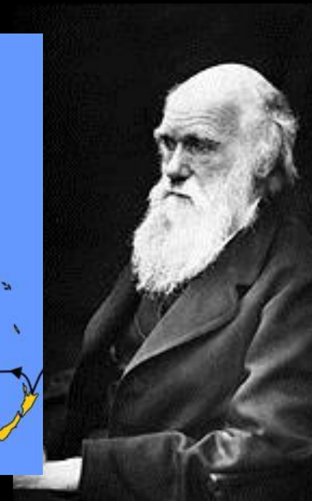
Genetické aspekty domestikace rostlin

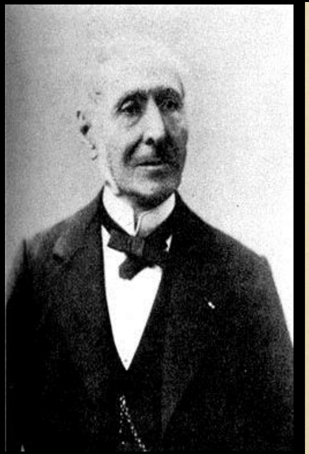
Petr Smýkal
Katedra botaniky
Univerzita Palackého v Olomouci

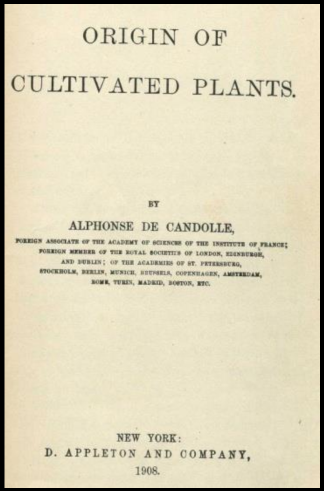


Charles Darwin (1809-1882)

Variation of Animals and Plants under Domestication (1868)

On the Origin of Species (1859)





ORIGIN OF

CULTIVATED PLANTS.

BY

ALPHONSE DE CANDOLLE,

FOREIGN ASSOCIATE OF THE ACADEMY OF SCIENCES OF THE INSTITUTE OF FRANCE; FOREIGN MEMBER OF THE ROYAL SOCIETIES OF LONDON, EDINBURGH, AND DUBLIN; OF THE ACADEMIES OF ST. PETERSBURG, STOCKHOLM, BERLIN, MUNICH, BRUSSELS, COPENHAGEN, AMSTERDAM, ROME, TURIN, MADRID, BOSTON, ETC.

NEW YORK:
D. APPLETON AND COMPANY,
1908.

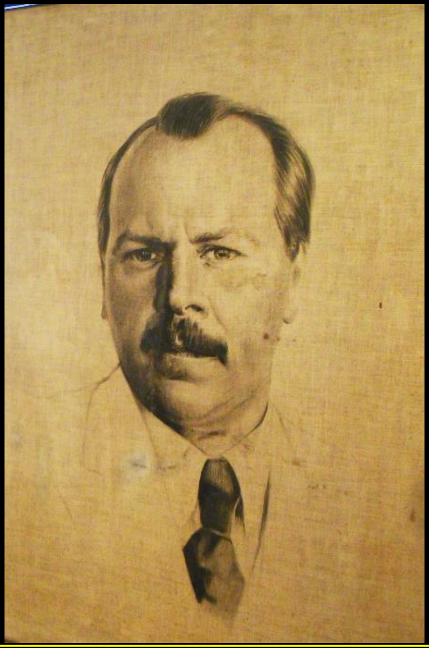
Alfonse De Candolle (1806 – 1893)

Géographie Botanique Raisonée (1855)

L'Origine des Plantes Cultivées (1883)

Nikolaj Ivanovič Vavilov (1887-1943)

Centers of Origin of Cultivated Plants (1926)
The Phytogeographical Basis for Plant Breeding (1935)



Místa neolitické revoluce

„Úrodný Půlměsíc“

9500 př.n.l.

Jižní Amerika

6000 př.n.l.

Střední Amerika

6000 př.n.l.

Jihovýchodní Asie

7000 př.n.l.

Kombinace přístupů pro zjištění možného geografického původu kulturních rostlin

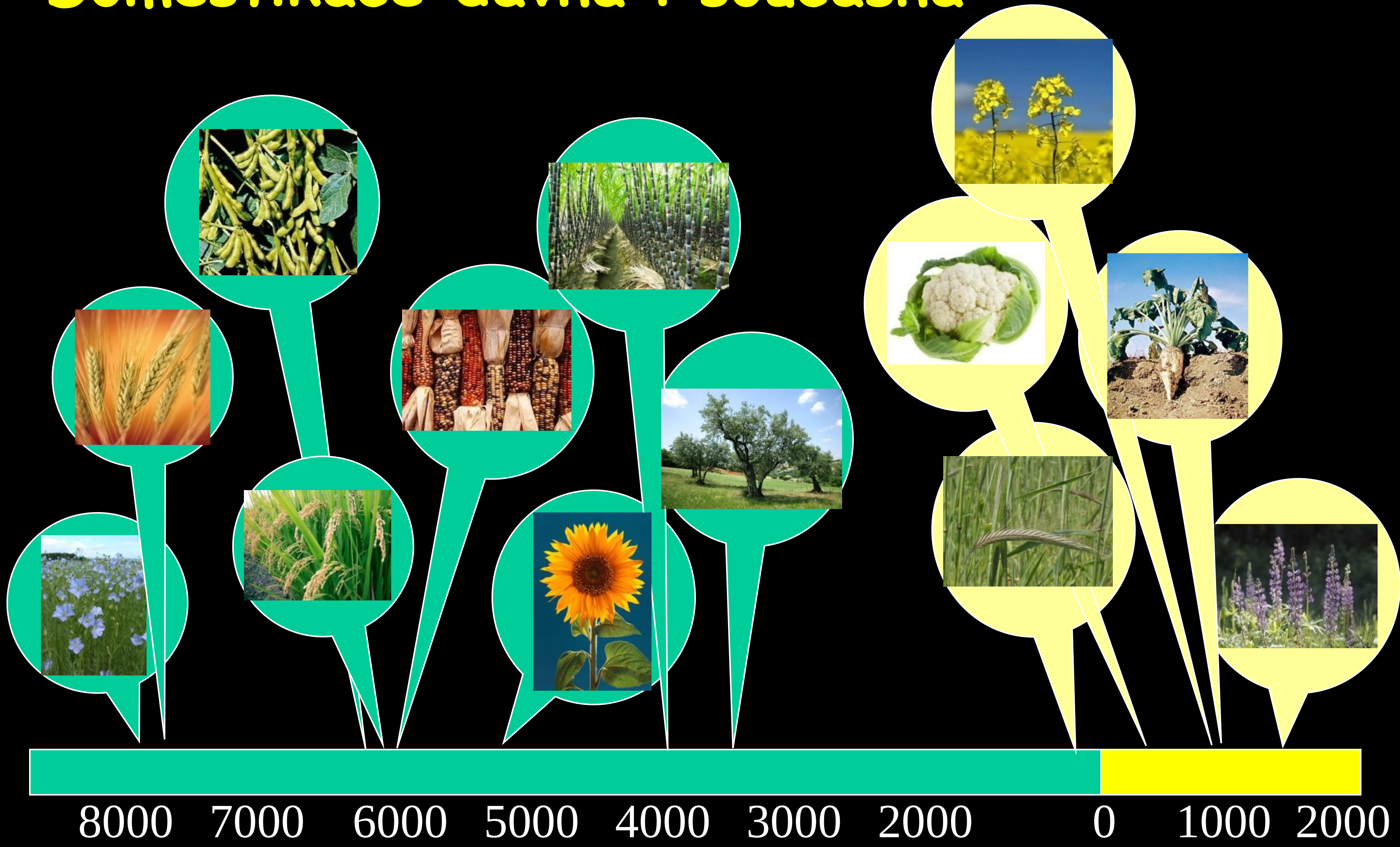
1. Plants (living): biosystematic analyses, including genetics, cytogenetics, chemotaxonomy, morphology, ecology, geography, and so on, of the crops and their near relatives (essentially the Vavilovian approach).
2. Plants (past): archaeobotany, palynology, Carbon-14 dating.
3. Men (living): linguistics, oral traditions, techniques of use and cultivation, attitudes towards the crop in culture, religion, magic and so on.
4. Men (past): history, art, archaeology (artifacts and refuse left by man).
5. Other sources: geology, hydrology, erosion and siltation patterns, soil analyses, limnology, animal remains, and so on, for supporting evidence of changes in climate, vegetation, and fauna, as well as for circumstantial evidence of agriculture.

Harlan, 1971

Studies on Ancient Rice—Where Botanists, Agronomists, Archeologists, Linguists, and Ethnologists Meet

Diffused series of events—Nesbitt 2004; Willcox 2005; Weiss et al. 2006; Morrell and Clegg 2007	Highly localised event—Abbo et al. 2001, 2006, 2010a; Özkan et al. 2002; Salamini et al. 2002; Lev-Yadun et al. 2000
Repeatedly recurring event—Ladizinsky 1998; Ladizinsky and Genizi 2001; Willcox 2005; Kilian et al. 2007; Allaby et al. 2010	Single occurrence—Lev-Yadun et al. 2000; Gopher et al. 2001
Slow and gradual—Tanno and Willcox 2006; Allaby et al. 2008, 2010; Brown et al. 2009; Fuller et al. 2010	Fast changing—Hillman and Davies 1990; Ladizinsky 1987; Zohary 1996
Exclusive, each species selected independently—Willcox 2005	Inclusive—Abbo et al. 2010b
Unintentional, unconscious, incident—Harlan et al. 1973; Zohary 2004; Mithen 2007	Intentional, conscious—Ladizinsky 1987; Abbo et al. 2005; Kerem et al. 2007; Abbo et al. 2009, 2010b

Domestikace dávná i současná



Fabaceae	41	fazole, hrách, čočka, soja, vigna
Gramineae	29	kukuřice, rýže, pšenice, proso
Brasicaceae	25	zelí, řepka,hořčice
Solanaceae	18	rajče, brambor, paprika, tabák
Cruciferae	13	řepka, zelí , ředkev
Cucurbitaceae	13	okurek, meloun, dýně
Rosaceae	11	jabloň, broskve, švestky
Liliaceae	11	cibule, česnek,pór
Daucaceae	9	mrkev, fenykl, kopr, kmín
Asteraceae	8	slunečnice, topinambur

Domestikované plodiny

Asie

rýže, sója, proso, cukrová třtina, banánovník, taro, jam


Střední východ - Středozemí

pšenice, ječmen, cizrna, hrách, čočka, vikev, len, olivovník


Amerika

slunečnice, kukuřice, fazole, podzemnice, tykev, brambory


Afrika

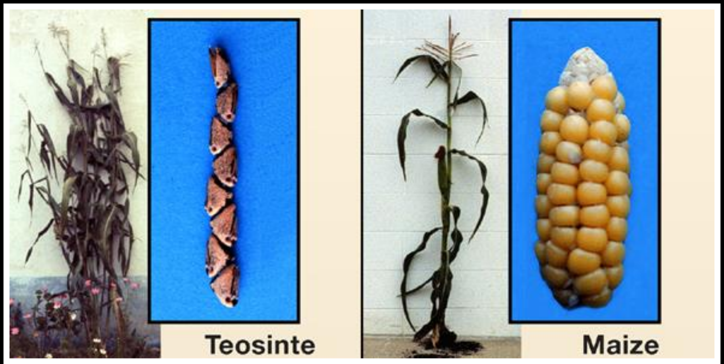
čirok, vigna, proso, káva, olejová palma, africká rýže


The "founder crops" of the Near Eastern agriculture, after Zohary and Hopf (2000).

