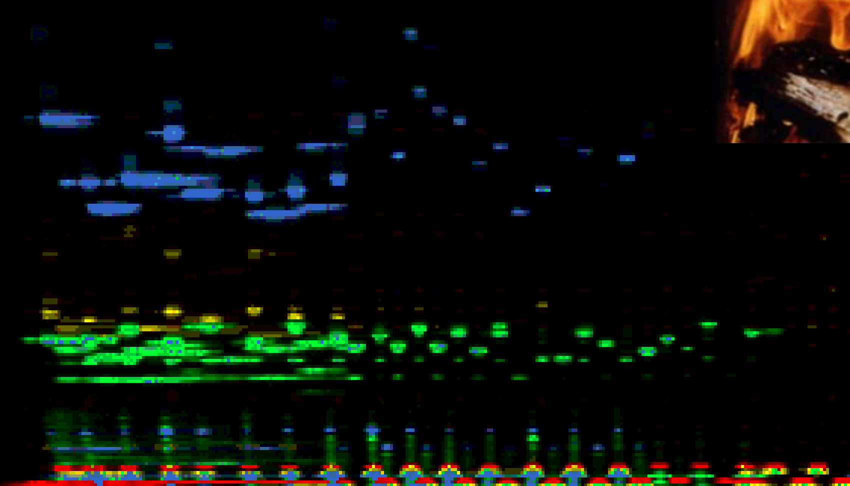
Genetics of plant domestication:
the basket and the clay pot challenging the PCR



D.G. Debouck

MolConnect, Bogotá, 5 September 2006

Food production by kinds and origins

	% of total
Cereals (wheat, maize, rice, barley, sorghum, . . .)	72.3
Roots & tubers (potato, cassava, sweet potato, . . .)	6.9
Pulses (soybean, bean, groundnut, . . .)	6.3
All meat, milk, eggs	6.0
Sugar (sugarcane, beet, . . .)	5.0
Oil (soybean, rapeseed, groundnut, sunflower, . . .)	2.6

from Mediterranean climate	36.7	82.8
from tropical savannahs	46.1	

from Fertile Crescent	40	96
from the Americas	30	
from East Asia	26	

source : Harlan 1995

Crops currently under incipient domestication

Setting the scene: definitions

plant domestication = human creation of a new form of plant (B Smith 1995)

plant domestication = to bring plant into the human domain (J Harlan 1995)

plant domestication = inadvertent/ deliberate human selection (D Harris 2005)

dependence on people for long-term survival

deliberate action = planting

time ⇩ *space*

wild species ➤ rural species ➤ field weed ➤ crop

wild species	rural species	field weed	crop
thrives in climax vegetation	**thrives in disturbed habitats**	**grows in cultivated fields**	**planted in cultivated field/ garden/ orchard**

- ✓ *increasing ecological disturbance (intensity, frequency)*
- ✓ *domestication can be unconscious through taming the environment (e.g. fire), or through repetitive behaviour*


Diego Rivera 1926

When ?

Neolithic revolution (10,000 years B.P.)

curiously : independently, simultaneously

in at least 8 places on earth

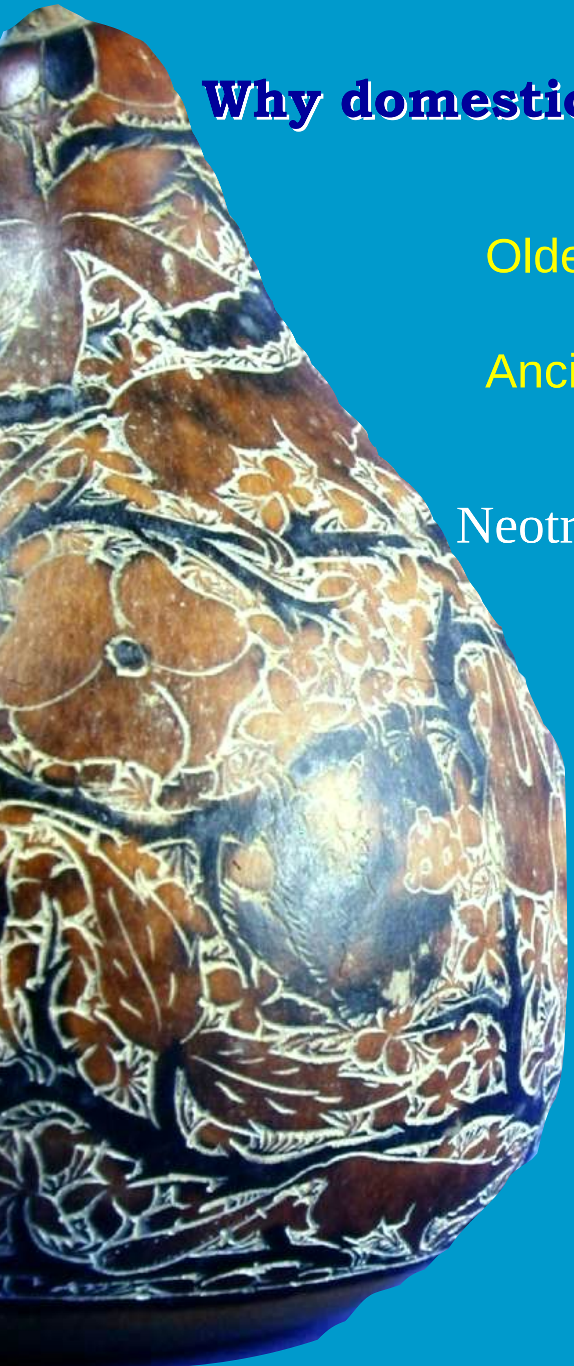
climate change ? Man-made extinction of mammals?

not many records of a full transition from hunting,

indicating a fast conversion ?

Important – independent - innovations

- better control of fire (e.g. light in Lascaux)
- basketry (7-6,000 years B.P.)
- ceramics (6-5,000 years B.P.)



