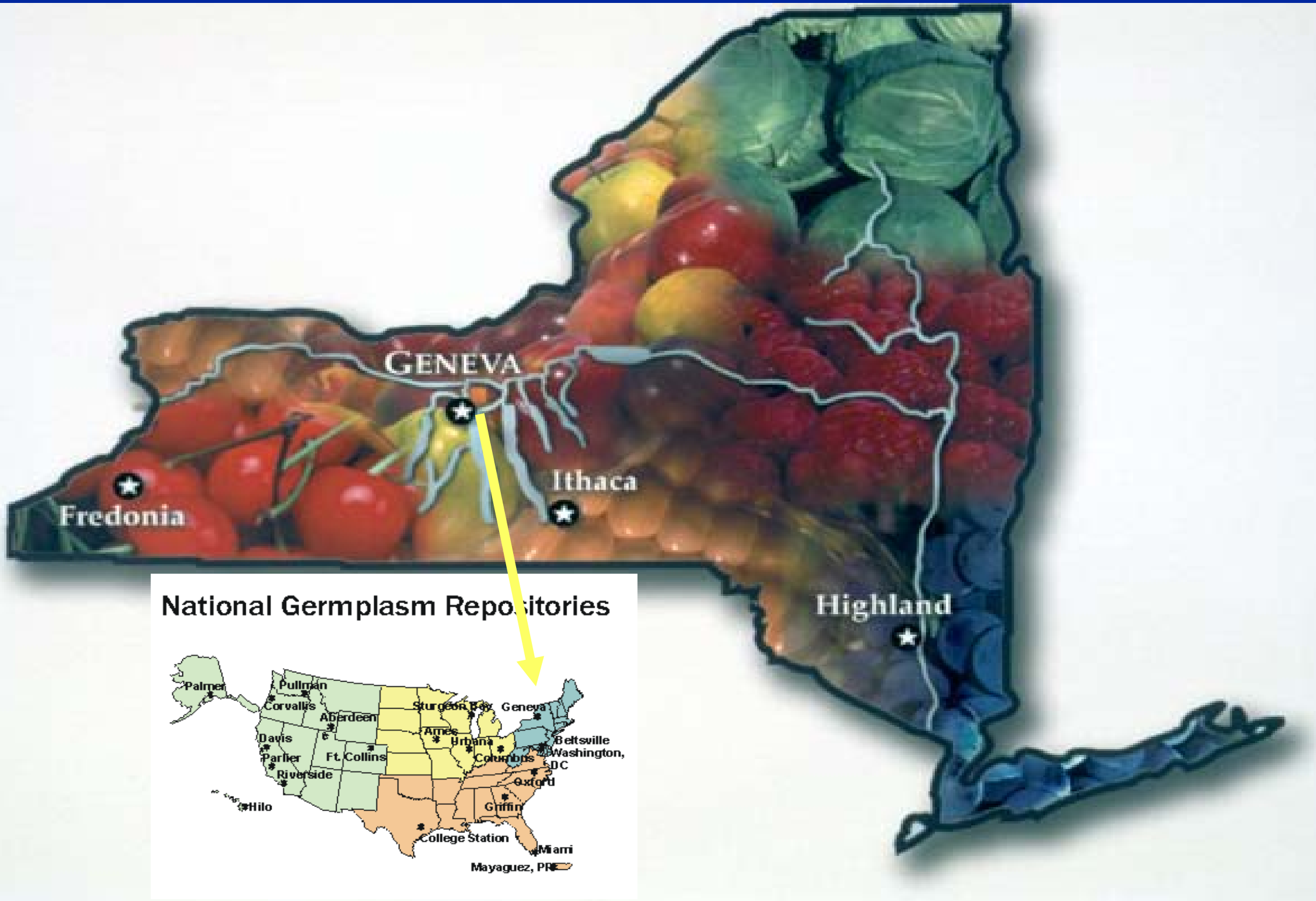
USDA Plant Genetic Resources Unit - Office, Lab, Greenhouse Facility

National Germplasm Repositories

Why do we have Gene Banks (Germplasm Repositories)? To prevent Genetic Erosion & Genetic Vulnerability - Solution: Genetic Diversity



Geneva – Vegetable crops Gene Bank started in 1950's & expanded adding fruit crops Gene Bank in early 1980's


GENEVA
Ithaca
Fredonia
Highland
National Germplasm Repositories
Palmer
Pullman
Corvallis
Aberdeen
Davis
Parlier
Ft. Collins
Riverside
Hilo
Sturgeon Bay
Ames
Urbana
Columbus
Geneva
Beltsville
Washington, DC
Oxford
Griffin
College Station
Miami
Mayaguez, PR

The Finger Lakes – Cayuga Lake as seen from Cornell campus in Ithaca, NY "High above Cayuga's Waters" as the Cornell song begins

USDA-ARS, Geneva, NY is composed of:

Total staff of 40+

A) Plant Genetic Resources Unit – A unit of the National Plant Germplasm System

- Three Research/Service Projects (6 scientists)

1) *Conservation and utilization of the genetic resources of apples, grapes and tart cherries*
2) *Conservation & utilization of germplasm of selected vegetable crops.*
3) *Development of pest, disease resistance, and stress tolerance in apple rootstocks*

B) Grape Genetic Research Unit

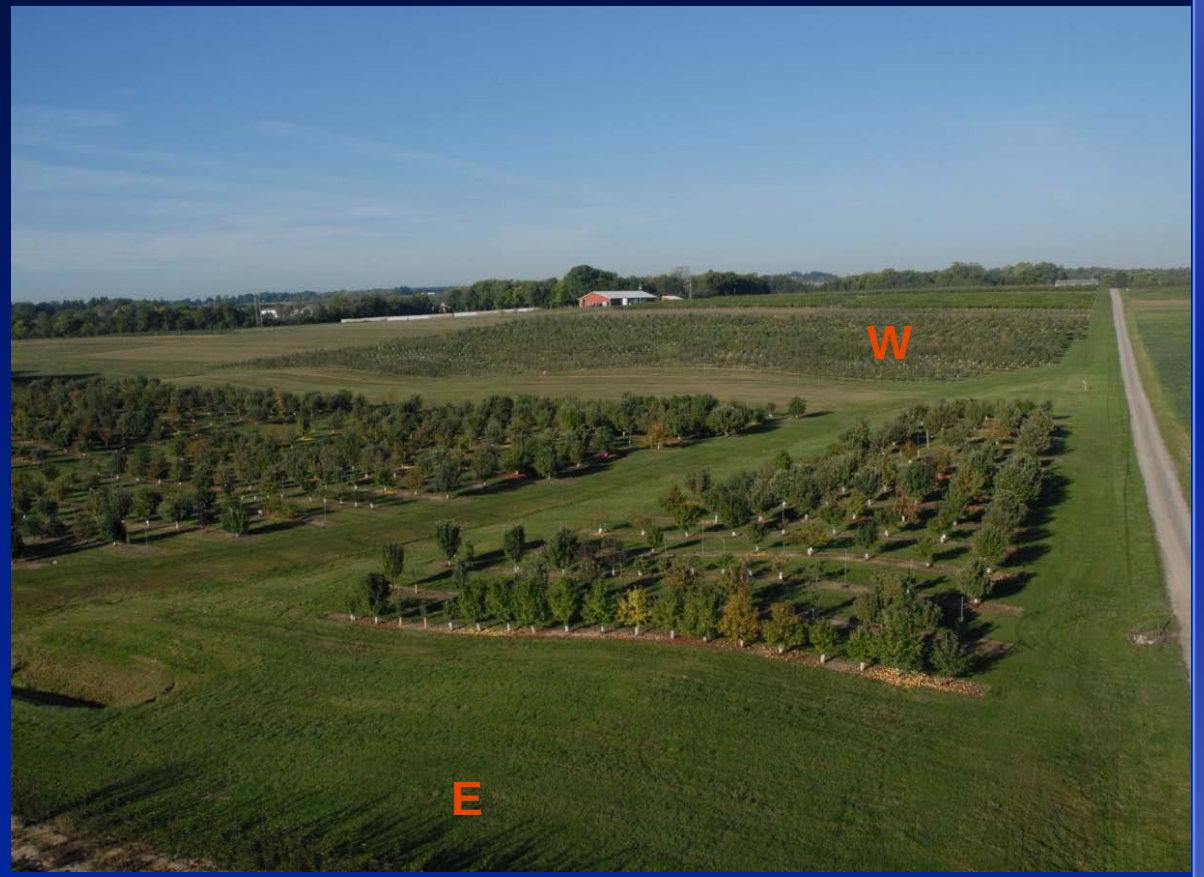
- Two Research Projects (5 scientists)

1) *Genetics and genomics of grape growth, development, and quality*
2) *Genetics and genomics of grape-pathogen interactions*

PGRU 50 Acre Farm Development

1985

2007



One mile north of the New York State Agricultural Experiment Station

Vegetatively-propagated germplasm (1,2,3) collections at PGRU – fall colors, October 2006 'Clonal Repository'

Prunus **- Sour Cherry - 120 accessions**

Vitis **- Grape - 1164 clonal accessions (own rooted) 40 seedlots from wild and 275 wild *Vitis* seedlings**

Malus **- Apple - 8500 accessions total - 2700 clones (grafted varieties) and wild seed lots as well as wild seedlings and hybrid seedlings**