Common name	Scientific name	Wild progenitor
Einkorn wheat	*Triticum monococcum* L.	*T. monococcum* ssp. *booeticum* (Boiss.) A. et D. Löve.
Emmer wheat	*Triticum turgidum* ssp. *dicoccum* (Schrank) Thell.	*T. turgidum* ssp. *dicoccoides* (Körn.) Thell.
Common barley	*Hordeum vulgare* L.	*H. spontaneum* C. Koch
Pea	*Pisum sativum* L.	*P. humile* Boiss. et Noë
Lentil	*Lens culinaris* Medikus	*L. orientalis* (Boiss.) Handel-Mazzeti
Chickpea	*Cicer arietinum* L.	*C. reticulatum* Ladiz.
Bitter vetch	*Vicia ervilia* (L.) Willd.	*V. ervilia* (L.) Willd.
Flax	*Linum usitatissimum* L.	*L. usitatissimum* ssp. *bienne* Mill.

Plané formy – předchůdci pěstovaných plodin

slunečnice



kukuřice

pšenice

Domestikační syndrom
výběr vhodných genotypů/fenotypů

- větší zásobní orgány - semena, hlízy
- rozpadavost klasu – šíření semen
- snížení, ztráta dormance
- odnožování x dominance
- popínavost x keřovitost
- partenokarpie
- pohlaví květu – oboupohlavnost
- samosprašnost – reprodukční isolace - homozygozita
- změny ploidie
- fotoperiodismus
- víceletost x jednoletost
- eliminace toxických látek

Patterns and processes in crop domestication: an historical review and quantitative analysis of 203 global food crops

Rachel S. Meyer[1,2]*, Ashley E. DuVal[3]* and Helen R. Jensen[4]*

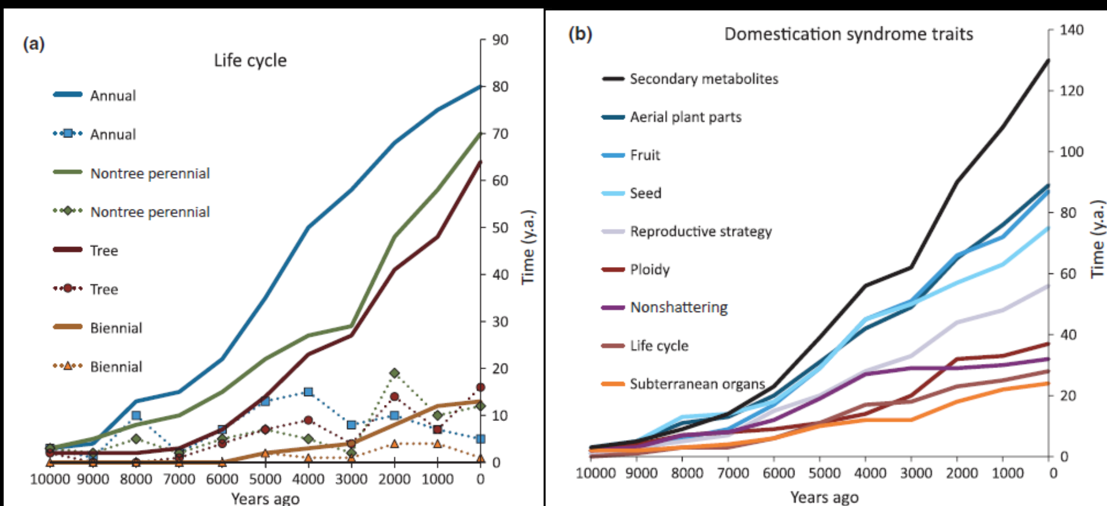
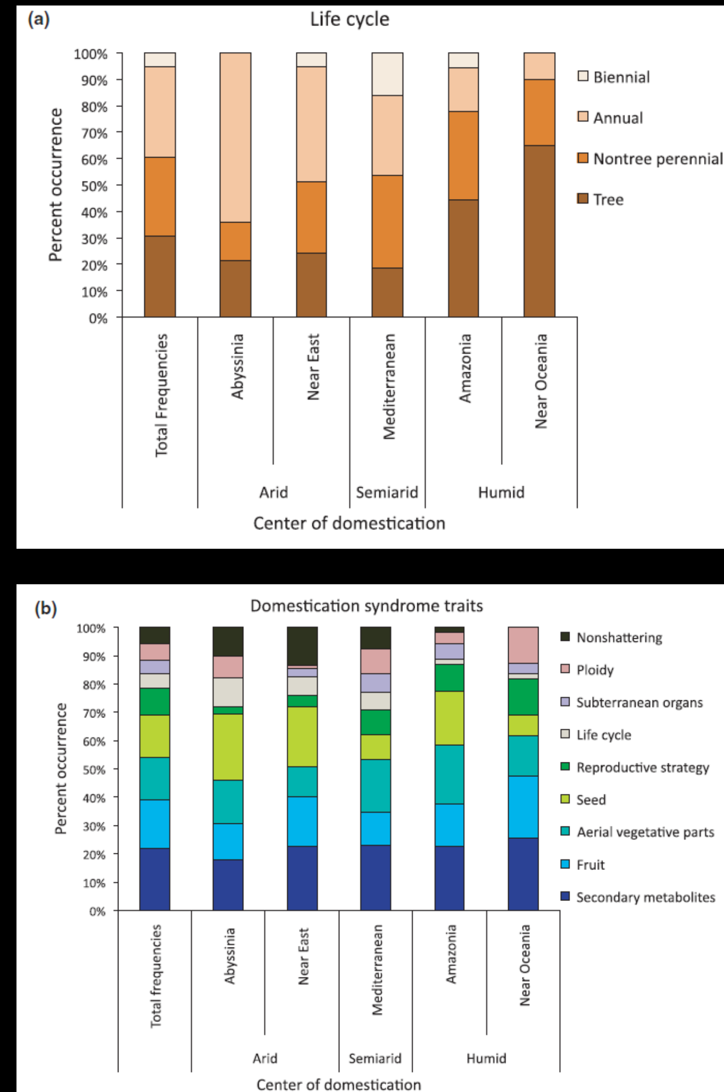


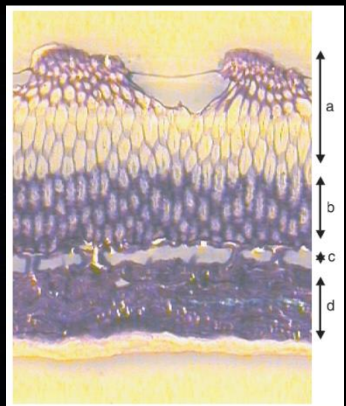
Fig. 2 The number of occurrences of life cycle types and domestication syndrome traits for 203 food crops as a function of the time at which domestication occurred. (a) The number of occurrences of different life cycles are shown both cumulatively (solid lines) and by interval within each 1000 yr period (dotted lines), from the earliest domestication events until the present. Temporal trends in the distribution of the different life cycles show that the appearance of domesticated annuals increases from 9000 to 4000 yr ago (ya), and then starts to slow. The broad dissemination and



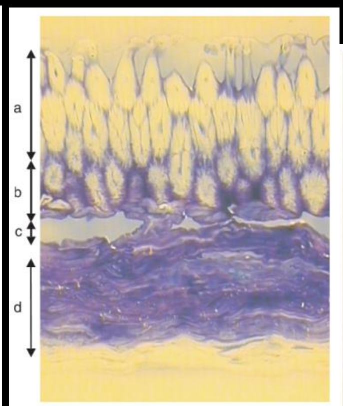
Domestikací modifikované znaky

Hrách (*Pisum sativum*)

znak	plané formy	domestikované
pukavost lusku	ANO	NE
dormance semen	ANO	NE
výška rostliny	vysoká	nízká
větvení stonku	ANO	NE
velikost semen	malá	velká
kvalita semen	nízká	vysoká
obsah antinutričních látek	ANO	NE
kvetení	dlouhý den	neutrální

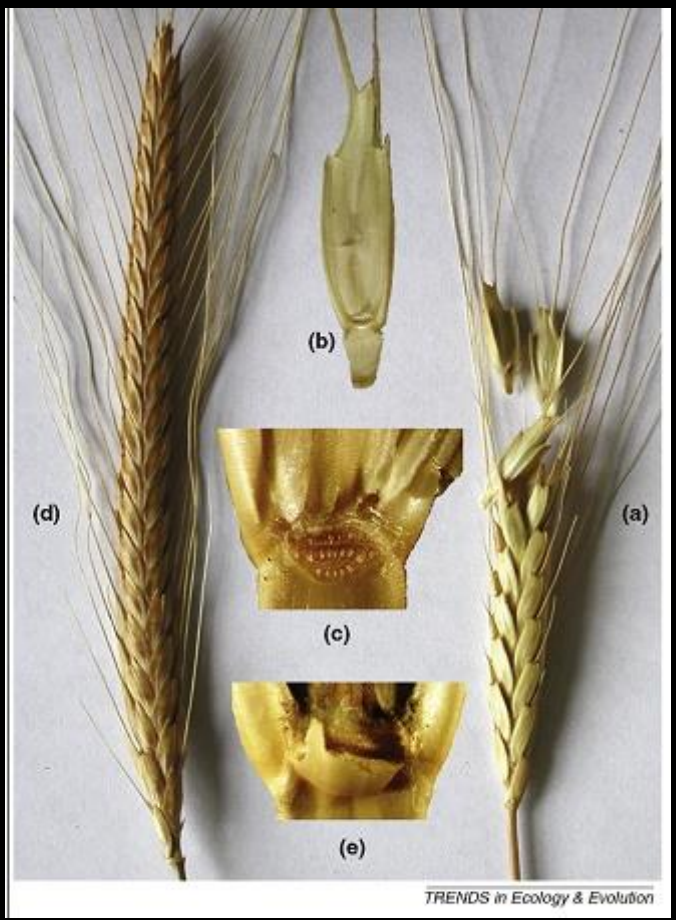


Erregula (hardseeded)



85E 10 (softseeded)