Why domesticate crops if you don't have pots to cook them?

Oldest date: Taperinha, Brazil: 6,900 years B.P.

Ancient site: Puerto Hormiga, Colombia: 5,300 years B.P.

Neotropical crops that appeared in preceramic context (7700-5000):

maize, Lima bean, common bean, squash, arrowroot, cassava

cotton, achira, guava, jack bean, bottle gourd, peanut, jicama

source: Piperno & Pearsall 1998

Lagenaria siceraria (Mol.) Standl. : one of the oldest ?!

- used as float for fishing nets, then as container, not as fire-pot
- initially harvested as a weed?
- most likely of African origin: Decker-Walters et al. 2004

The eloquent bones of Abu Hureyra, Syria. by Theya Molleson, 1994

Jack Harlan, 1975: “Why abandon the Golden Age and take up the burden?”

Cover of Scientific American, August 1994

The daily grind of preparing flour left its mark on Neolithic bones.

Diego Rivera 1926

Why ?

No model to copy !

more work, no knowledge in genetics (Mendel 1865!)

presence of antinutritional factors in many wild plants

unconscious ? inconspicuous ? autocatalytic !

No reverse !

increase of human populations, to six billions today

stratification of human societies, urbanization

flowering of arts, of diseases

mutual dependency, fragility

Hope and commitment !

Where ?

Geographic dimension

In which place (s) did the domestication take place ?

Biological dimension

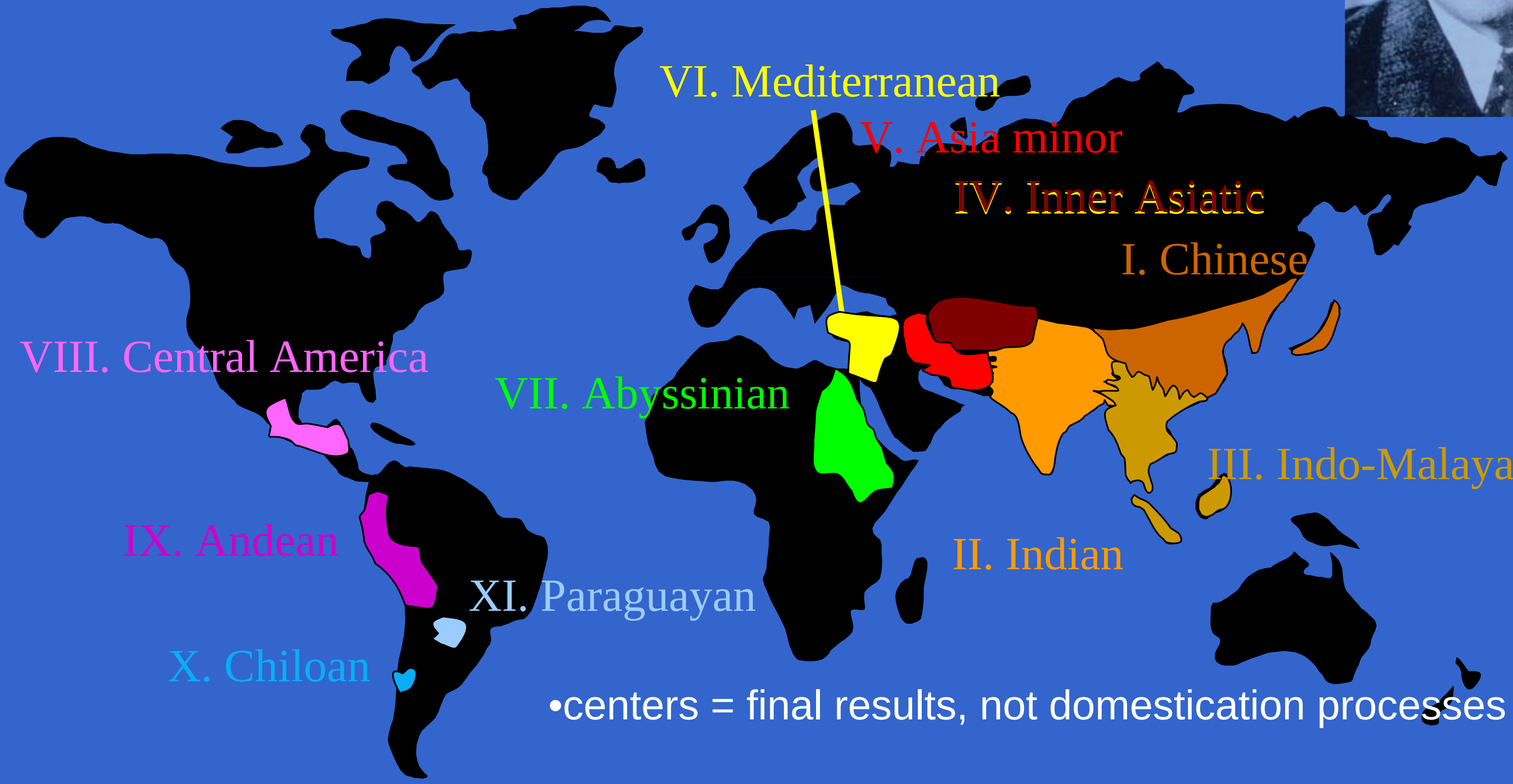
From which wild progenitor (s) did the crop arise ?

[material basis for many further studies]

[a close weed might not be the wild progenitor !]