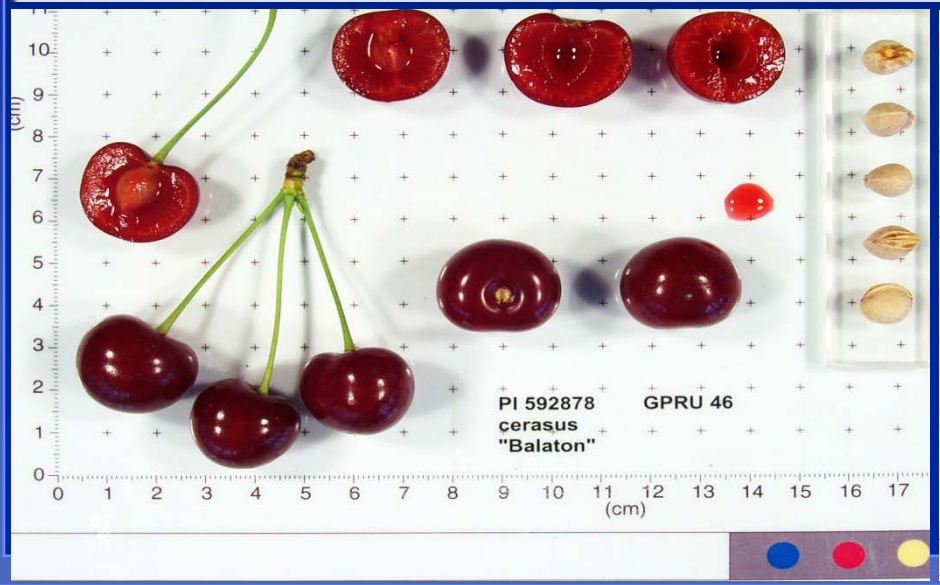
Apple trees originating from seed

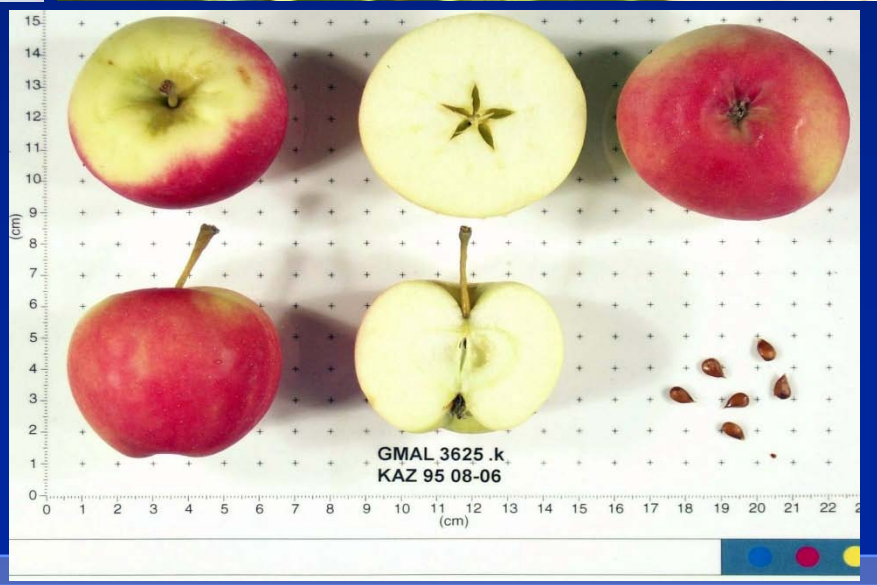
3300 wild *Malus* seedlings from 360 populations: Kazakhstan, Russia, China, Turkey, Armenia, Georgia & Germany

Digital imaging of fruit samples – loaded to 'GRIN' web site:

http://www.ars-grin.gov/npgs/searchgrin.html

'Vignoles'
PI 181481





Seedling of *M. sieversii* from Kazakhstan

Acquisition, Maintenance and Distribution of Apple Collection

Apple (*Malus*) collection at Plant Genetic Resources Unit Geneva, NY, U.S.A.

Consisting of:

- **2700 clones (varieties) - all maintained as duplicate field plantings**

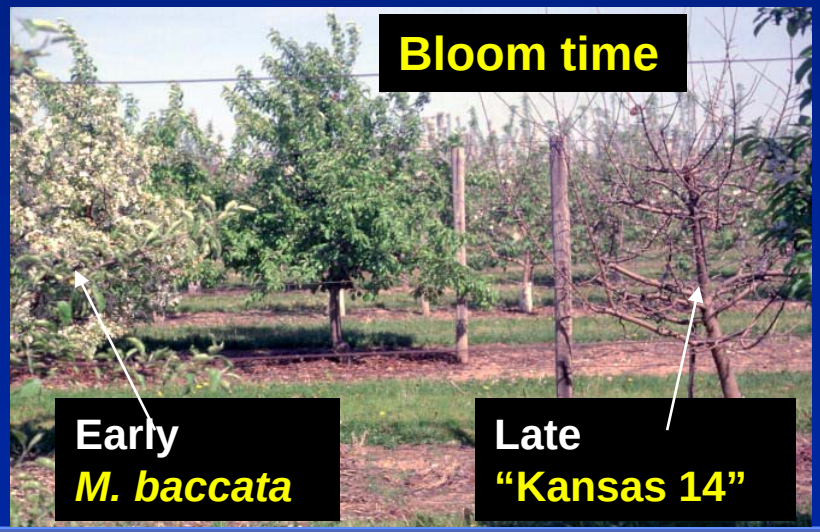
- **1500 accessions of wild *Malus* species (stored as seed) from world centers of origin; 977 of wild acc. are *Malus sieversii* from Central Asia**

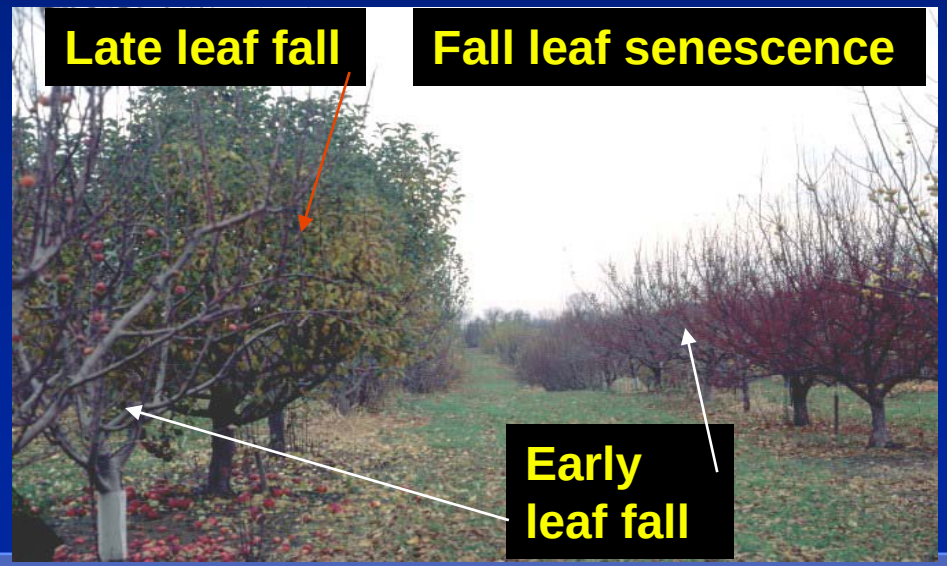
- **3300 seedlings under evaluation from 360 of wild apple seed packets**

- **1335 seedlings (hybrid populations – 'Gala' x *Malus sieversii*)**

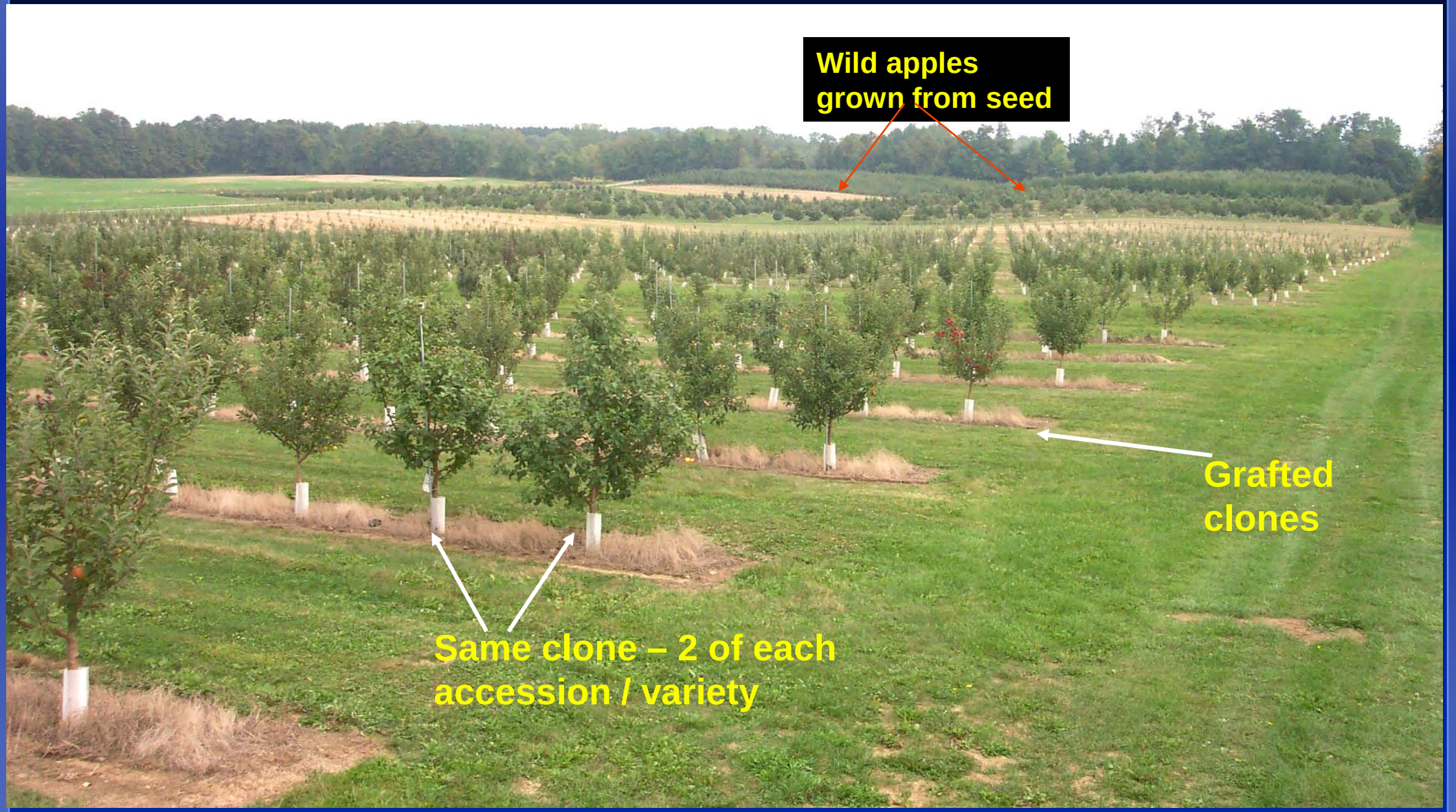
- **A total of approximately 8500 accessions**
  - **detailed records of all on 'GRIN' web site**

Diversity in *Malus*





PGRU field collection in 2005



Cryopreservation of *Malus*

A back up collection at $1.50/accession/yr!