Šíření a klíčení semen
klíčové znaky domestikace

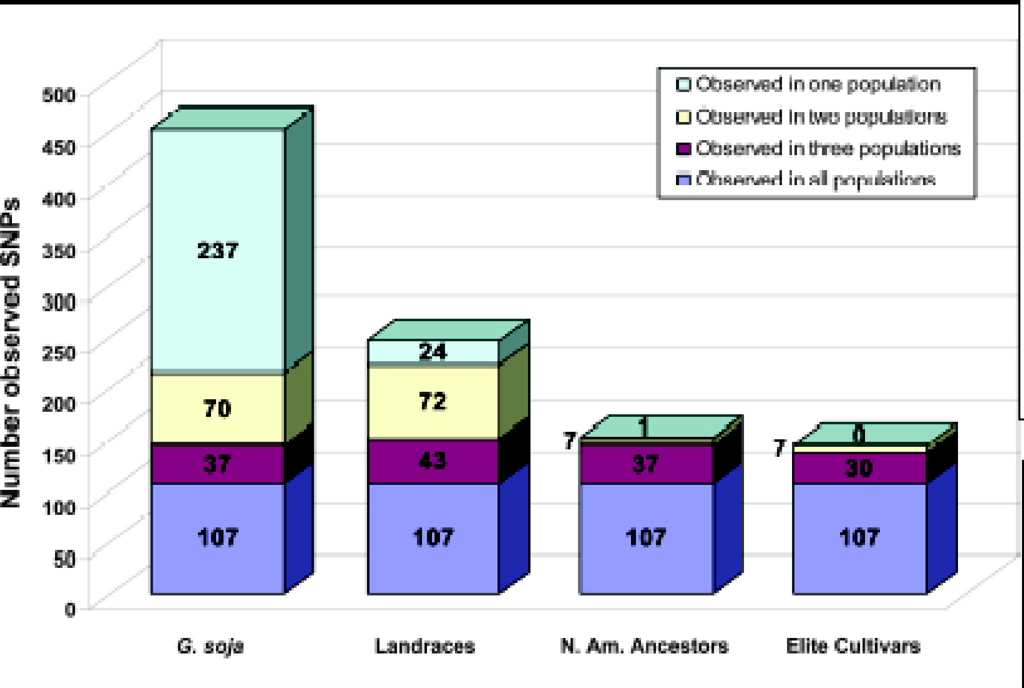


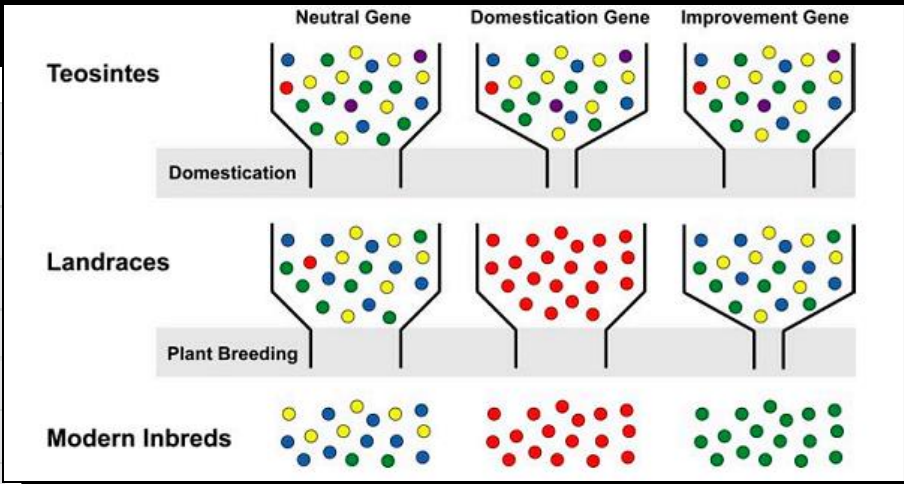
Šíření a klíčení semen
klíčové znaky domestikace

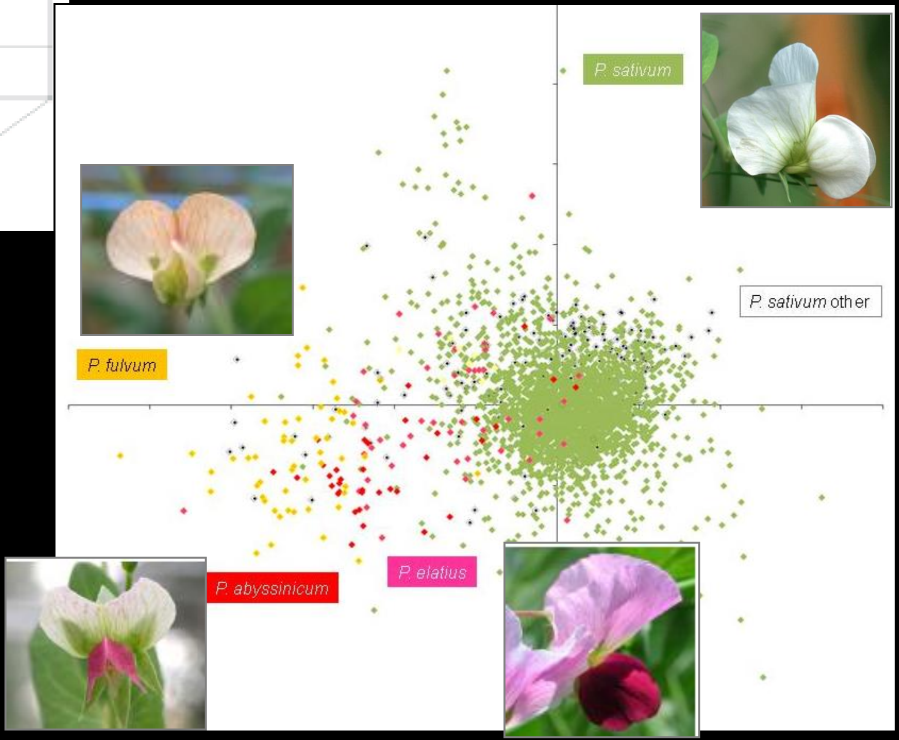
dormance
u planých forem

uniformní klíčení
kulturních forem

Domestikace a výběr







Pěstované formy/druhy
70% diverzity
planých druhů

Význam genetické diversity

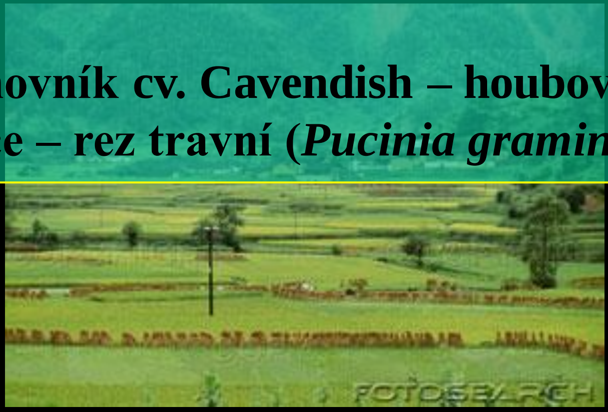
Mayové - monokultura kukuřice - choroby/škůdci/eroze

Irsko (1846) - *Phytophtora infestans* u brambor

USA (1970) – hybridní kukuřice x *Helminthosporium maydis*
T typ CMS ve vazbě na gen náchylnosti

USA - *Xanthomonas* campestris u citrusů

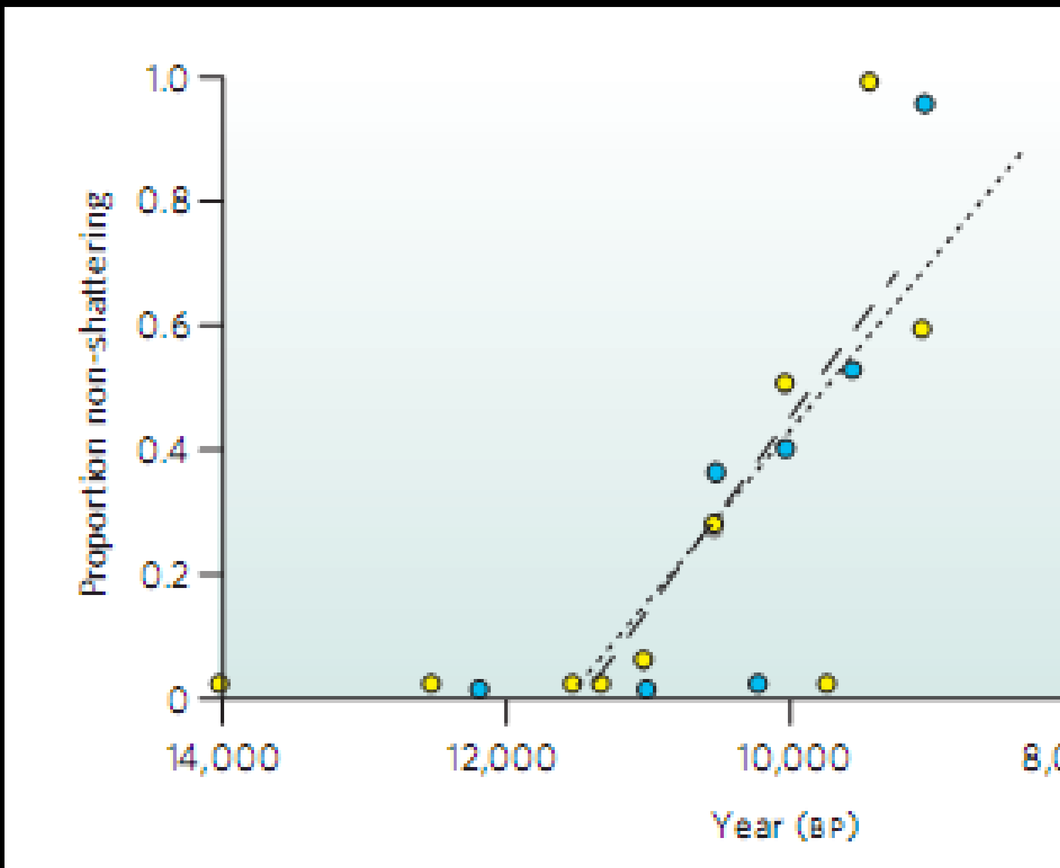
současnost - banánovník cv. Cavendish – houbové choroby
- pšenice – rez travní (*Pucinia graminis*) Ug99



Rychlost domestikace

fixace znaku 100 – <u>2000</u> let

frekvence výskytu nerozpadavého klasu
v archeologických nálezech versus modelování a experimenty