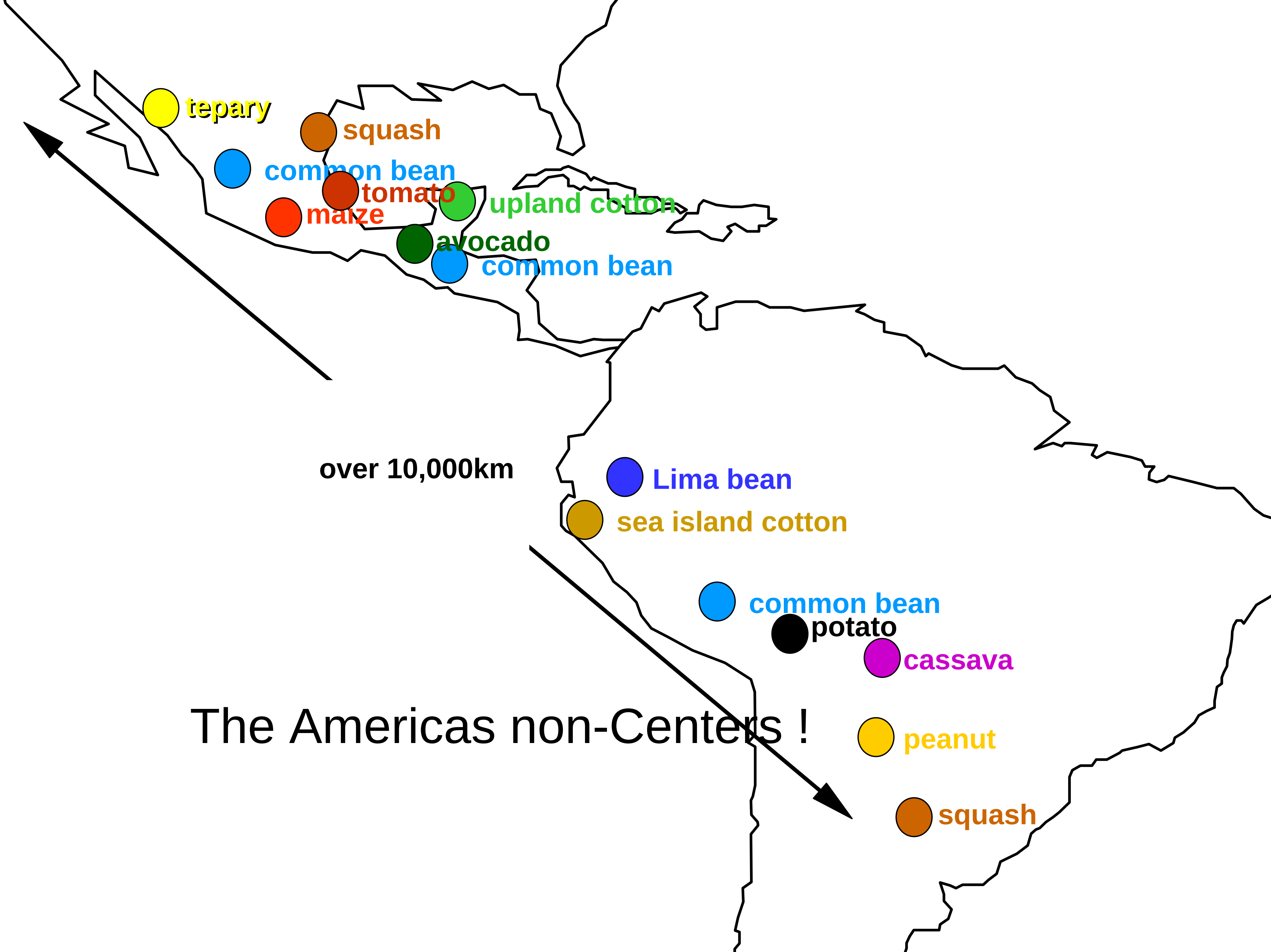
(remember the teosinte from Chalco !)

World centers of origin of cultivated plants



- centers = final results, not domestication processes
- overall : not supported by molecular evidences

Works of N Vavilov et al. (1926, 1935)


tepary
squash
common bean
tomato
maize
upland cotton
avocado
common bean
over 10,000km
Lima bean
sea island cotton
common bean
potato
cassava
peanut
squash
The Americas non-Centers !

Definition of the wild relative(s) from which the Neotropical crop derives

Crop	Works
maize, *Zea mays* L.	Doebley et al. 1987; Matsuoka et al. 2002
common bean, *Phaseolus vulgaris* L.	Gepts et al. 1986; Chacón et al. 2005
Lima bean, *Phaseolus lunatus* L.	Gutiérrez et al. 1995
pumpkin, *Cucurbita pepo* L.	Decker-Walters et al. 1993; Sanjur et al. 2002
cushaw, *Cucurbita argyrosperma* Huber	Sanjur et al. 2002
potato, *Solanum tuberosum* L.	Debener et al. 1990; Hosaka 1995; Spooner 2005
cassava, *Manihot esculenta* Crantz	Roa et al. 1997; Olsen & Schaal 1999, 2001

(recent dates; evidences brought by molecular markers)