Collection maintained in liquid nitrogen tanks in Ft. Collins, CO (National Center for Genetic Resources Preservation)

Processing 1 inch bud segments

Liquid nitrogen (-196 °C) tank at PGRU Geneva, NY

Recovery of accessions by bud grafting

Hundreds of seedlings budded with cryopreserved buds testing viability

New Acquisitions

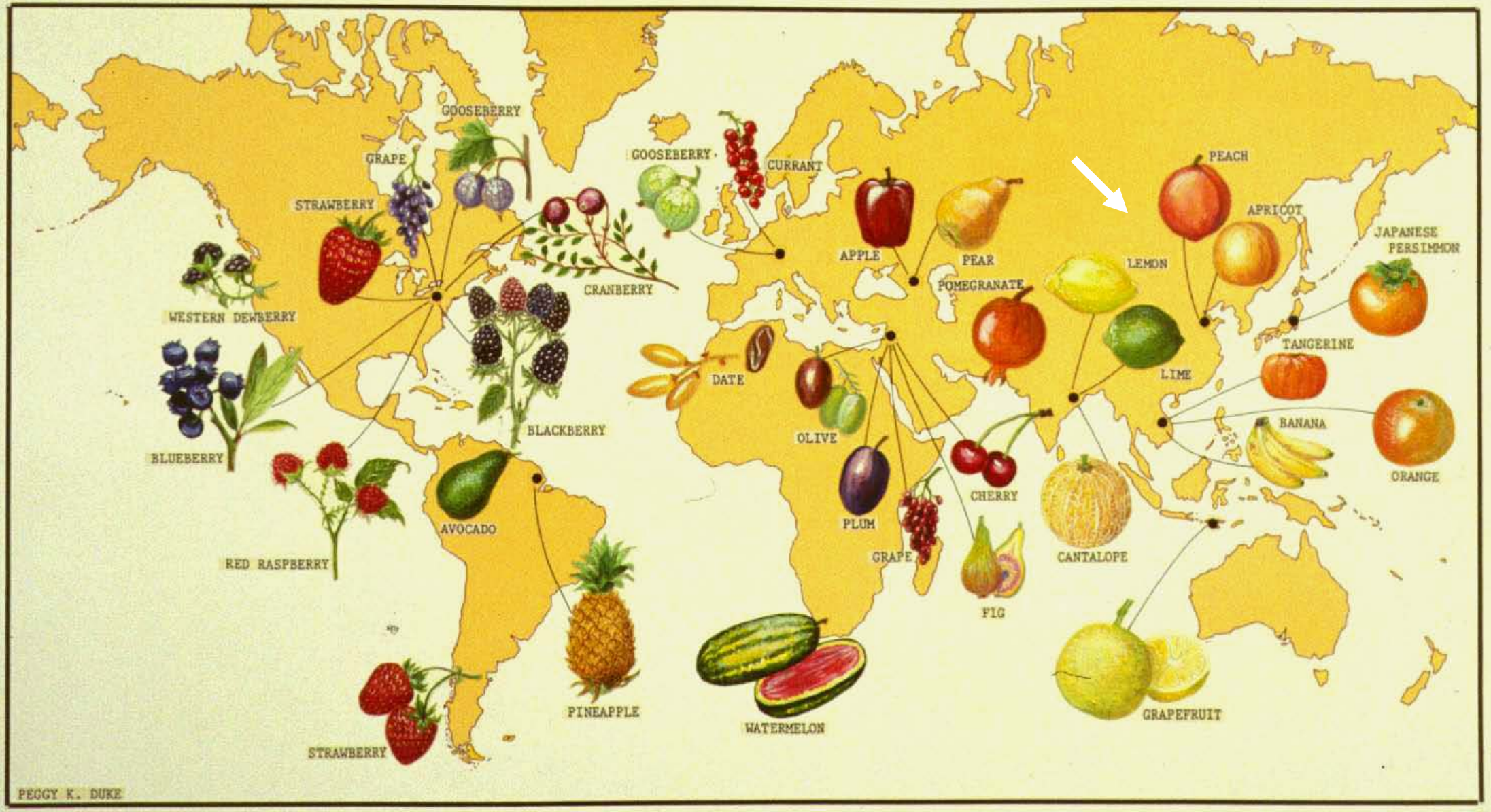
From Alma Ata, Kazakhstan

- *Alma Ata = ‘Father of the Apple’*

Renamed ‘Almaty’ after fall of USSR

To Geneva, New York

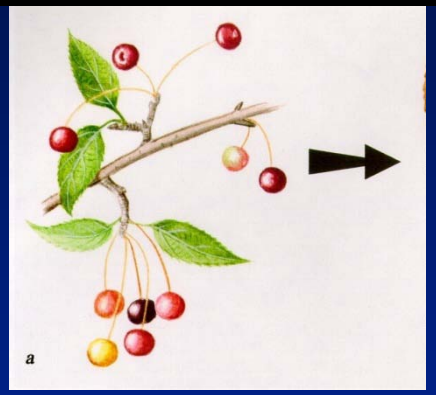
- *Geneva = ‘Mother of the Apple’*



CENTERS OF ORIGIN FOR SOME FRUITS

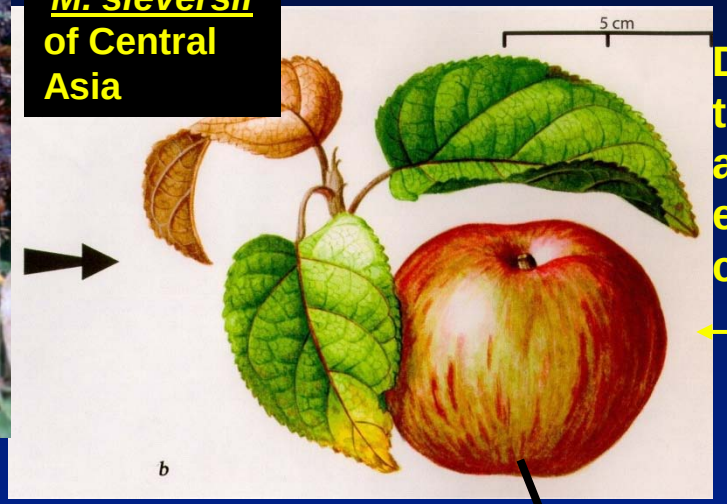
The Origin of the Cultivated Apple

Ancient *Malus* species of China: bird disseminated to Central Asia



Mammal disseminated

M. sieversii of Central Asia



Dr. B. Juniper: theory on early and recent evolution of the cultivated apple

North America became a secondary center of origin: "Red Delicious", "Golden, Delicious", "Jonathan", etc.

Johnny Appleseed

‘The Story of the Apple’

Recent book (2006) by ‘Juniper’ & ‘Mabberly’ from Oxford University

-Taxonomists in U.S. use *Malus x domestica* to represent commercial apples and *Malus sieversii* to represent the wild apples of Central Asia.

- Taxonomists in England, e.g. ‘Juniper’ use *Malus pumila* to represent both commercial apples and the wild apples of Central Asia.

- Juniper’s book with references from work of many world-wide scientists shows convincing evidence that the wild apple of Central Asia is ‘the’ ancestor of commercial apples.

Germplasm collections to add mostly wild *Malus* species to the PGRU collection

Year	Country	Species	Personnel
1987 – 1988	Western U.S. & Canada Eastern U.S. & Canada	*Malus fusca, M. ioensis, M. coronaria & M. angustifolia*	Weeden, Dickson
1989	Uzbekistan, Tajikistan, Kazakhstan	*Malus sieversii*	Aldwinckle, Dickson, Sperling
1993	Kazakhstan, Kyrgyzstan	*Malus sieversii*	Forsline, Dickson, Mink, 1 New Zealand scientist
1995	Kazakhstan	*Malus sieversii,*	Forsline, Dickson, Luby, 2 S. African scientists
1996	Kazakhstan	*Malus sieversii*	Forsline, Hokanson, Unruh, Pellett
1997 & 2001	China (Sichuan)	*Malus* species (7 endemic to Sichuan)	Forsline, Aldwinckle. Benson, Geibel
1998	Russia & Germany	*Malus orientalis & M. sylvestris*	Forsline, Iezzoni, Karle, Fischer, Geibel
’99, ‘01 ‘02, ‘04	Turkey, Armenia, Georgia	*Malus orientalis*	Forsline, Aldwinckle, Postman, Hannan


RUSSIA
50°E
60°E
70°E
80°E
KAZAKHSTAN
Lake Balkhash
Tarbagatai
Djungarsky
Aral Sea
Almaty
Karatau
Talasky
Zailisky
Ketmen
UZBEKISTAN
KYRGYZSTAN
40°N
Caspian Sea
TURKMENISTAN
TAJIKISTAN
CHINA
IRAN
AFGHANISTAN
PAKISTAN
INDIA
N
1
2
3
4
5
6
7
8
9
10
11
12