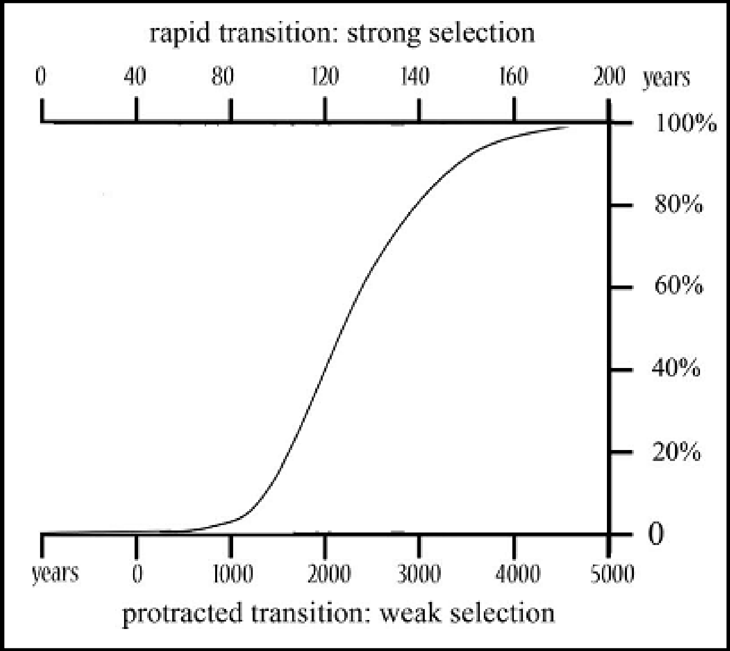
recesivita x dominance
mono x polygenost
samo x cizosprašnost

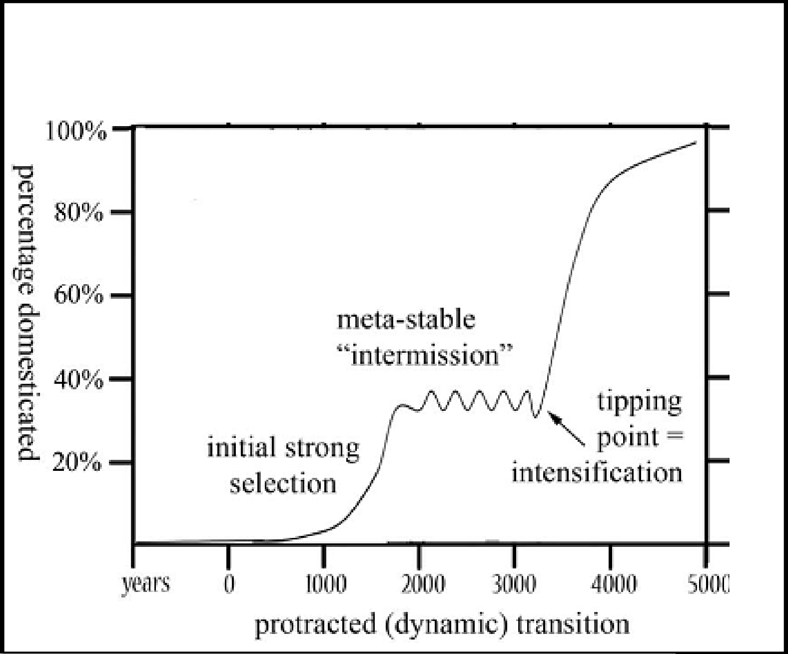
F

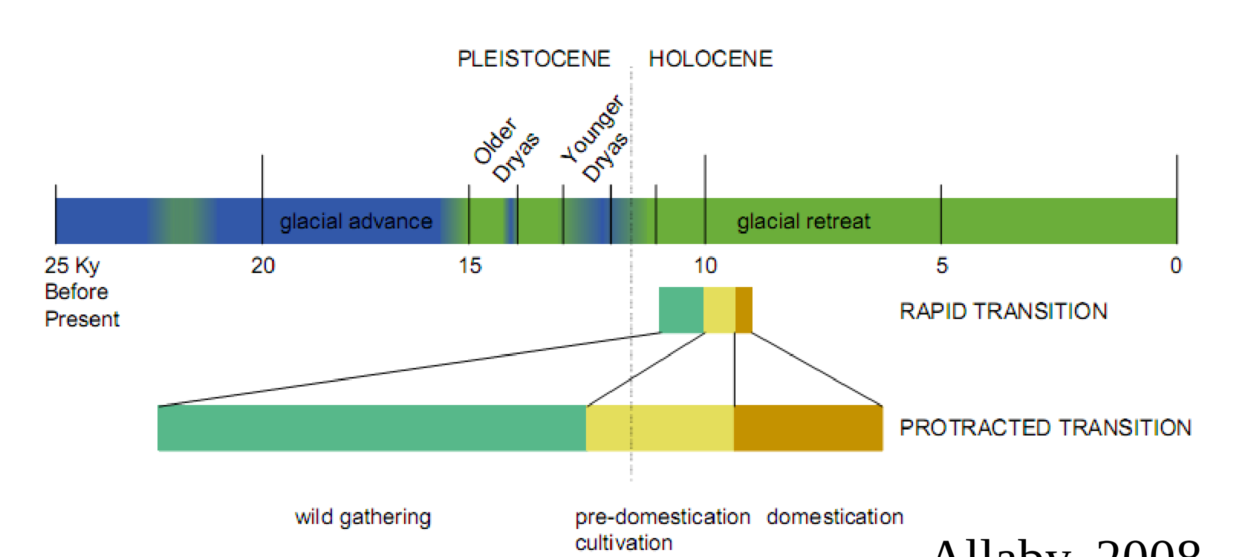
Dates (year BP)	Archaeological site	Domestication rate (%)
10,200	Qaramel	22
9,250	Nevali Cori	32
9,300-8,500	Aswad	30
8,500-7,500	Ramad	59
7,500	el Kerkh	59
6,500	Kosak Shamali	95