Still unclear: sweet potato, fig-leaf gourd, sea island cotton

4 haplotypes

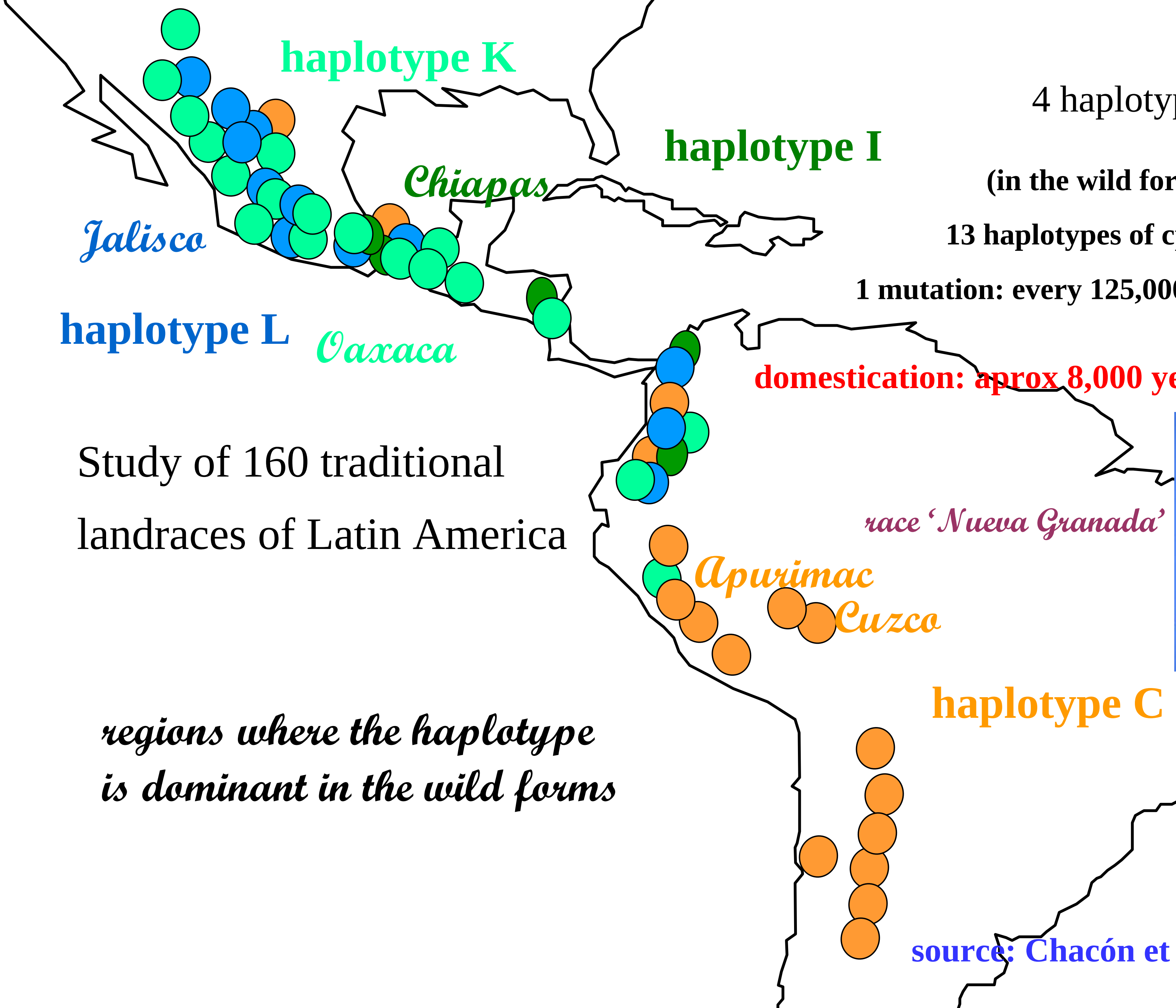
(in the wild form

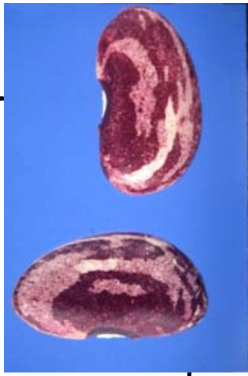
13 haplotypes of cpDNA

1 mutation: every 125,000 years)

domestication: aprox 8,000 years B.P.

Study of 160 traditional landraces of Latin America





race 'Nueva Granada'

source: Chacón et al. 2005

Diego Rivera 1926

How ?