Collection team for 1989 Central Asian expedition to Uzbekistan, Tajikistan and Kazakhstan (site 3)

'The late' Calvin Sperling

Professor Herb Aldwinckle, Cornell University

Prof. Djangaliev–2005; He was 77 yrs old when first met in 1989 – Died at age 96 in 2009

Elizabeth Dickson, Cornell grad student

Uzbekistan

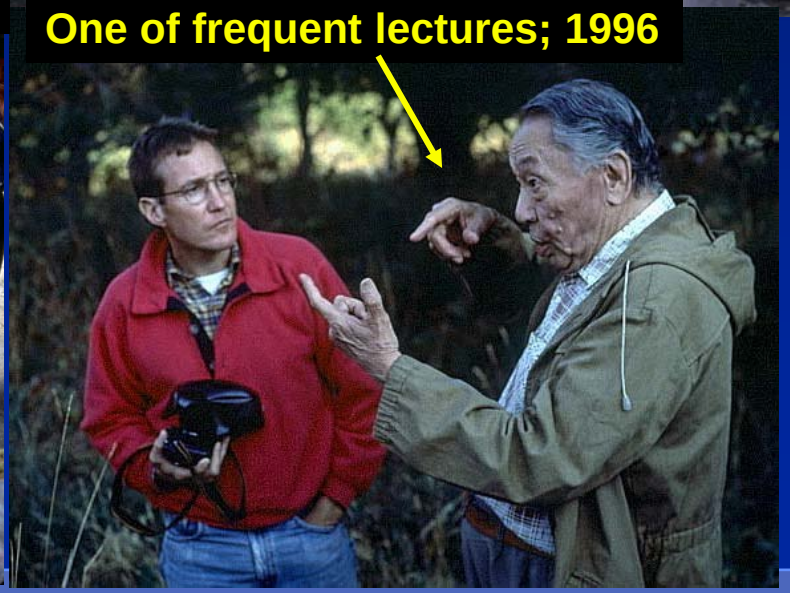
Professor Djangaliev

Visit to Geneva: making plans, Oct. 1992

In Kazakhstan: first morning, Sept. 1993 - ready to leave to board helicopter

Collection admiration, 1995

One of frequent lectures; 1996



Local Kazak media highlighting American & S. African visitors 1995

1993 collection team: USA & New Zealand

Preparation in NY for departure

Mink

Noiton –
N. Zealand

Dickson

Transfer in Moscow – hotel and visit to Red Square

Moscow to Alma Ata via 'Aeroflot'

Significant travel by helicopter to remote collection sites

Djangaliev

Team in Alma Ata with Kazakh hosts

1995 USA and S. African collection team

Dickson
Forsline
Britz
Luby
Human

Arrival at site 9

Seed extraction at hotel: site 9

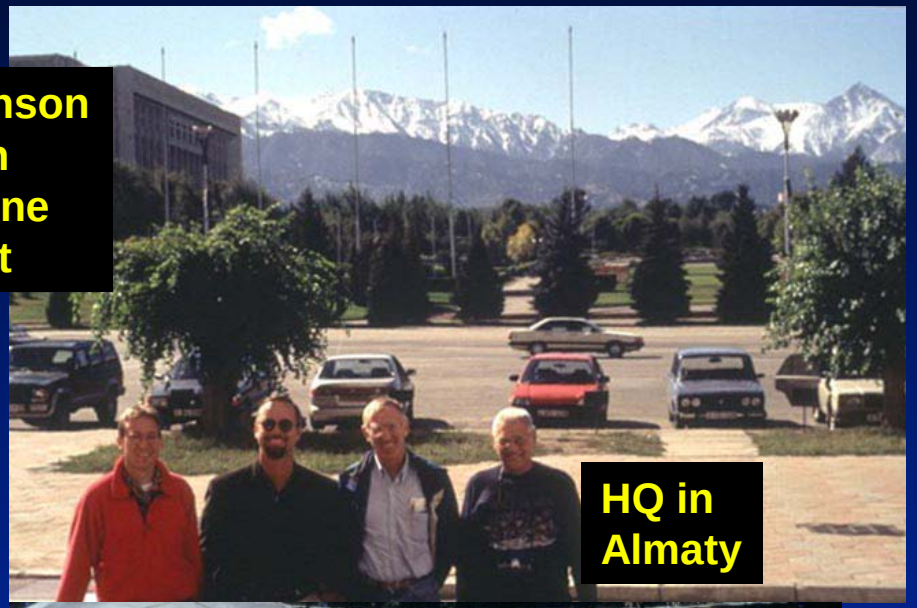
Meals in
yurt: site 5

Housing in sanitarium at HQ in Almaty

Gala dinner with hosts in Almaty: return to USA

1996 USA collection team

Hokanson
Unruh
Forsline
Pellett


HQ in Almaty


Site 9


Site 5


Site 12


50°N
50°E
60°E
70°E
80°E
40°N
RUSSIA
KAZAKHSTAN
UZBEKISTAN
TURKMENISTAN
IRAN
AFGHANISTAN
PAKISTAN
INDIA
CHINA
TAJIKISTAN
KYRGYZSTAN
Aral Sea
Caspian Sea
Lake Balkhash
Tarbagatai
Djungarsky
Almaty
Zailisky
Karatau
Talasky
Ketmen
1
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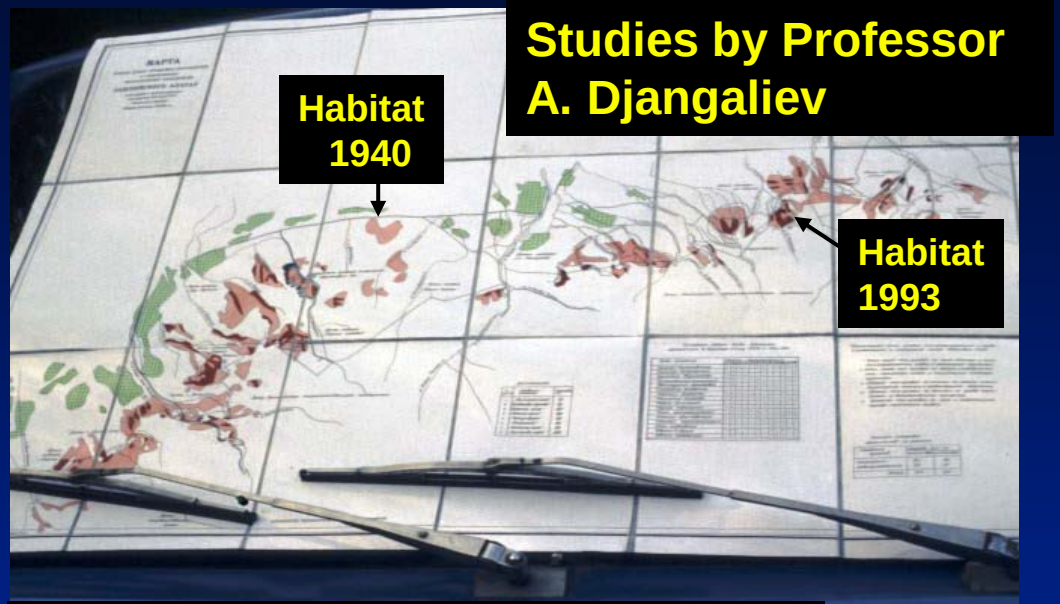
10
11
12
N