ječmen, pšenice, rýže

Rychlost domestikace

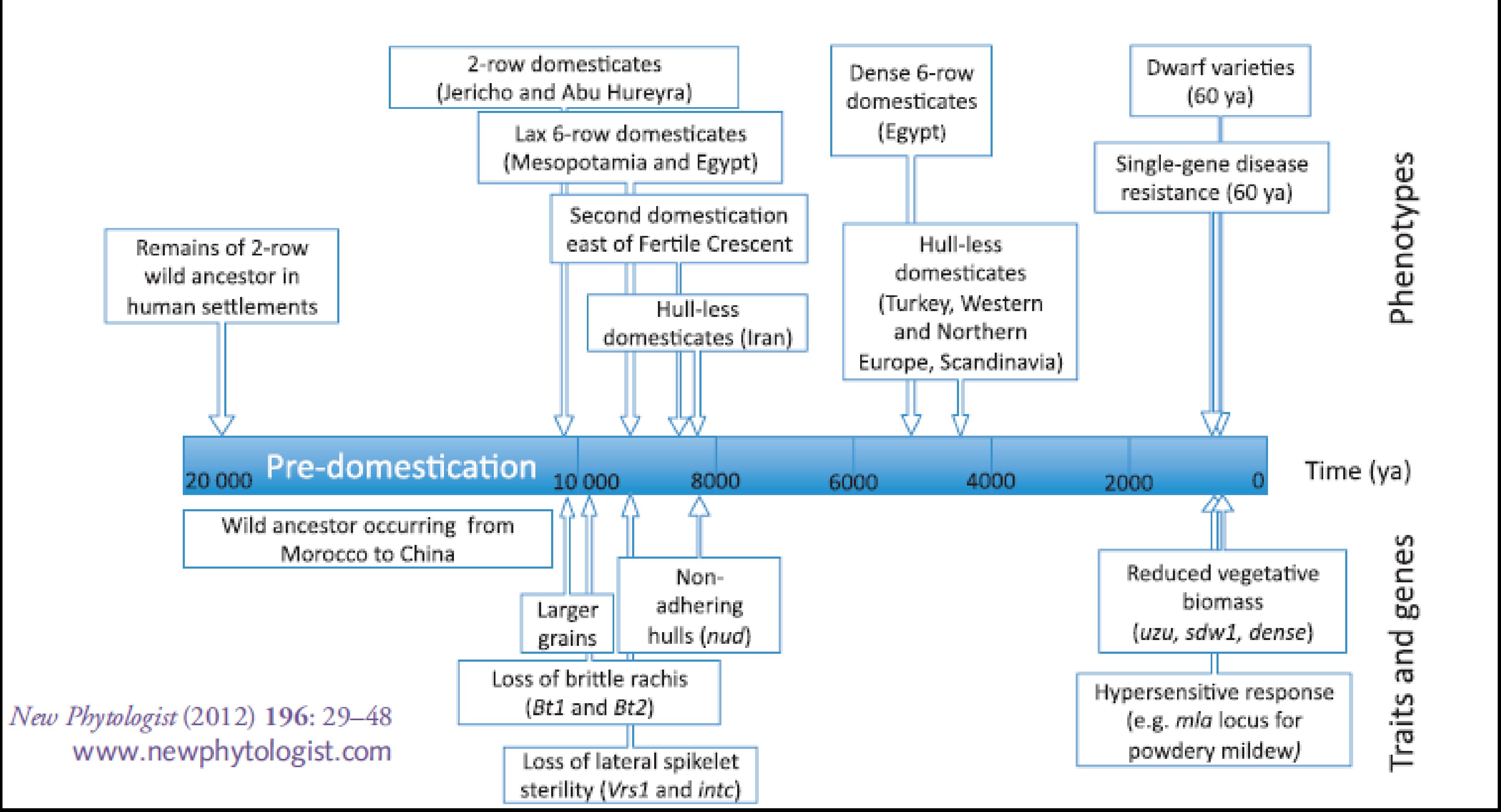




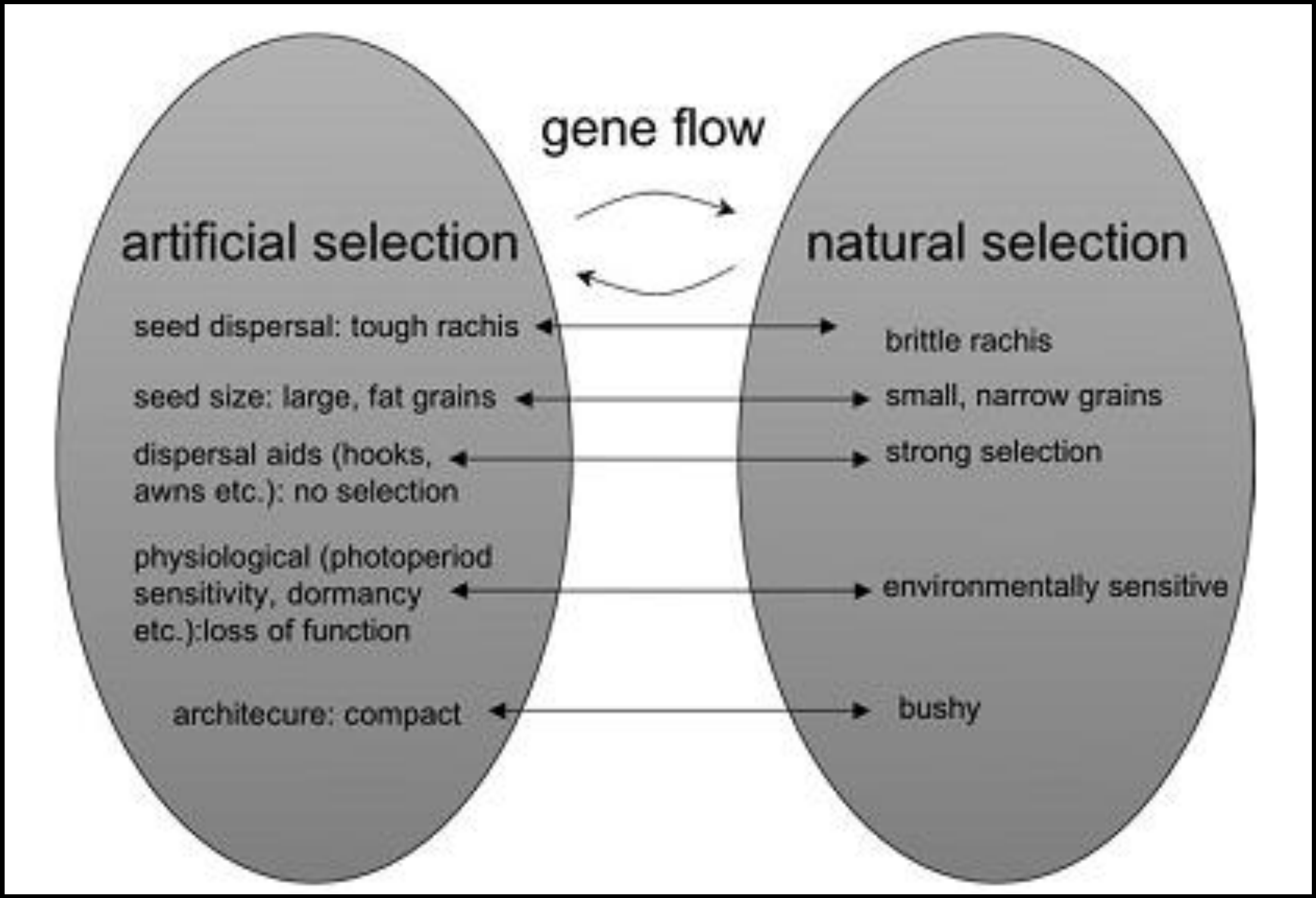


Allaby, 2008

The domestication history of barley (*Hordeum vulgare* ssp. *vulgare*) from its wild ancestor (*Hordeum vulgare* ssp. *spontaneum*),



Tok genů mezi planými a kulturními formami



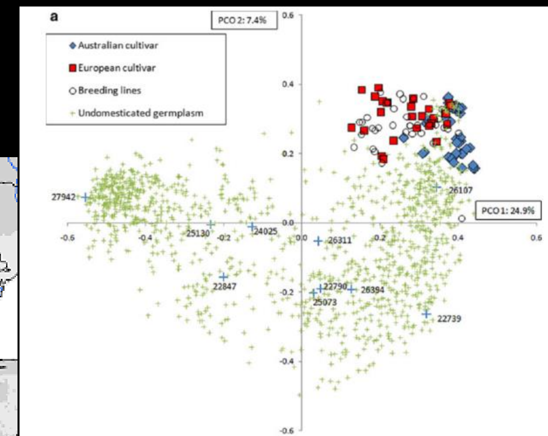
zpomaloval proces

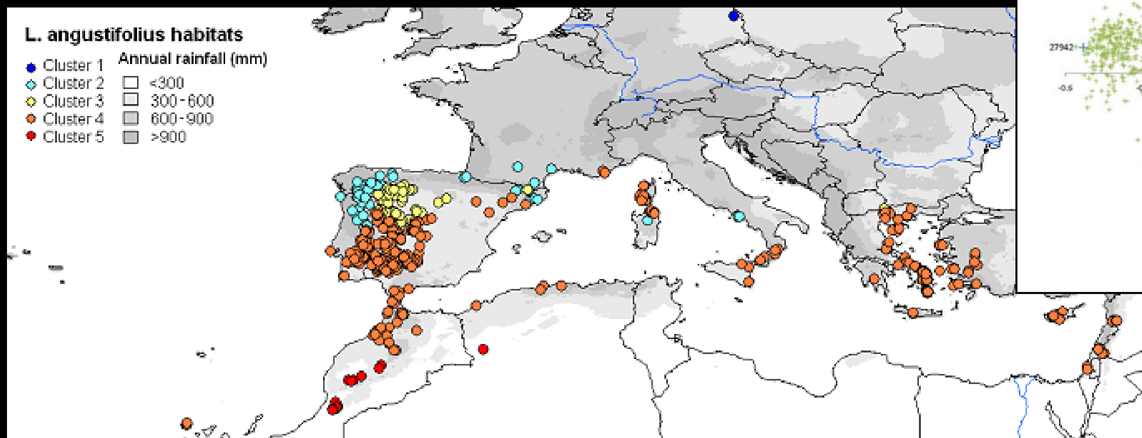
proto rychlejší fixace znaků mimo genová centra

Recentní domestikace lupiny (50-100 let)

Lupinus albus, ***L. angustifolius, L. luteus*** *-Středozemí*

L. mutabilis – J. Amerika





- Vernalizace
- Fotoperioda
- Dormance
- Pukavost lusků

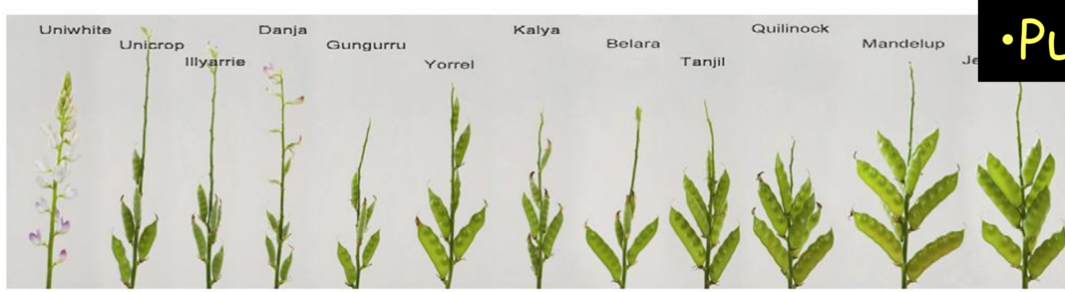


Fig. 7. Changes in main stem fecundity over 40 years of lupin breeding, represented by selected cultivars from Uniwhite (1967) to Jenabillup (2007).

Recentní domestikace lupiny (50-100 let)

Vernalization response[a]	Cultivar	Release date	Photoperiod response[b]	Temperature response[c] (no vern factor in model)	Temperature response (with vern factor in model)	Vernalization coefficient[d]
Obligate	Uniwhite	1967	0.70	–0.0 NS	0.39	19
Obligate	Marri	1976	0.78	–0.0 NS	0.47	16
Obligate	Geebung	1987	0.72	–0.0 NS	0.39	16
Obligate	Uniharvest	1971	0.69	–0.0 NS	0.42	15
Facultative	Jindalee	2002	0.64	0.0 NS	0.35	13
Facultative	Chittick	1982	0.72	0.10	0.33	8
Non-responsive	Tanjil	1998	0.15	0.66	0.63	0
Non-responsive	Wonga	1996	0.18	0.68	0.66	0
Non-responsive	Unicrop	1973	0.1 NS	0.69	0.67	0
Non-responsive	Danja	1986	0.15	0.71	0.71	0
Non-responsive	Tallerack	1997	0.20	0.72	0.69	0
Non-responsive	Quilinock	1999	0.23	0.73	0.69	0
Non-responsive	Gungurru	1988	0.1 NS	0.74	0.71	0
Non-responsive	Coromup	2006	0.0 NS	0.74	0.73	0

L. angustifolius, L. luteus

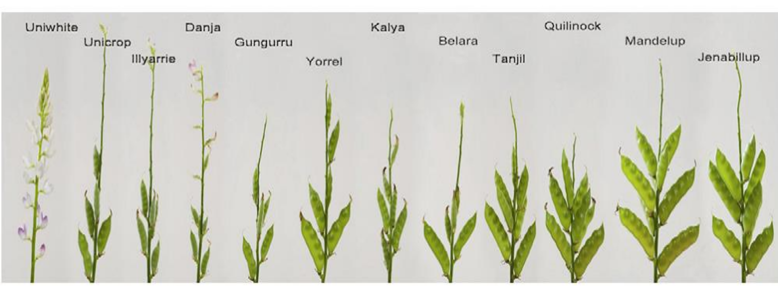
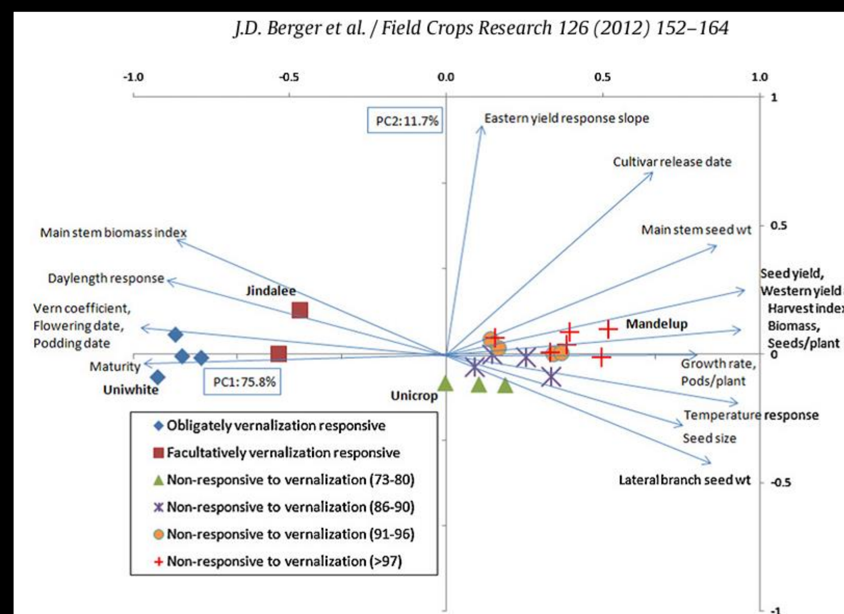


Fig. 7. Changes in main stem fecundity over 40 years of lupin breeding, represented by selected cultivars from Uniwhite (1967) to Jenabillup (2007).



Lokalizace domestikačních genů

Locations of domestication genes

A genetic map of *L. angustifolius* was developed using a mapping population derived from a cross between a domestic line and a natural population originally collected from Morocco which was blue-flowered, late, bitter, hard-seeded, with shattering pods and a non-pigmented cortex at the base of the stem (alleles *Leuc, ku, Iuc, Moll, Ta* and *Le*) (Nelson *et al.* 2010).