Domestication Syndrome

Myth or reality ? Key traits and linkages

Unconscious *versus* Conscious selection

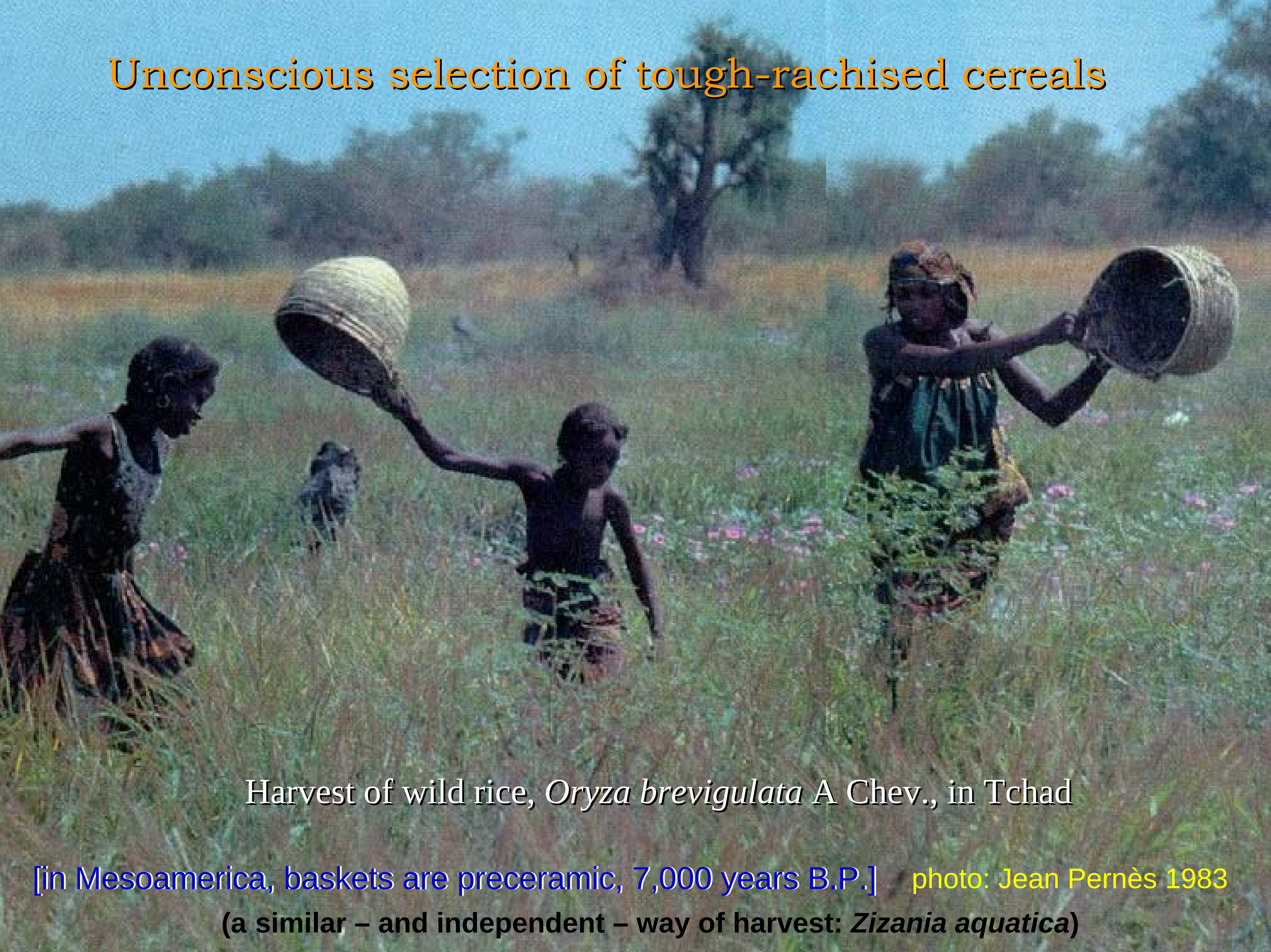
Mutation rates, progress in selection

Genetic control of domestication syndrome in bean

Phenotypical trait	Number of genes
pod dehiscence	2-3
growth habit	5
seed color	9
seed pattern	9
reaction to photoperiod	3
seed size	polygenic

adapted from Gepts & Debouck 1991

Unconscious selection of tough-rachised cereals

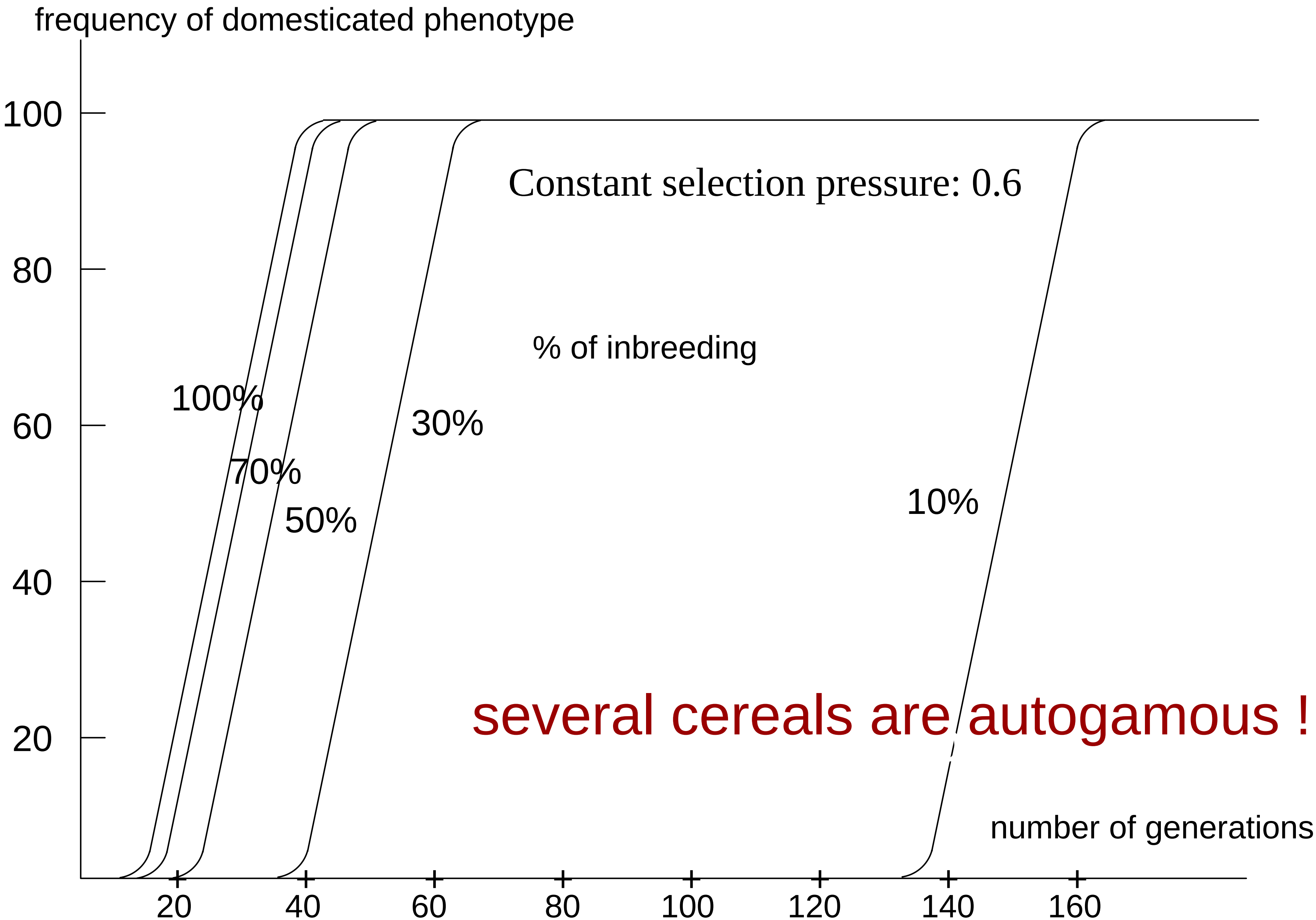


Harvest of wild rice, *Oryza brevigulata* A Chev., in Tchad

[in Mesoamerica, baskets are preceramic, 7,000 years B.P.] photo: Jean Pernès 1983