Kazakhstan site 3: ‘89,‘93,‘95,‘96

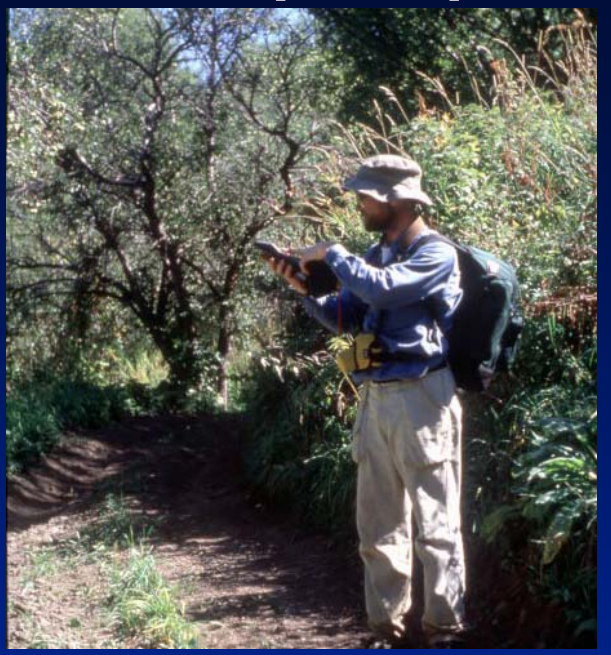


Studies by Professor A. Djangaliev

Depleted by dacha developments

Fruit from 30 randomly-collected trees

Kazakhstan site 4: ‘93,‘95,‘96



Luby using GPS - 1995

Scab infected tree – G. Mink 1993

Unruh & Hokanson 1996

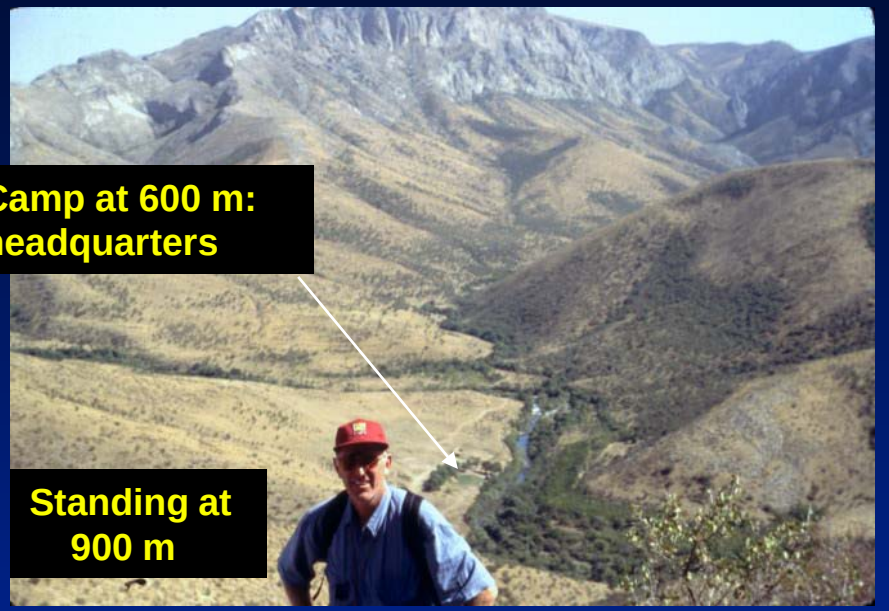
Kazakhstan site 5: ‘93,‘95,‘96

First collection morning (Sept. 1993) starting out at 1200 m with hike to 1800 m

300 yr old tree

Life in forestry camp at site # 5 after arrival by helicopter

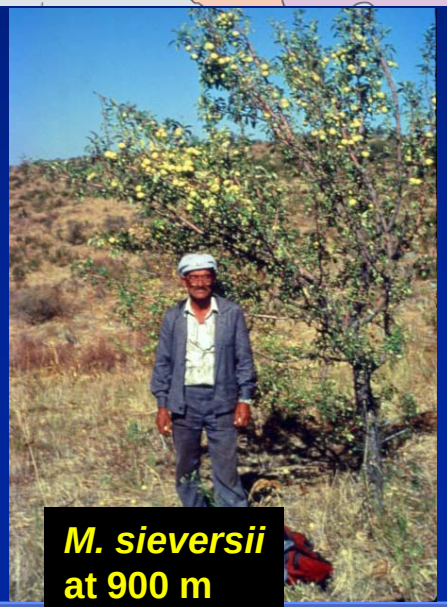
Kazakhstan site 6: ‘93 & ‘95



Camp at 600 m: headquarters

Standing at 900 m

Desert habitat



M. sieversii at 900 m

Fruit from 30 randomly-collected trees at 900 m

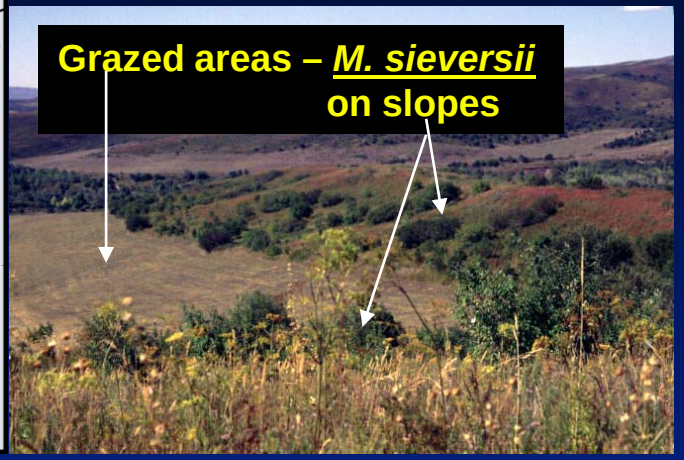
Kyrgyzstan site 7: 1993

Apple and walnut forests as seen from helicopter

Village in Kyrgyzstan near collection sites

Heavy grazing in *M. sieversii* areas

Kazakhstan site 9: ‘95 & ‘96



Fruit from 30 randomly-collected *M. sieversii* trees

M. sieversii

Heavy grazing of habitat

Characterizing apples at site 9 in 1995 – Dickson, Forsline & Luby

Kazakhstan site 10: 1996

Breakdowns – a common occurrence

M. niedzwetzkyana

Red-flesh apple

Fruit from 20 randomly-collected trees

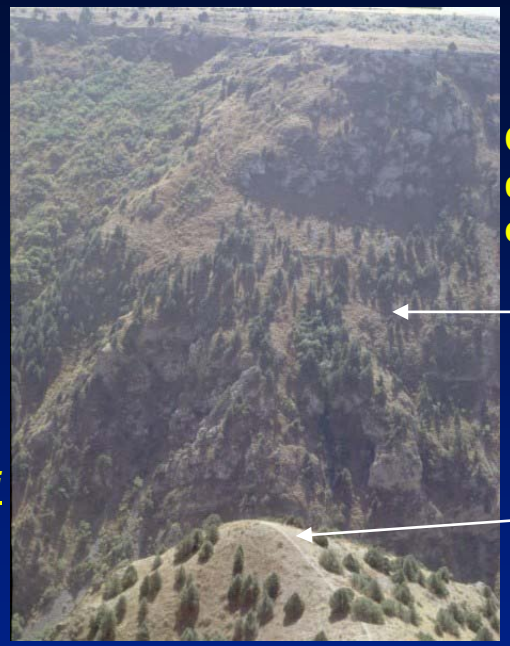
Uygur tribes tradition of flat-bread baking

Kazakhstan site 11: 1996

Elite ‘Nearly White’-type
M. sieversii

Kazakhstan site 12: 1996

Bottom of canyon; *M. sieversii* on this side

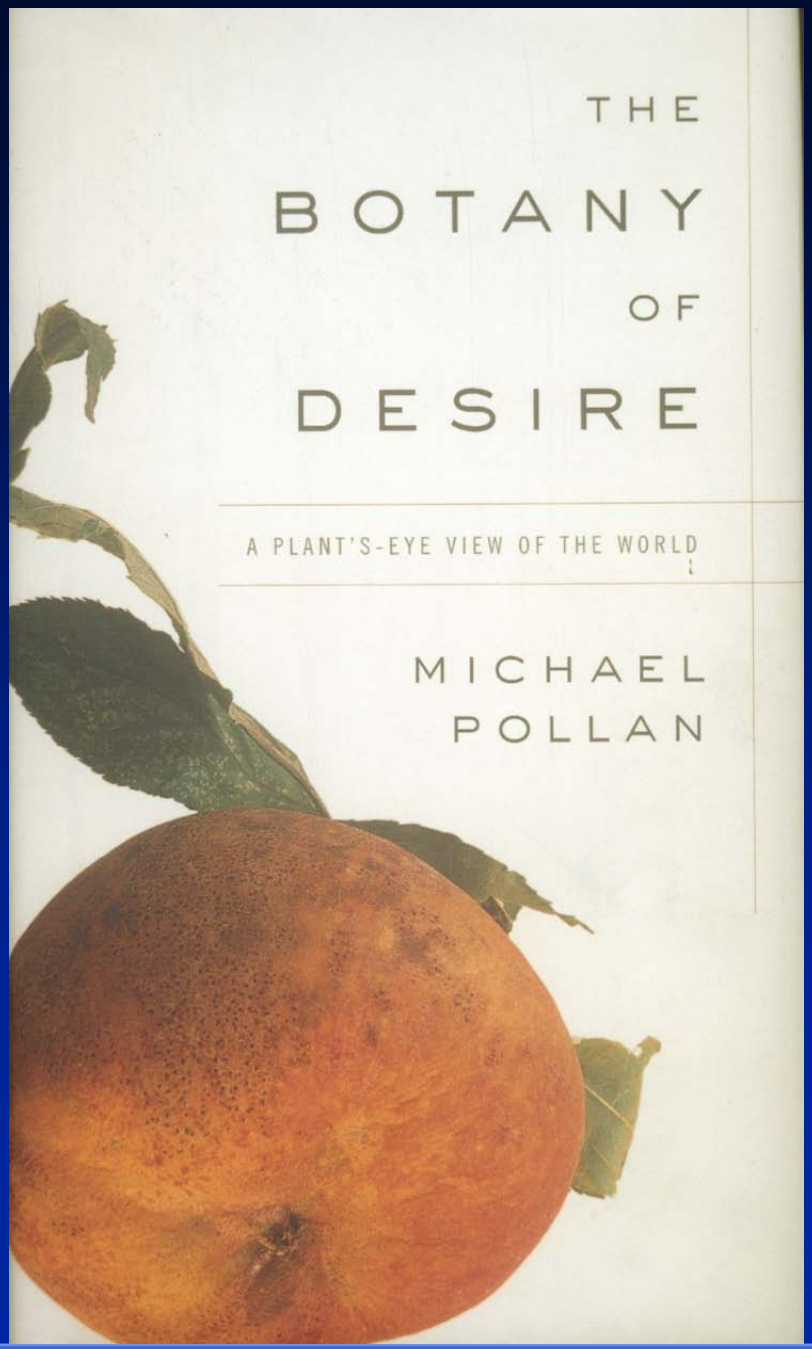


Canyon 400 m deep w/ *M. sieversii* on the N-facing wall

Trail to bottom

Fruit from 10 randomly-collected *M. sieversii* trees


150,000 wild apple seeds collected over 4 expeditions - seed storage at -18^0 C (0^0 F)



Short narrative from Michael Pollan in the book:

Since the wild apple's survival in the wild was now in doubt, Forsline collected hundreds of thousands of seeds, planted as many as he had space for in Geneva and then offered the rest to researchers and breeders around the world. He said "I'll send seeds to anybody who asks, just so long as they promise to plant them, tend to the trees, and then report back someday". The wild apples had found their Johnny Appleseed

Grow-out and evaluation of wild apple seedlings centered at PGRU with collaborative plantings in:

Minnesota, New Jersey, Colorado, Washington, Ohio, Wisconsin, Illinois, Manitoba, Nova Scotia, British Columbia, South Africa, New Zealand, Italy, Norway, Germany, Switzerland, Denmark, and Lithuania

Plantings at PGRU are being studied by scientists from:

Belgium, Michigan State University, Cornell University, Washington State University, Ohio State University, and USDA-ARS locations (Kearneysville, WV, Geneva, NY, and Fort Collins, CO)