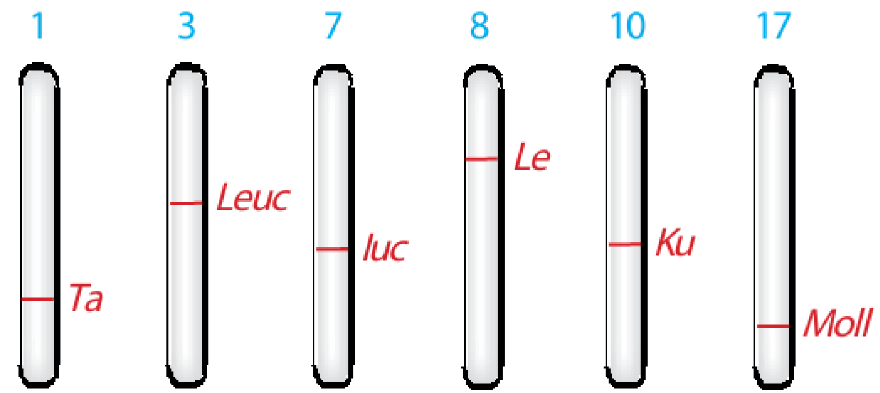
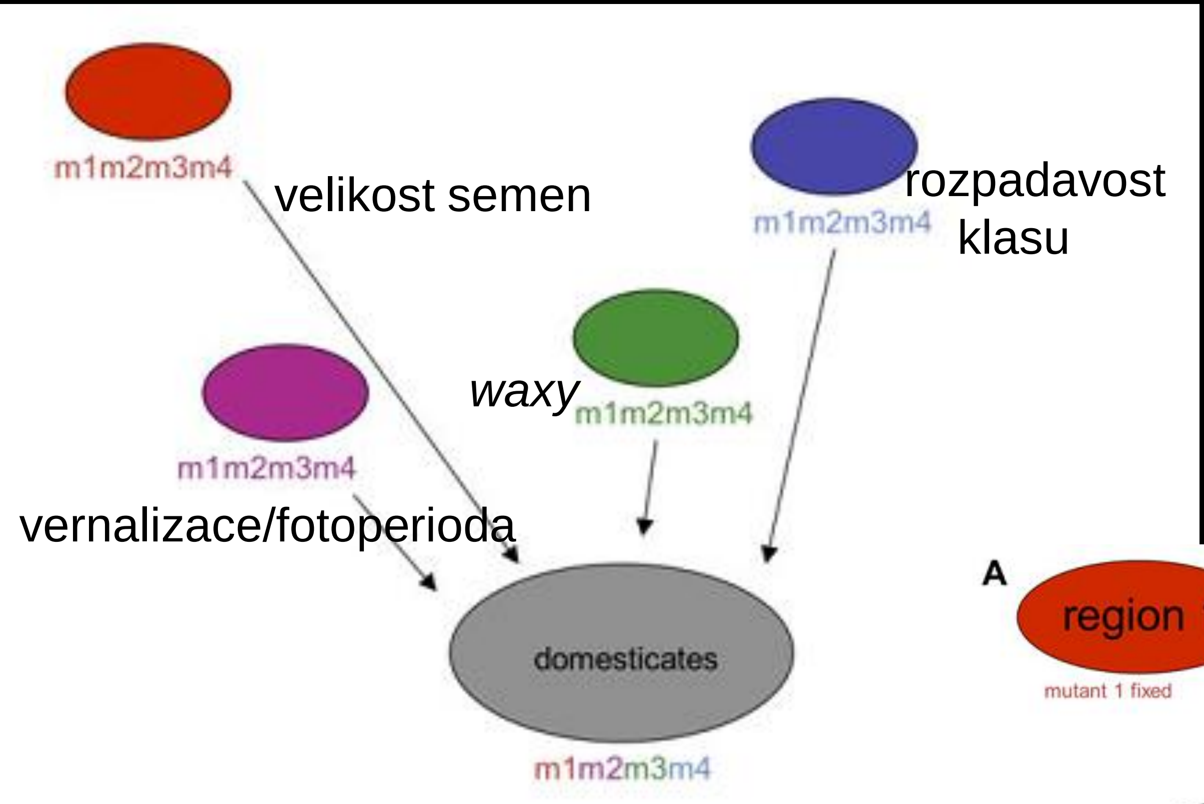


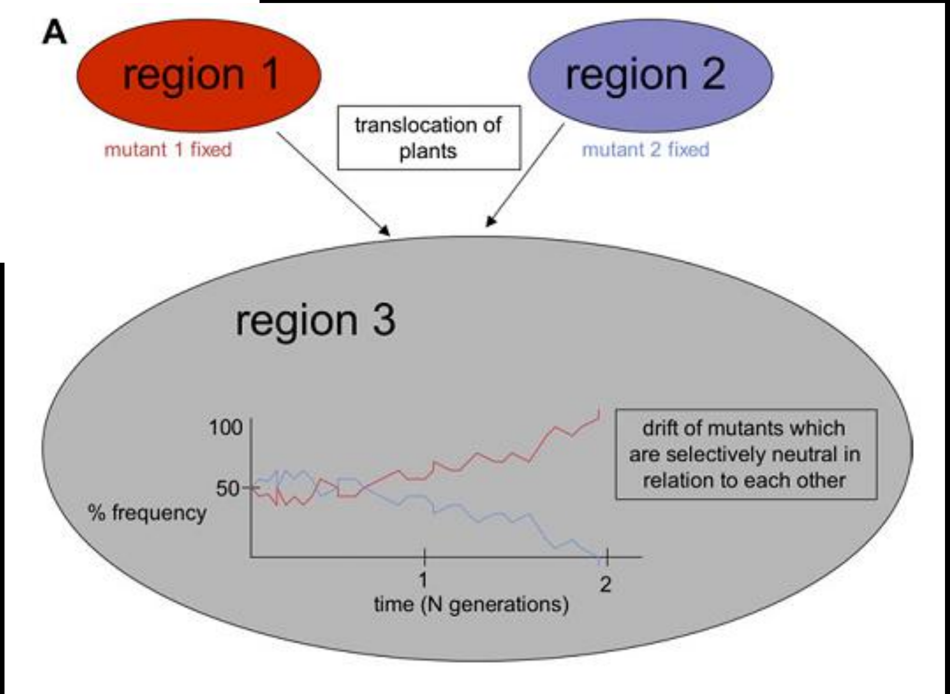
Table 1. Important domestication genes of narrow-leafed lupin (adapted from Gladstones, 1970).

Domestication trait	Characteristic
leucospermus (leuc)	Seeds with white background and various degrees of brown marbling
mollis (moll)	Permeable seed coat
lentus (le)	Reduced pod shattering (accompanied by red pigment in cortex of lower stem and inside pod walls)
tardus (ta)	Reduced pod shattering
iucundus (iuc)	Low alkaloid
Ku	Dominant early flowering (removes vernalization requirement)

ve shluku nebo roztroušené ?

Chronologie fixace znaků

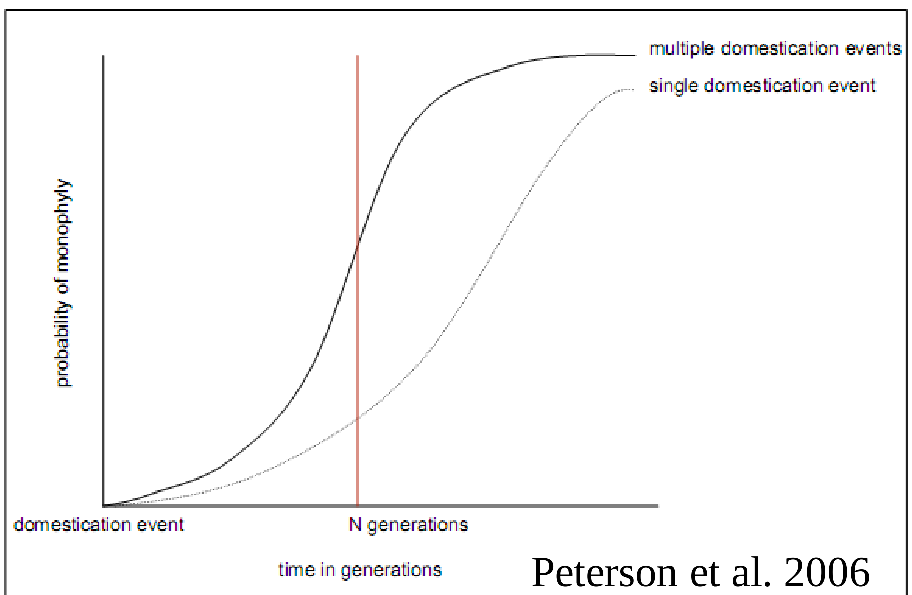


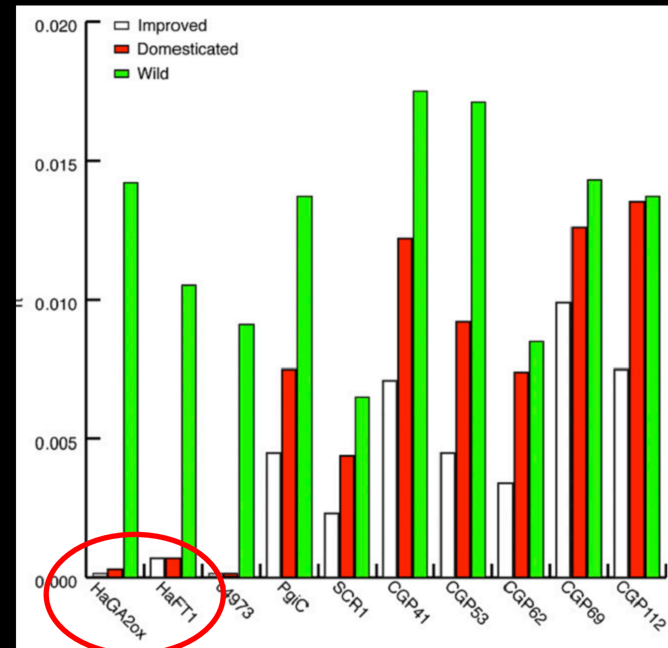


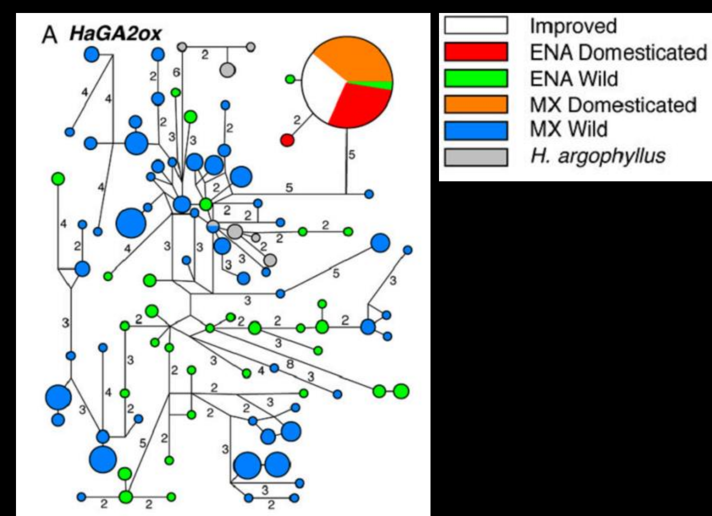
nezávislý vznik na více místech je po kontaktu setřen vlivem působení driftu

Domestikace jednou nebo vícenásobně ?