(a similar – and independent – way of harvest: *Zizania aquatica*)

Relative abundance of tough-rachised einkorn in artificial planting of wild type



several cereals are autogamous !

source : Hillman & Davies 1990

Genetic differences between maize and its wild progenitor

maize | teosinte | *Zea mays* L. | Other cereals

Zea mays L.	Other cereals
1. brittle rachis	
1L: 28%, 5S: 18%, 2S: 12%, 4C: 10%	all
2. 4-ranked and more	
2S: 42%, 5S: 12%, 9: 10%, 3L: 8%	pearl millet
3. 2nd spikelet fertile	
1L: 24%, 3: 12%, 4S: 6%, 2S: 6%	barley, sorghum
4. soft glumes	
4S: 42%, 2S: 14%, 3L: 6%, 1L: 6%	barley, wheat
5. ears on short branches	
1L: 32%, 3L: 8%, 6S: 8%, 4C: 7%	

Correlations:

1/4: 0.30, 1/5: 0.30

adapted from Doebley et al. 1992, 1993; Harlan 1995

In pulses, two characters are key in the domestication process :

1. Lack of pod dehiscence

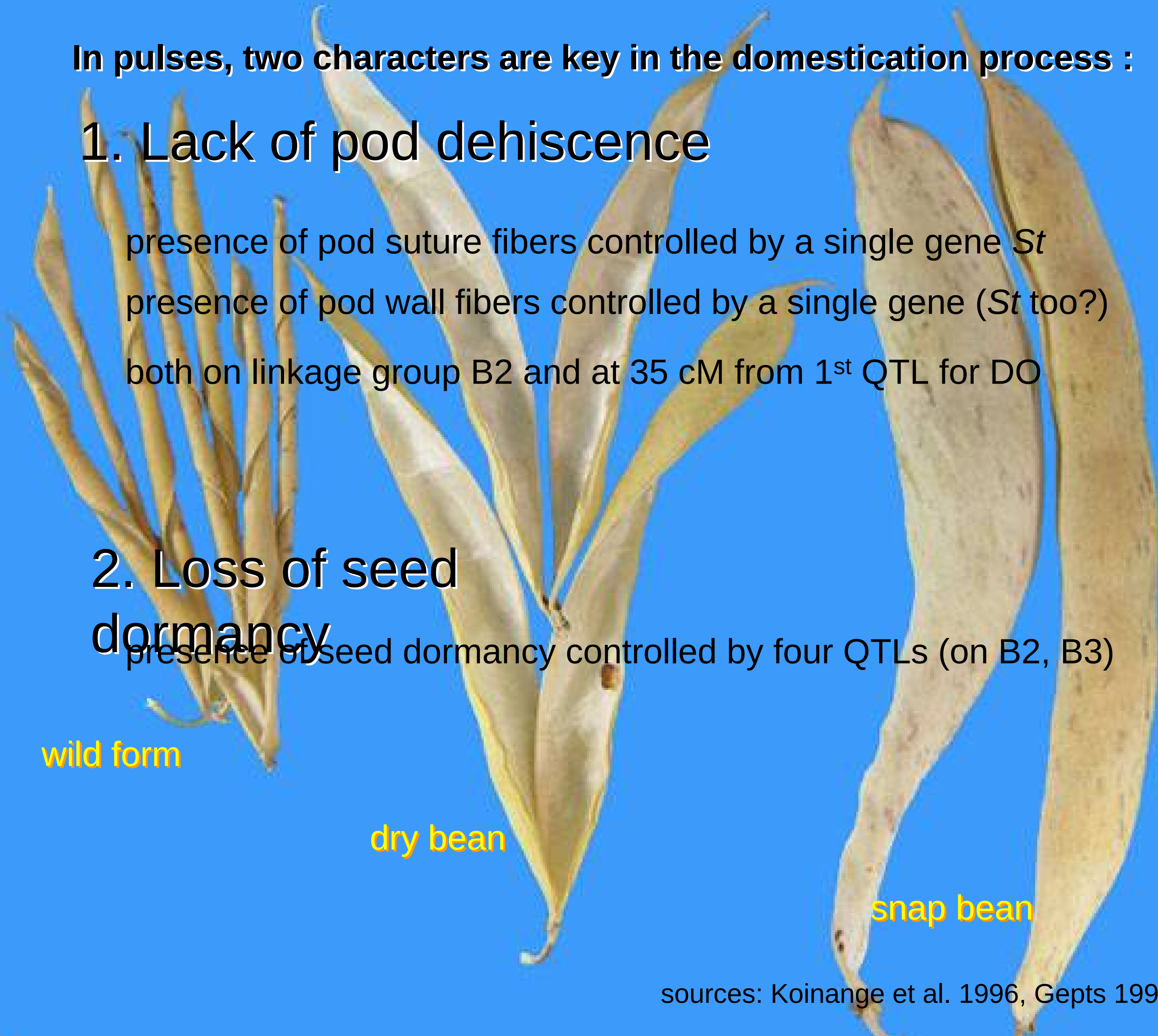
presence of pod suture fibers controlled by a single gene *St*

presence of pod wall fibers controlled by a single gene (*St* too?)