1600 M. sieversii seedlings (planted 1997 &1998) were grown out at University of Minnesota

Sep. 7, 2005

Oct. 28. 2004 – J. Luby

Aug. 22, 2006

85 seedlings selected, grafted and now part of the permanent PGRU collection

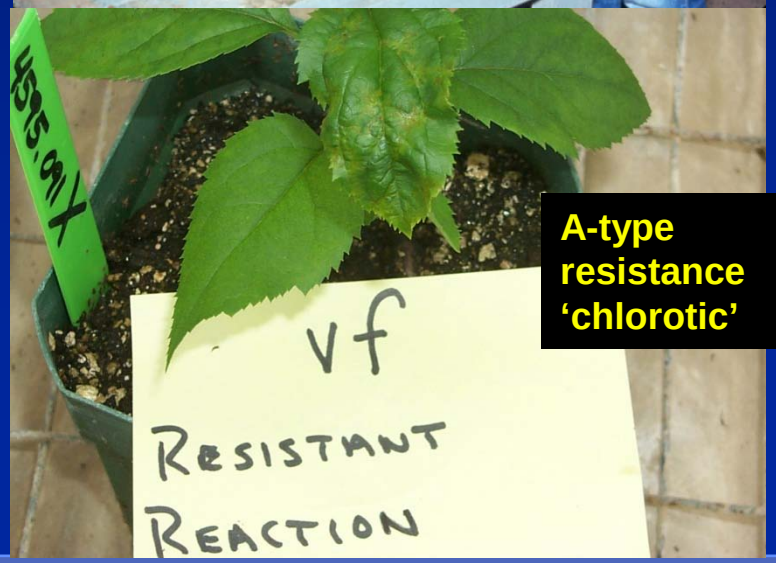
M. sieversii seedling grow outs in Germany, New Zealand & Switzerland

Dresden, Germany
1999

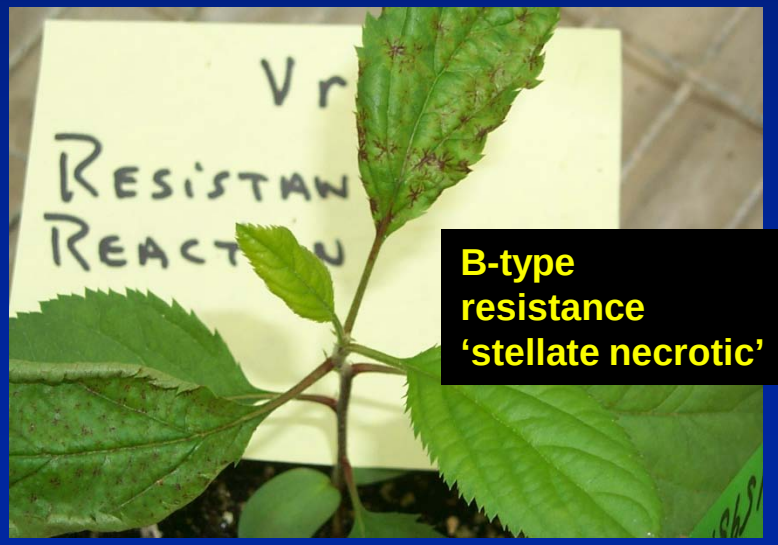
Vincent Bus;
New Zealand, Oct. 2001
- visited again in March 2007

Forsline, Kellerhals and
Gersbach: Switzerland, 2010

Screening young *M. sieversii* seedlings for apple scab (*Venturia inaequalis*)



A-type resistance 'chlorotic'



B-type resistance 'stellate necrotic'

Apple scab resistance of *Malus sieversii* populations from Central Asia

H. Aldwinckle, P. Forsline, H. Gustafson and S. Hokanson

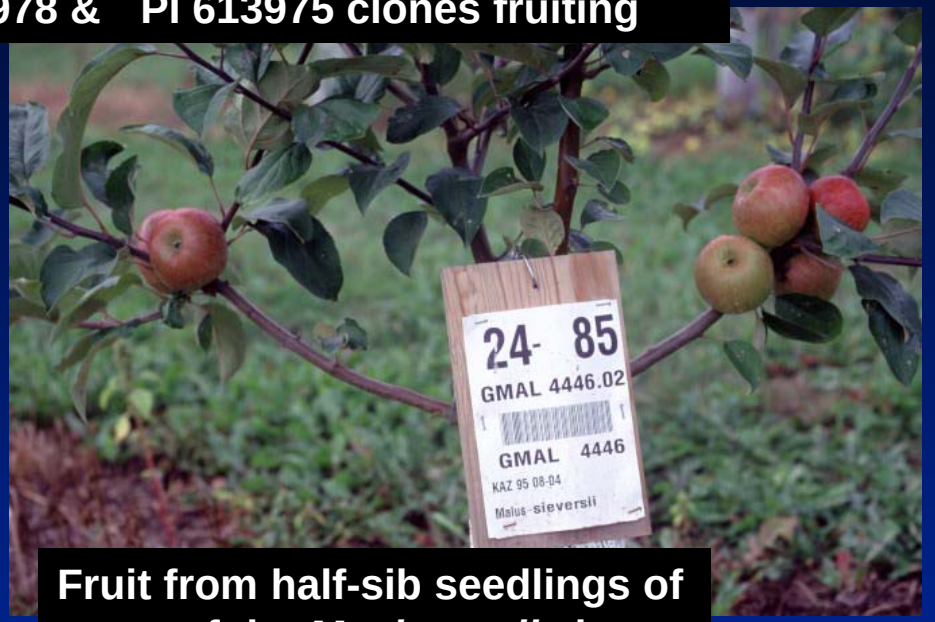
Kazakhstan Site No.	# of Seedlings Inoculated	% Resistant
4	405	50
6	705	37
5	1224	29
9	1325	28
7	383	25
2	101	24
11	244	23
3	460	17
12	133	14
10	123	6
1	21	5
Totals →	5124	28

Horticultural Evaluations

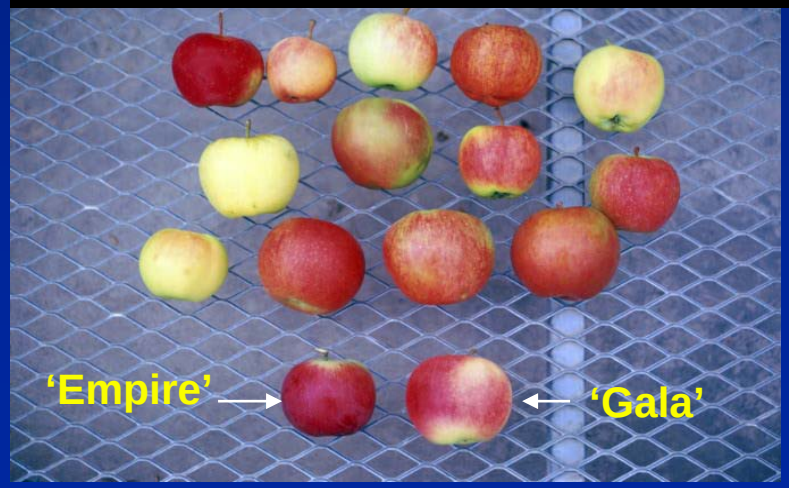
Wild *Malus sieversii* clones and seedlings in grow-out plantings

PI 613972 clone in bloom

PI 613978 & PI 613975 clones fruiting

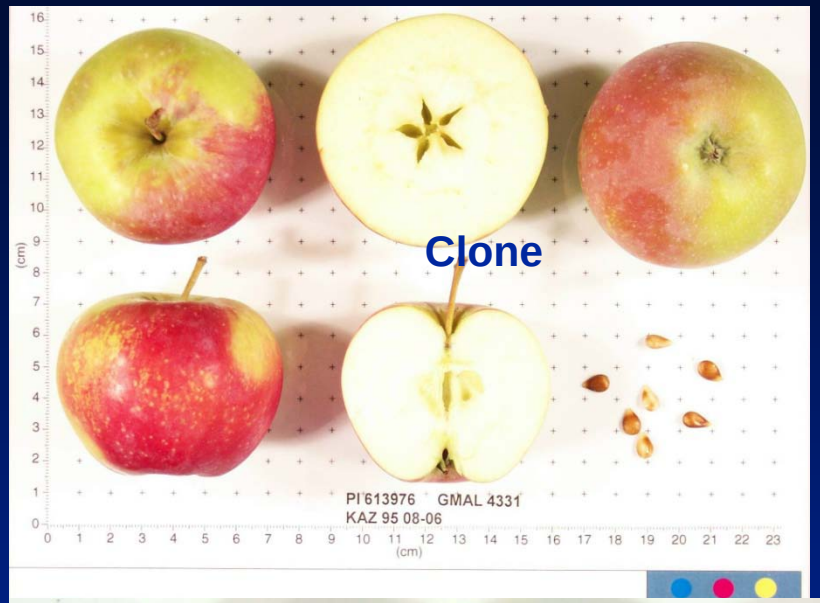


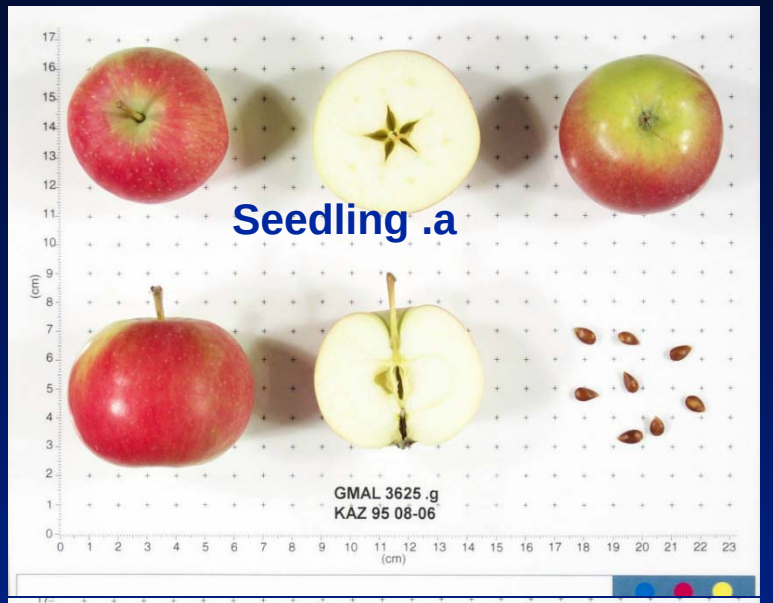
13 different *M. sieversii* *'Elite' clones*