Figure 3. Probability of obtaining a monophyletic domesticate clade over time for an N sized population





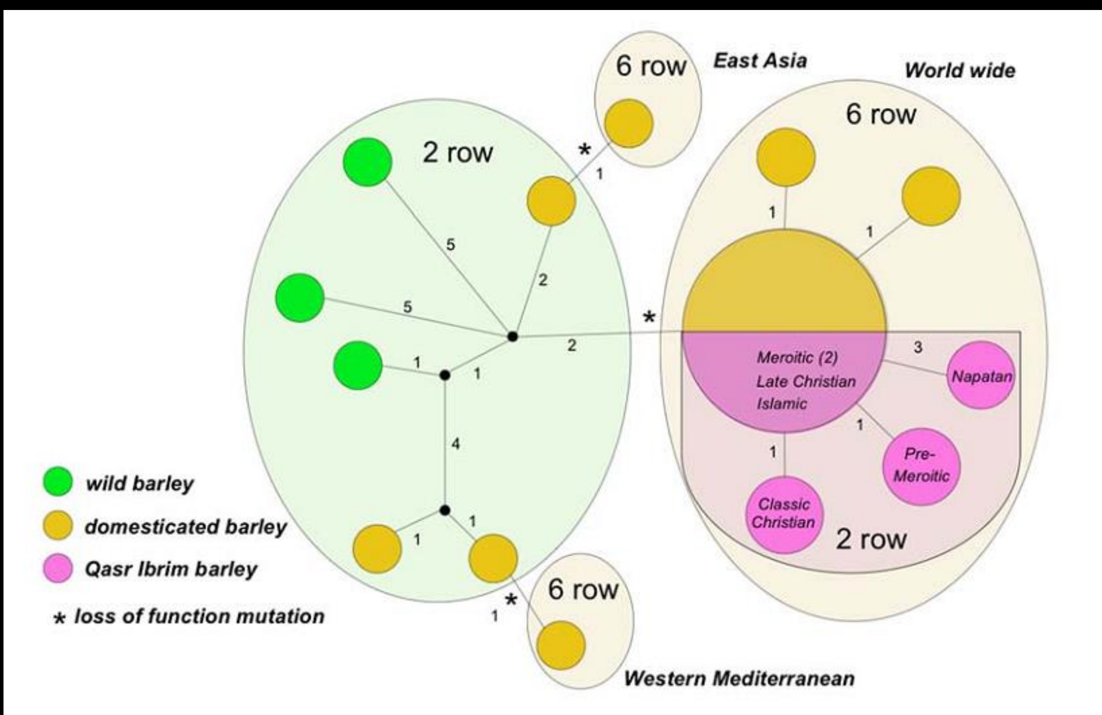


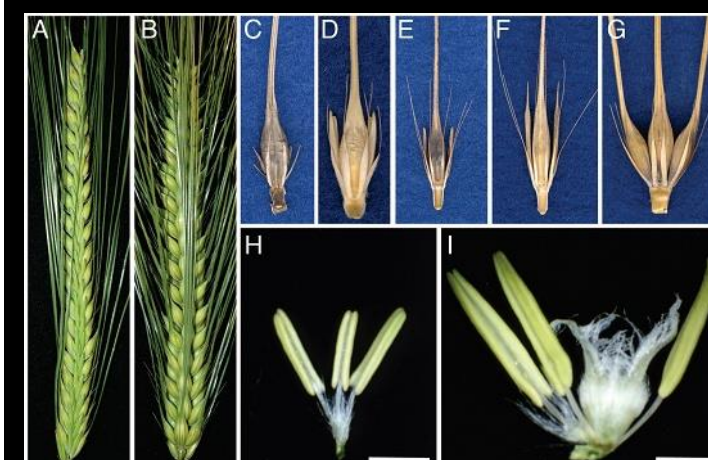
Archeobotanika - archeogenetika

A

Sample Assemblage	Date of Origin	73 G->C 2 specific	139 G->T 2 specific	157 C->T 2 specific	483 A->G a1 haplotype specific	604 A->G a1 haplotype specific	694 G->A 3 specific	873 G->T 3 specific	914 CG->CTG a2 specific	1020 C->G a3 specific	1235 C->T 2 specific	1352 GAG->GA- a1 specific	1589 C->T 1 specific	1668 G->T 2 specific	Amplicon lengths	Post-mortem damage
Islamic	1400 - 1812 AD	G	G	C	A	A	G	G	CG	C	C	GA-	T	G	106 - 235bp	
Late Christian	1100 - 1400 AD	G	G	C		A	G	G	CG	C	C	GA-	T	G	106 - 235bp	
Classic Christian	850 - 1100 AD	-	-	-		-	G	-	-	-	C	GA-	T	-	60 - 150bp	1
Meroitic	100 - 350 AD	G	G	C		A	G	G	CG	C	C	-	T	G	106 - 235bp	
Pre-Meroitic	1 - 100 AD	-	-	-		-	-	G	CG	C	-	-	-	-	100 - 215bp	1
Napatan	800 - 300 BC	-	-	-		A	G	G	CG	C	C	GA-	T	G	100 - 215bp	3

vrs1 lokus ječmene



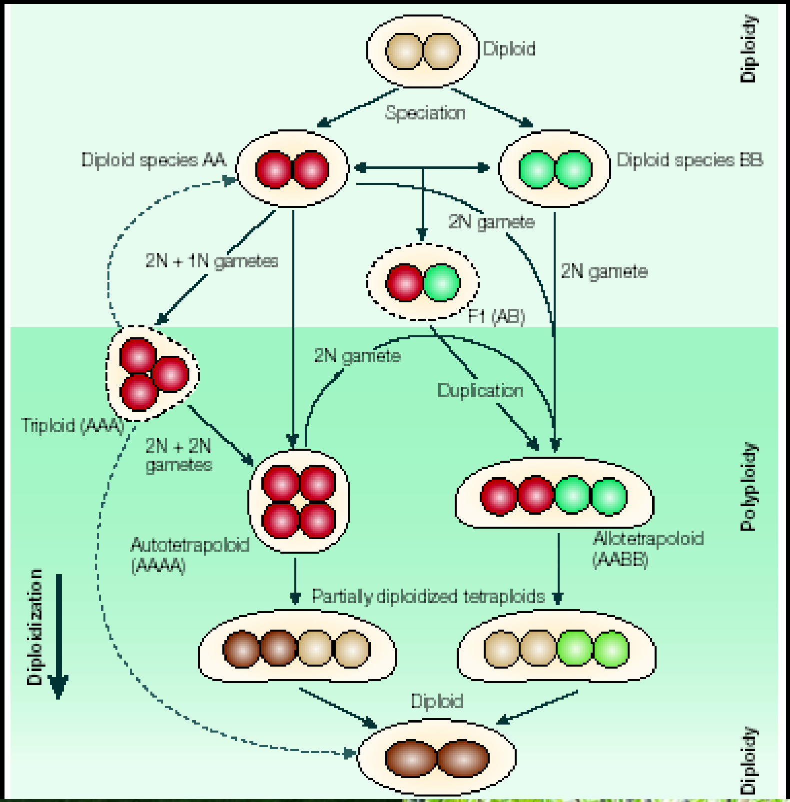


Genetické změny během procesu domestikace

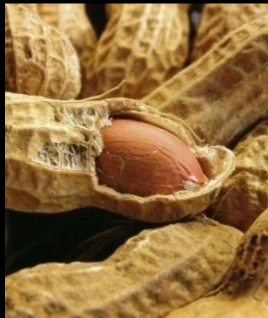
(příčina nebo důsledek)

- změny ploidie
- hybridizace
- mutace

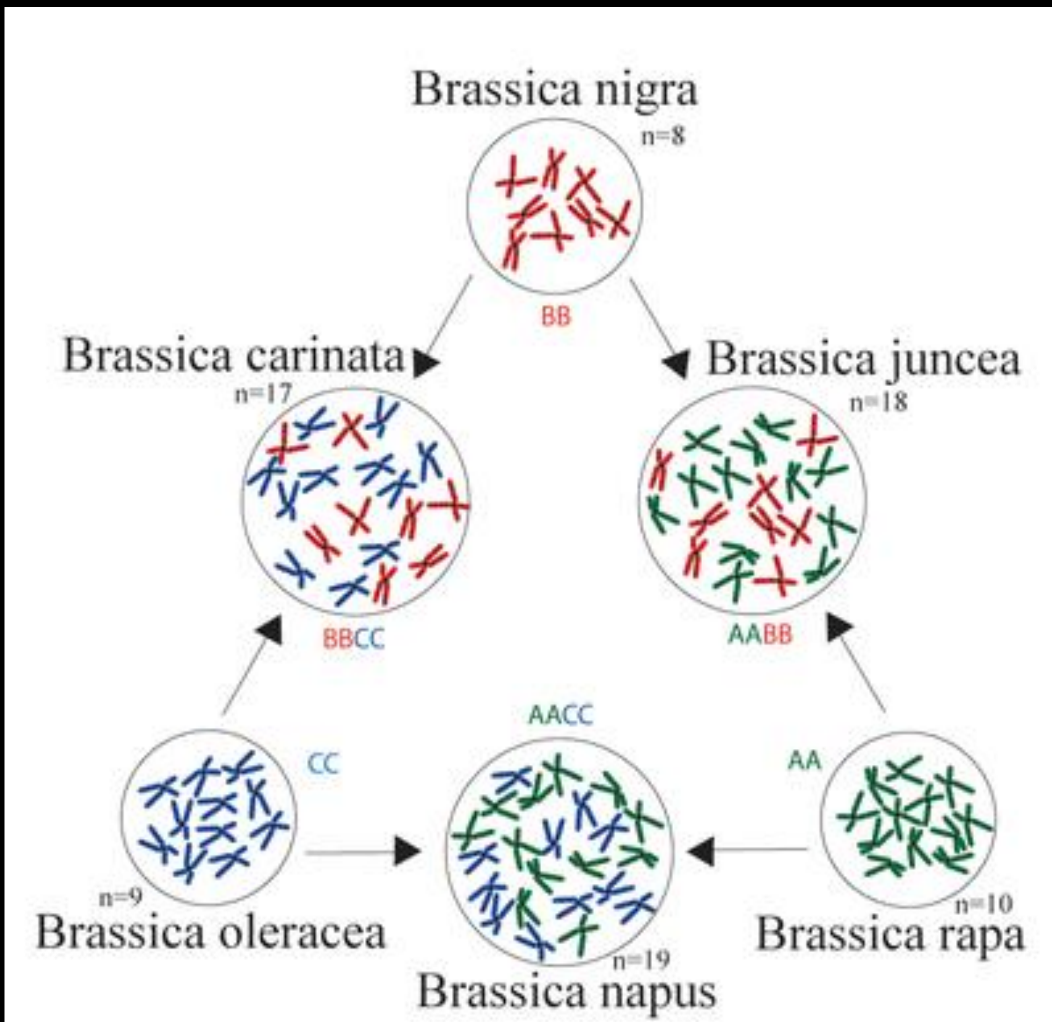
Polyploidie - častý stav genomu kulturních rostlin