both on linkage group B2 and at 35 cM from 1st QTL for DO

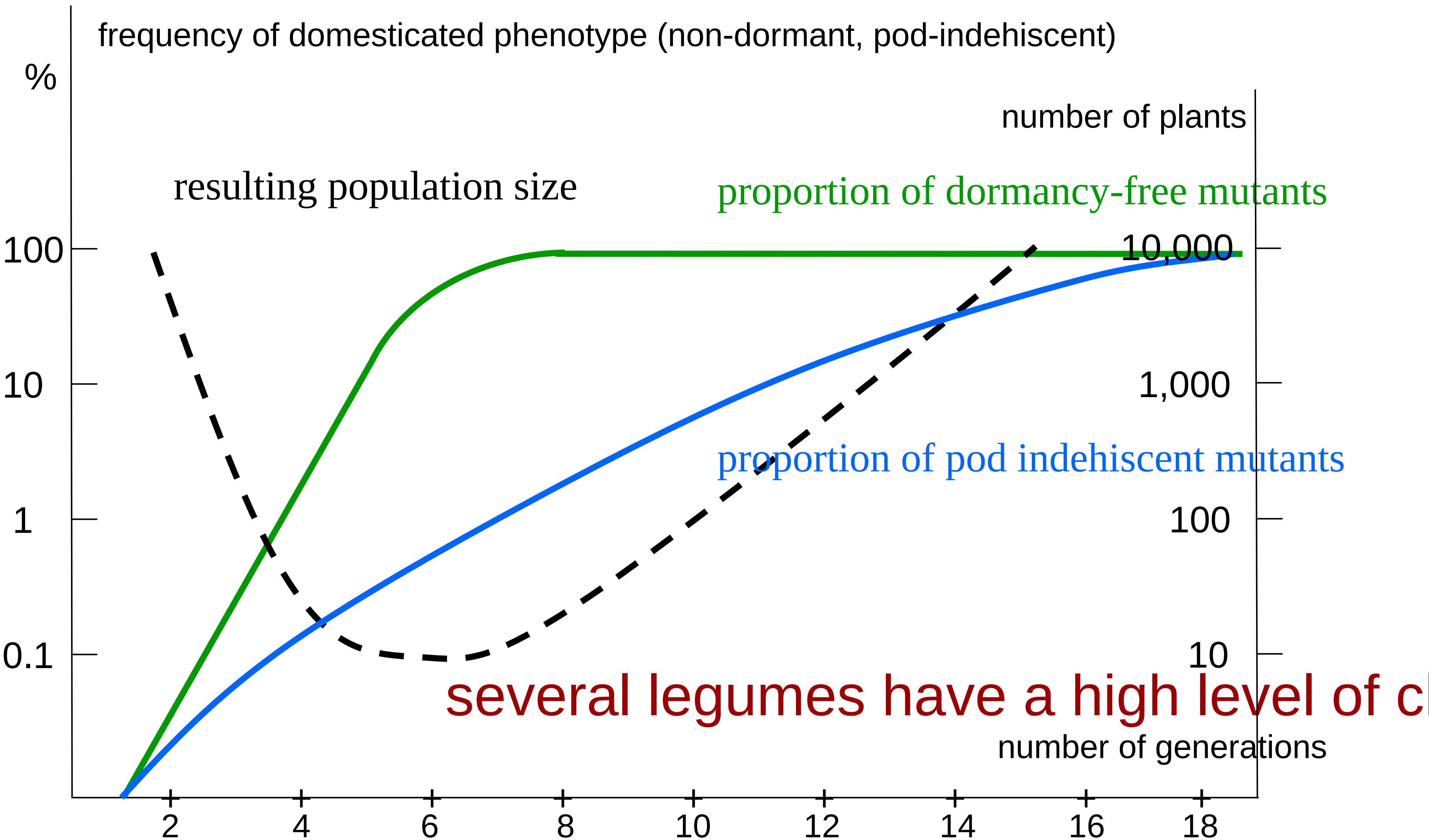
2. Loss of seed dormancy

presence of seed dormancy controlled by four QTLs (on B2, B3)



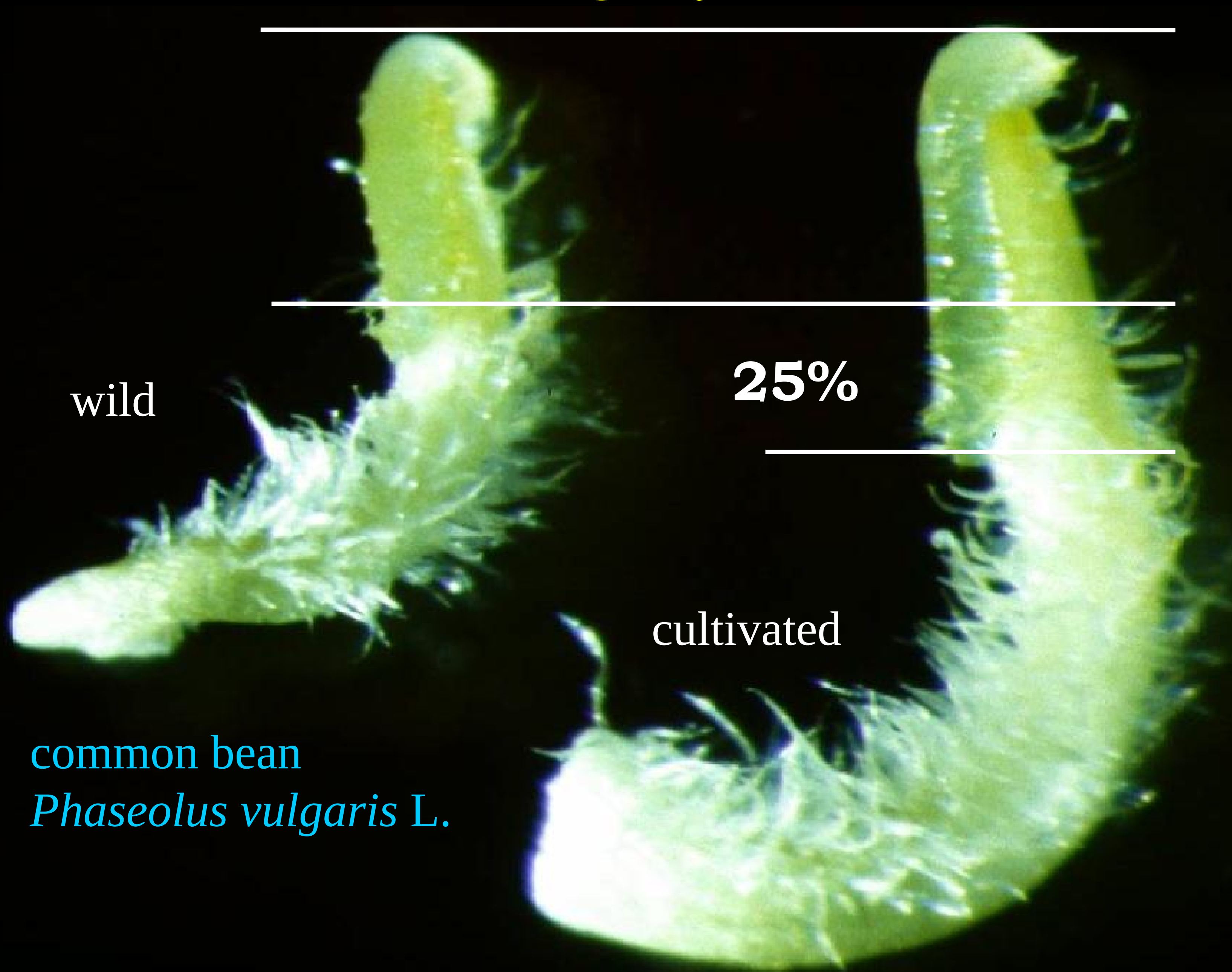
sources: Koinange et al. 1996, Gepts 1999