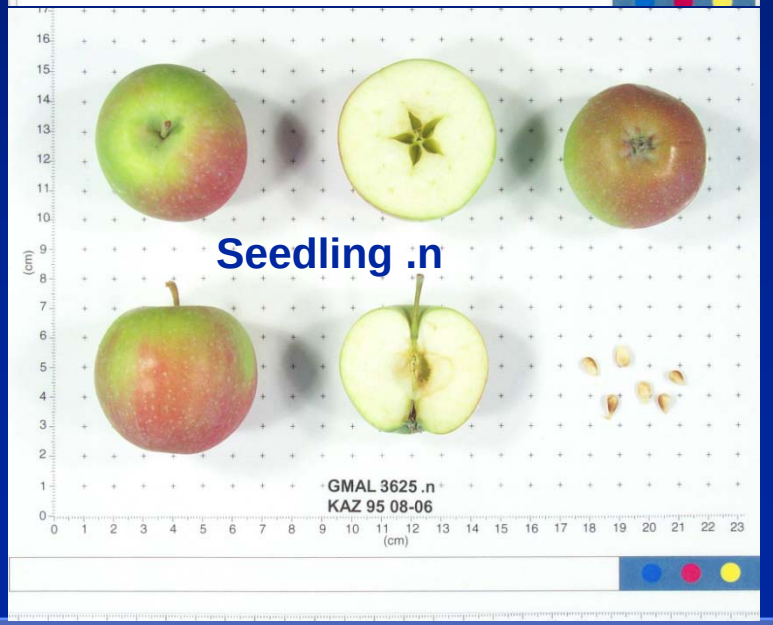


Fruit from half-sib seedlings of some of the *M. sieversii* clones

Elite clone (PI 613976) and progeny (3 half-sibs)







As they Appear on the GRIN website

M. sieversii clonal 'Elites' fruiting in Geneva in 2008 & 2009

M. sieversii seedlings fruiting in Geneva in 2008 & 2009


Prolific fruiting of *M. sieversii* in Geneva in 2010

Pruning 10.000 trees annually is a monumental task

High quality wild apples available

Unique wild apples in the PGRU collection

Sources of 12 common commercial apple cultivars and resemblance to *M. sieversii*

Process to breed apples: '*sex life of apples*'

Crosses that I made In May 2002 in order to evaluate hybrids of 'Gala' X *M. sieversii*

1) Emasculate (remove male parts) of flower of maternal parent at pre-bloom stage leaving only female parts (pistils and ovaries):

Bees are no longer attracted, disseminating random pollen because petals are also removed

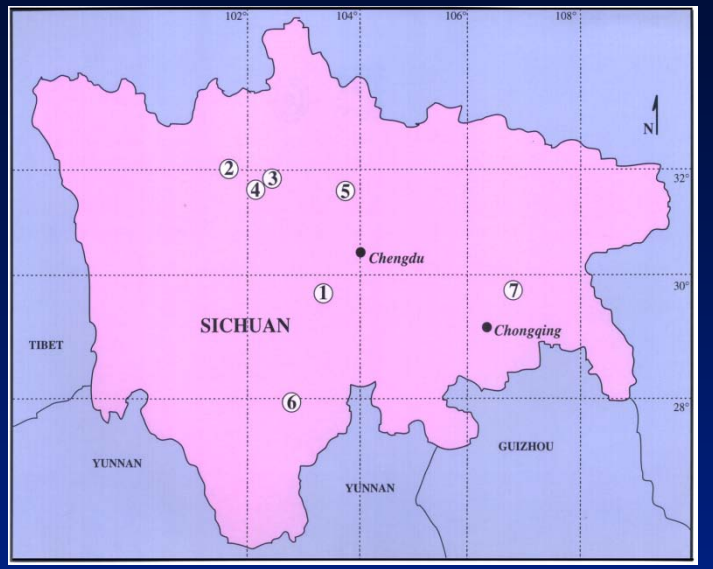
2) Note on this branch the multiple flowers that now have only female parts (pistils) remaining

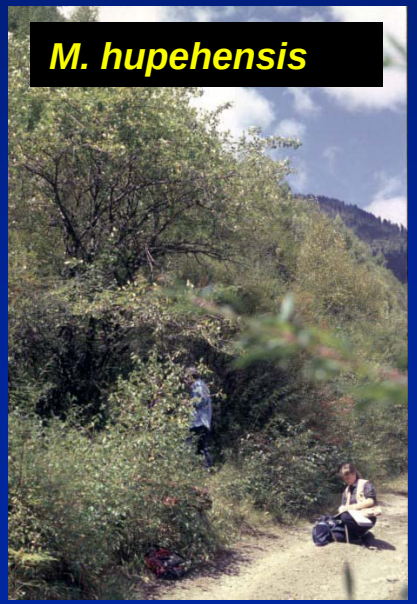
3) When all the flowers have been emasculated, rub pollen from paternal parent onto the pistils

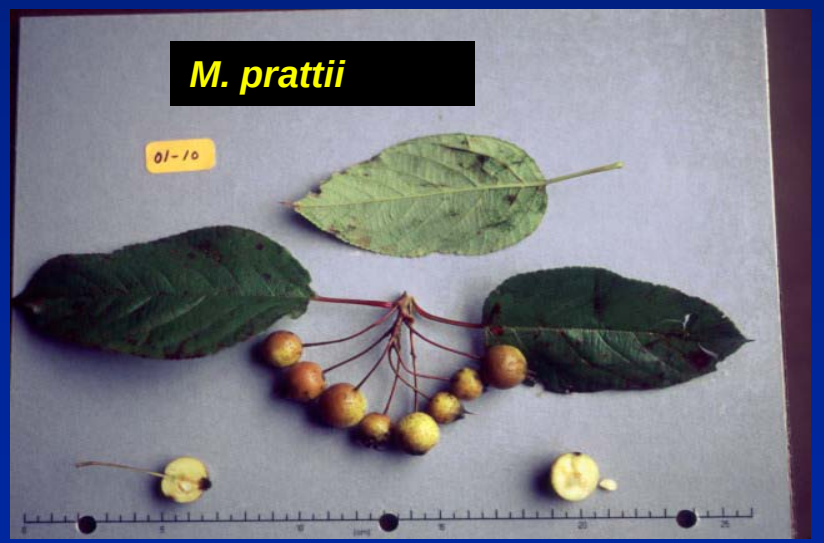

Scientists collecting apples from resulting hybrid apple trees in September, 2012 for genetic mapping studies to determine resistance to various diseases

Other Recent Collections

Malus sp. collections in Sichuan, China; 1997







Chinese *Malus* species screened for diseases in greenhouse: Now field-grown as orchards in Geneva for horticultural evaluation

Malus orientalis in Russian Caucasus; 1998

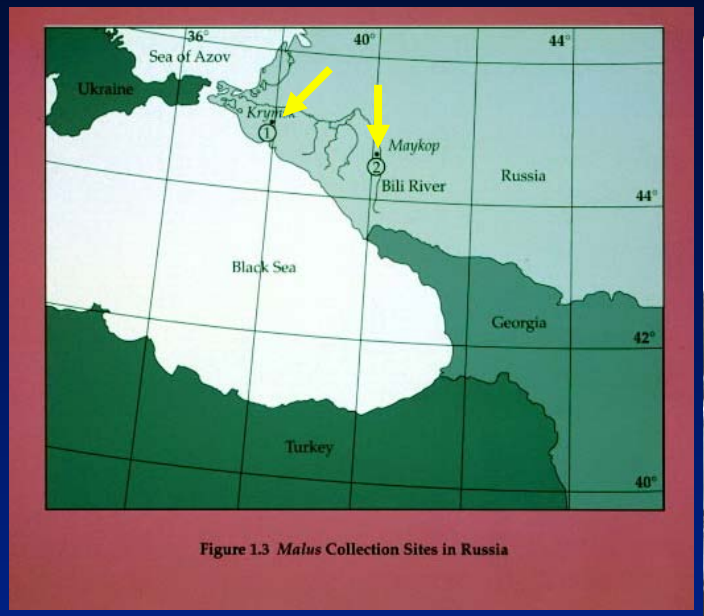
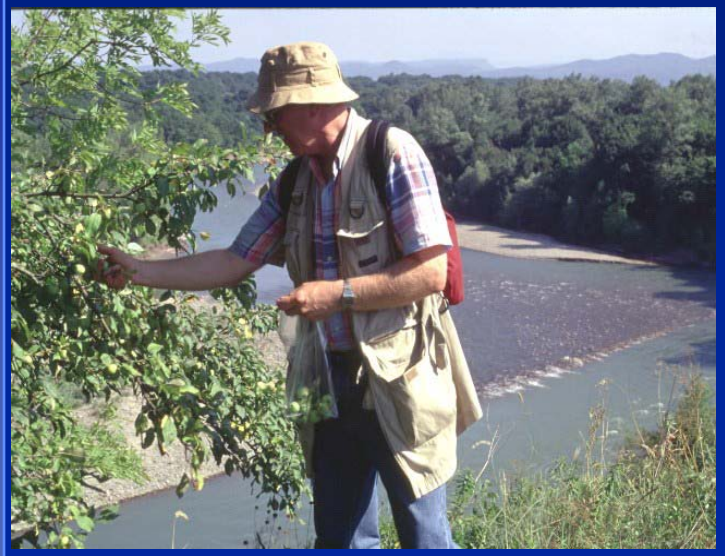
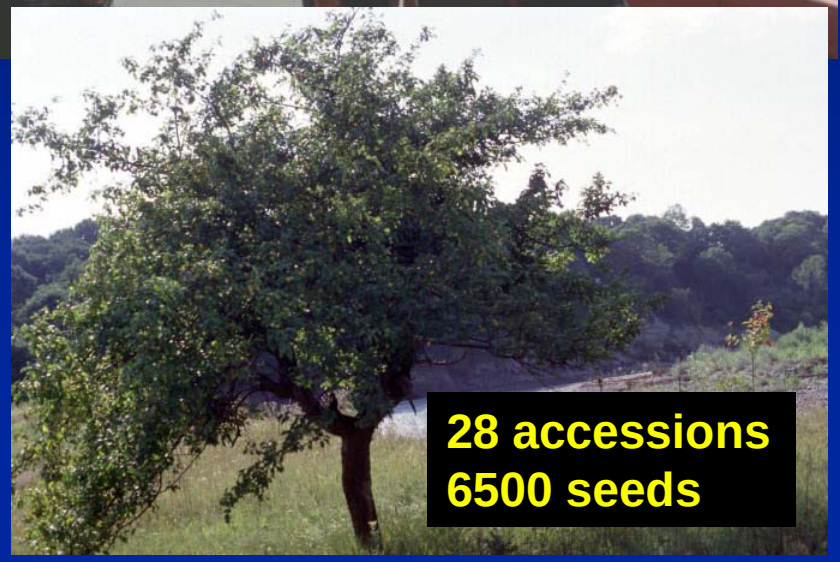


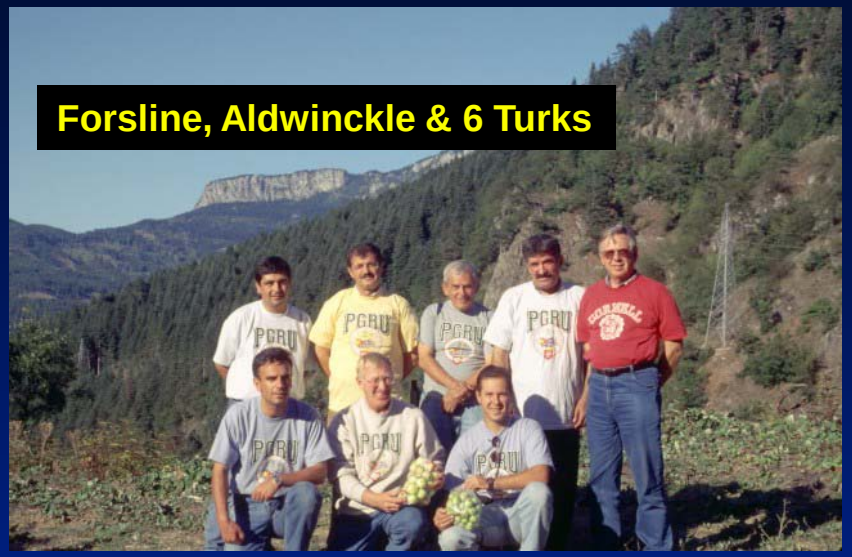
Figure 1.3 *Malus* Collection Sites in Russia

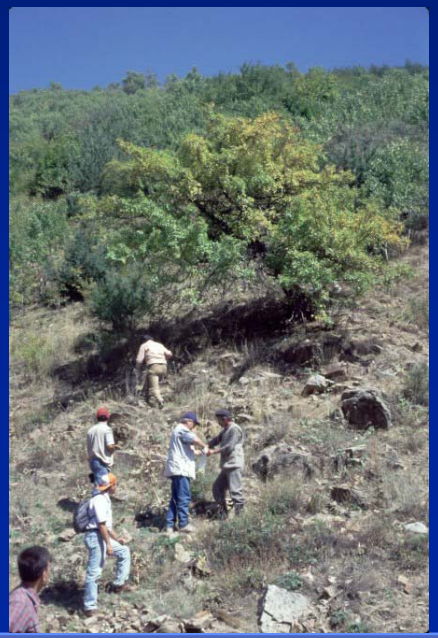

Vavilov Inst. St. Petersburg




28 accessions
6500 seeds

Malus orientalis in Turkey; 1999





Field grow-out in Geneva of *Malus orientalis* collected near Black Sea in Russia & Turkey

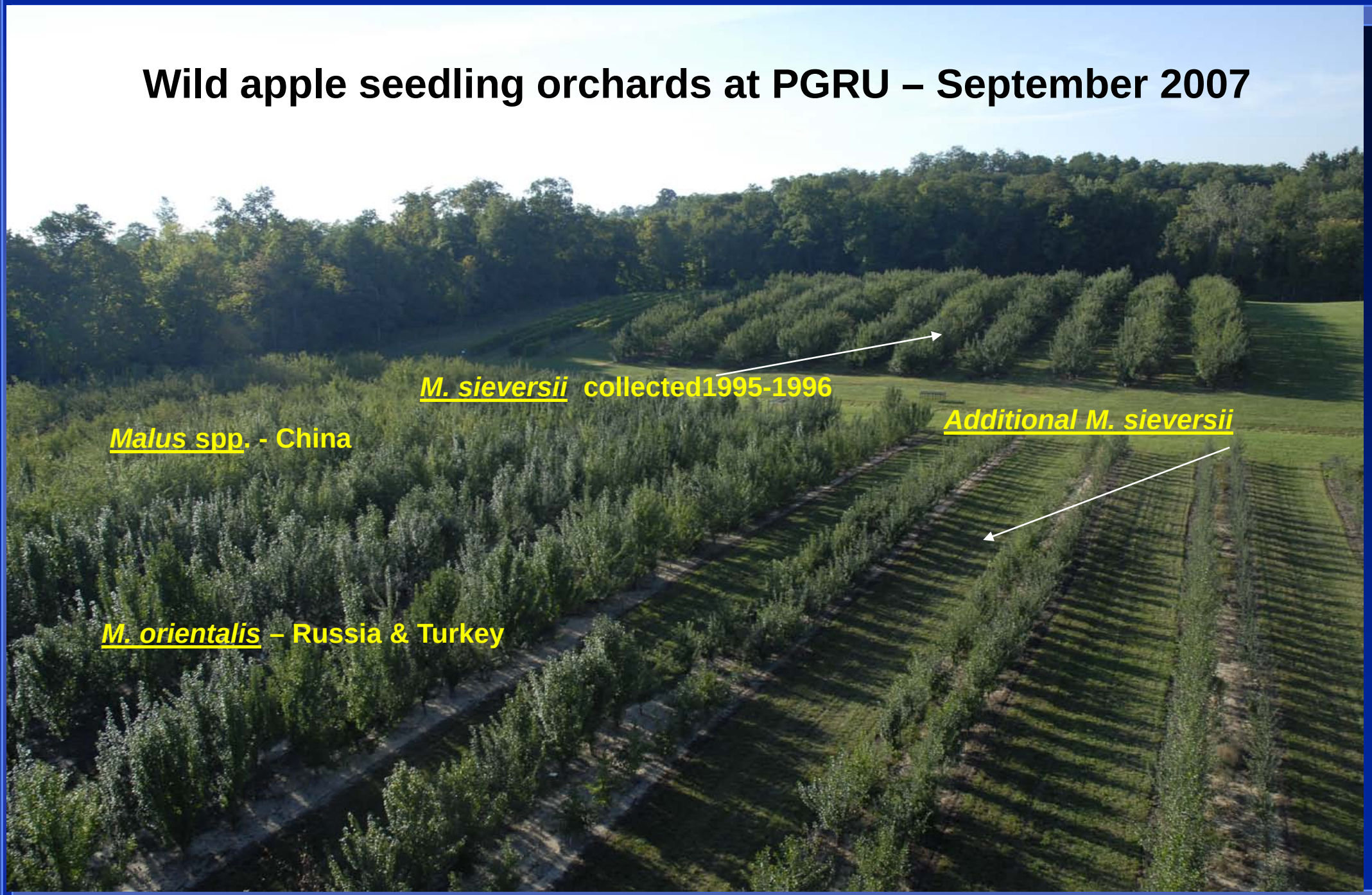
Documentary completed:

On September 17-19, 2007 Kikim Media, Menlo Park, CA filmed a documentary at Plant Genetic Resources Unit (PGRU) in Geneva, NY. The documentary is centered around the recently-published book, "The Botany of Desire: A Plant's-Eye View of the World" by Michael Pollan. The first chapter of the book describes man's relationship to apples.

The documentary aired on PBS October 28, 2009 (DVD available from PBS web site); can also be seen as a webcast on OPB

Clonal apple collections at PGRU – September 2007

Wild apple seedling orchards at PGRU – September 2007




The joys of tasting diverse apples!!!

Searching Databases in GRIN
(Germplasm Resources Information Network)

http://www.ars-grin.gov/

The Future - Expanded apple genetic resources available with emerging technologies (Genomics, Bioinformatics, etc.) for apple improvement


Giving tours in the Geneva collection after retirement (2010 & 2011)

Other activities since retirement on January 1, 2010

- Invited talks given Internationally (Denmark, Belgium and Switzerland)
- Invited talks at botanic gardens, churches, amateur horticultural groups and service groups
- Moved to Oregon in December, 2011
- Joined “Home Orchard Society” of Oregon
- Continue membership with committees joining in regular conference calls
- Staying in touch with collaborators by phone and e-mail (i.e. ‘Botany of Desire’ seed requests) and co-authoring additional publications
- Continuing collaboration with scientists at Washington State University (Pullman and Wenatchee) where orchards of wild apple trees from seeds that I collected are being evaluated


Enjoying our new home in
Oregon relating my love of
apples to grandson “Emmett”


Thank you for
your attendance