Progress of domestication in lentil, for two traits: seed dormancy and pod fibers



source : Ladizinsky 1987

towards increased autogamy ?



Conscious selection

Periodical appearance of white-seeded mutants in populations of wild pulses

Phaseolus lunatus L., wild form

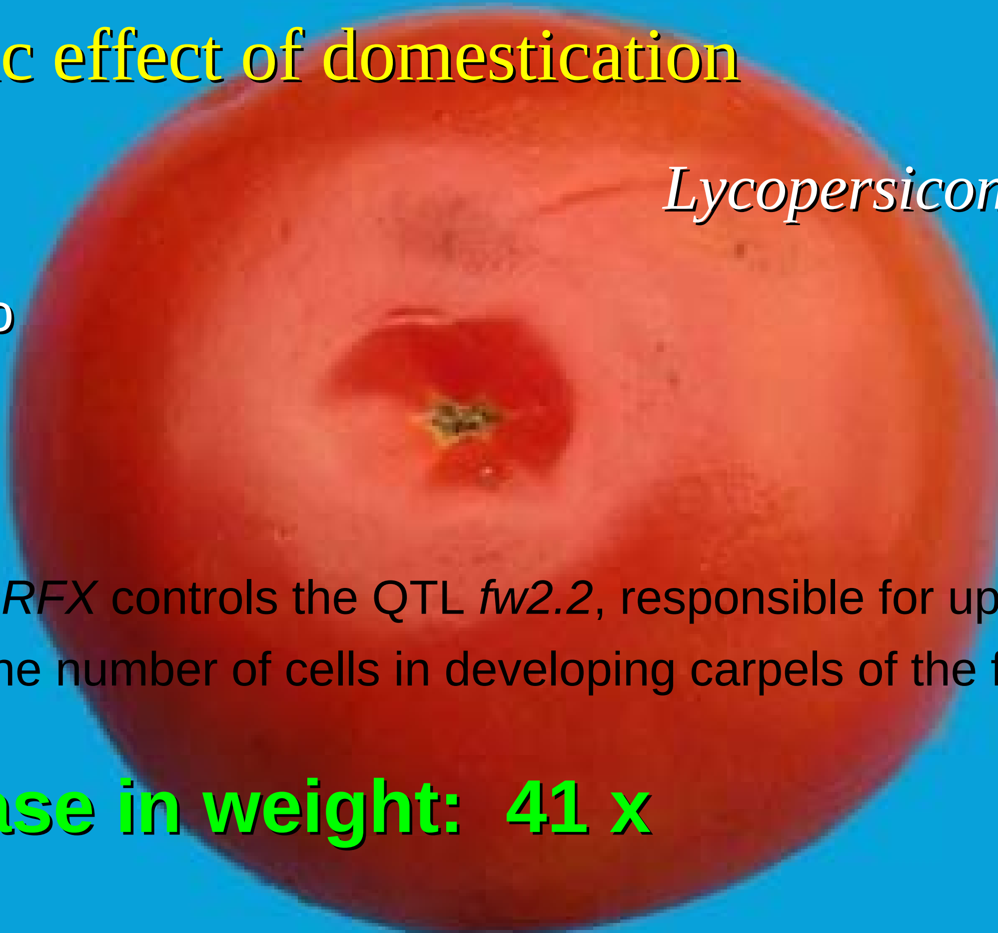
collected in February 1979 in Hopelchen, Campeche, Mexico

photo: Martínez 2006

Dramatic effect of domestication

Lycopersicon esculentum Mill.

Milano tomato



248.6 g

A single gene *ORFX* controls the QTL *fw2.2*, responsible for up 30% increase in weight

ORFX controls the number of cells in developing carpels of the flower (Frary et al. 2000)

Increase in weight: 41 x

Cherry tomato

6.0 g

cm

Dramatic effect of domestication

Capsicum annuum L.

Conclusions

there were no model to copy, no ‘blue-print’ for plant domestication

perhaps none was absolutely necessary, because it was unconscious

some plants were genetically candidates for domestication

traits of the syndrome are controlled by a few genes

few QTLs with major phenotypic expression, often correlated

conservation of same gene sequences would explain the ‘sister’ domestications

breeding system often autogamous, with enough gene flow, but not too much

selection practice(s) along traits of the syndrome, constant because of cultural identity

in 10-200 generations domestication was achieved; efficacy of ‘coa’ agriculture

most of the ‘wild’ genepool was simply untouched and is thus accessible

what would be the ‘ecological cost’ of major shifts among ‘domestic’ QTLs ?


Thank you !