3n: banán, jablko, zázvor, řepa
4n: durum pšenice, kukuřice, bavlník, brambor, zelí, tabák, podzemnice
6n: chrysantéma, pšenice, oves
8n: jahodník, jiřiny, cukr. třtina

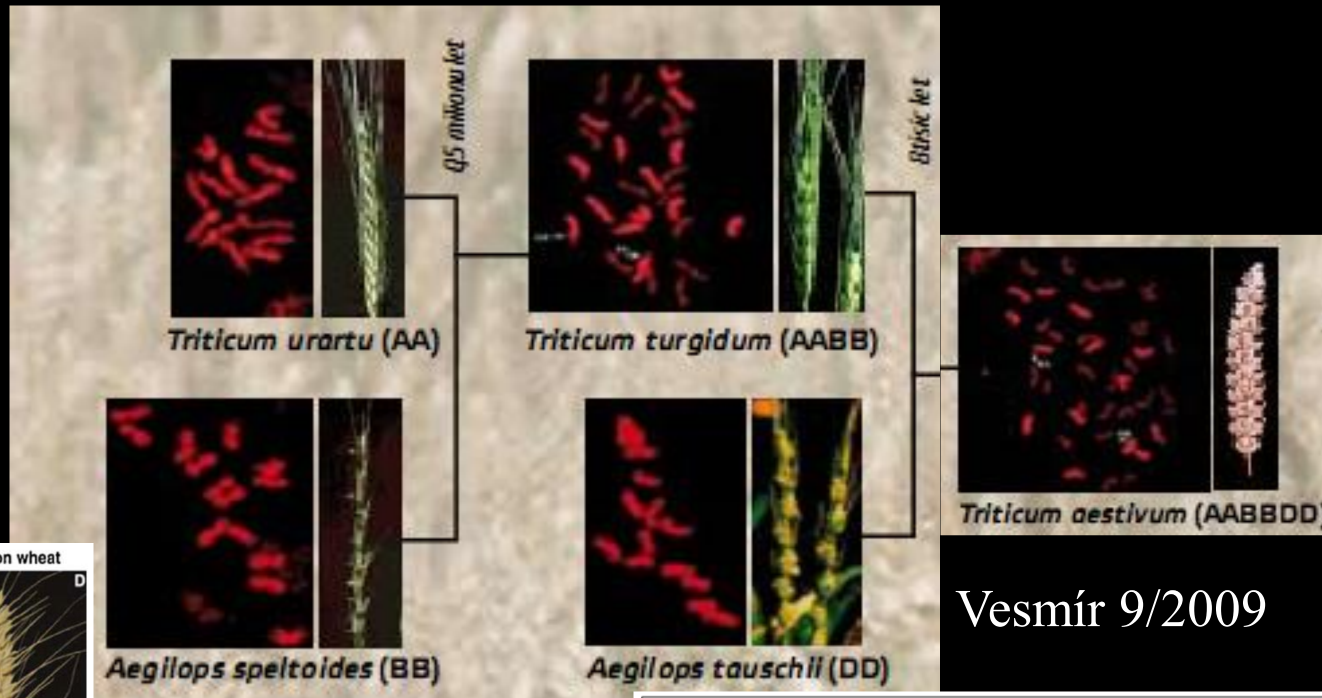


Mezidruhová / mezirodová hybridizace

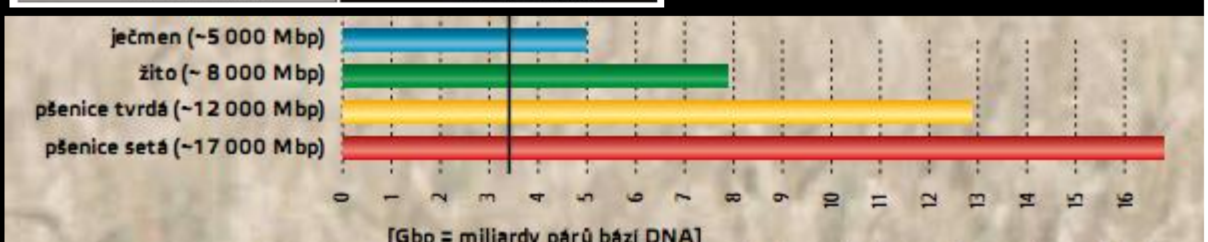


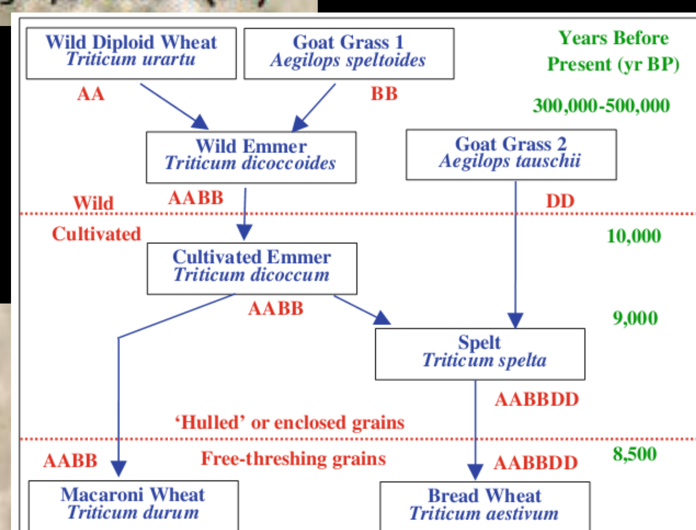
JAROSLAV DOLEŽEL

Tráva s trojím věnem



Vesmír 9/2009





Triticale (x Triticosecale, žitovec)

"From a scientific curiosity to a viable crop in the course of a few decades"

Triticum durum (AABB)
X
Secale cereale (RR)

(x T. aestivum AABBDD)

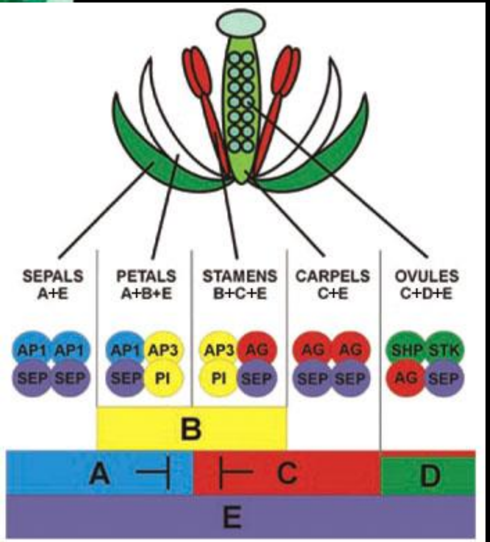
hexa nebo octaploidní

První kříženci 1940

Nyní produkce 15 miliónů tun

Mutace – změny funkce genů

Květák (*Brassica oleracea var. botrytis*)



Mutace v MADS-box genu (transkripčním faktoru)
apetala-1/cauliflower
opakovaná tvorba květních meristémů

Domestikace ve světle molekulární biologie aneb za vším hledejme geny

Teosinte picture by H. Iltis

Geny zodpovědné za domestikační vlastnosti

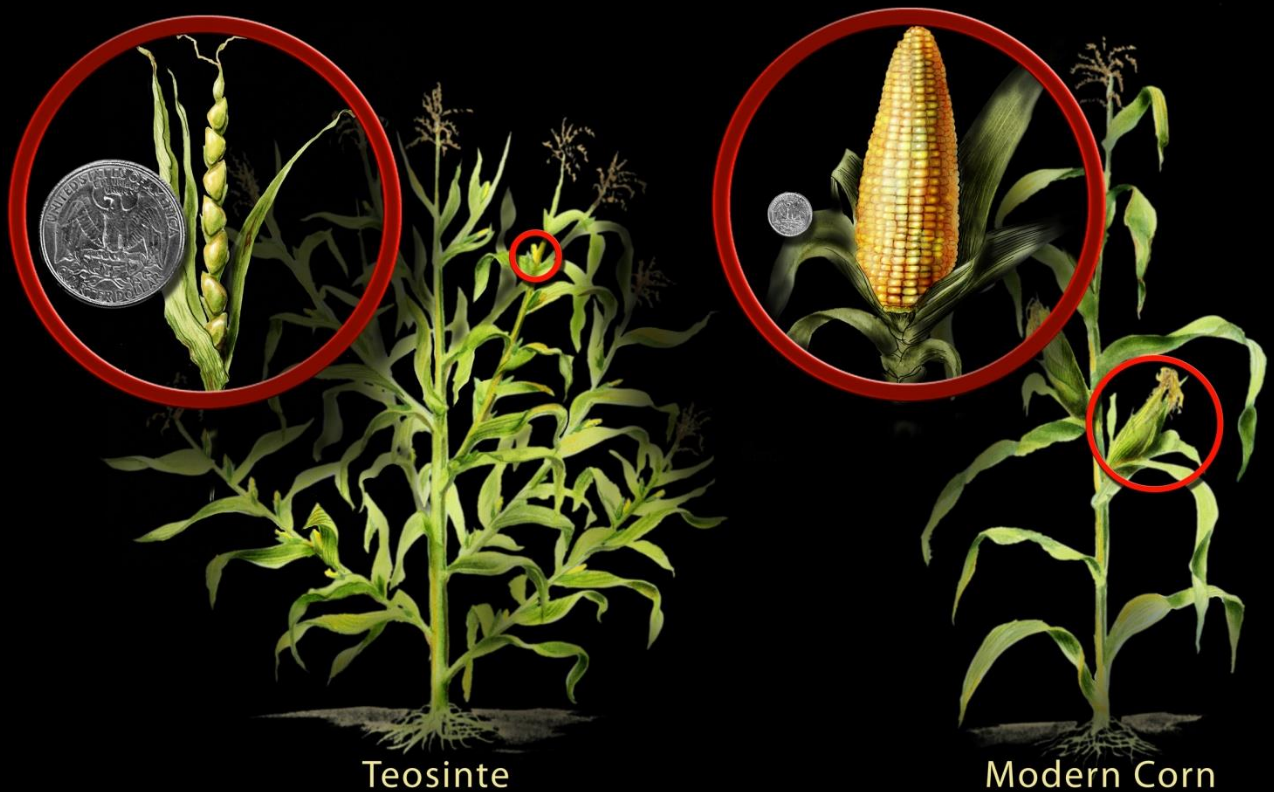
Jaký typ genů ?

Jednotlivé geny s velkým účinkem nebo více genů ?

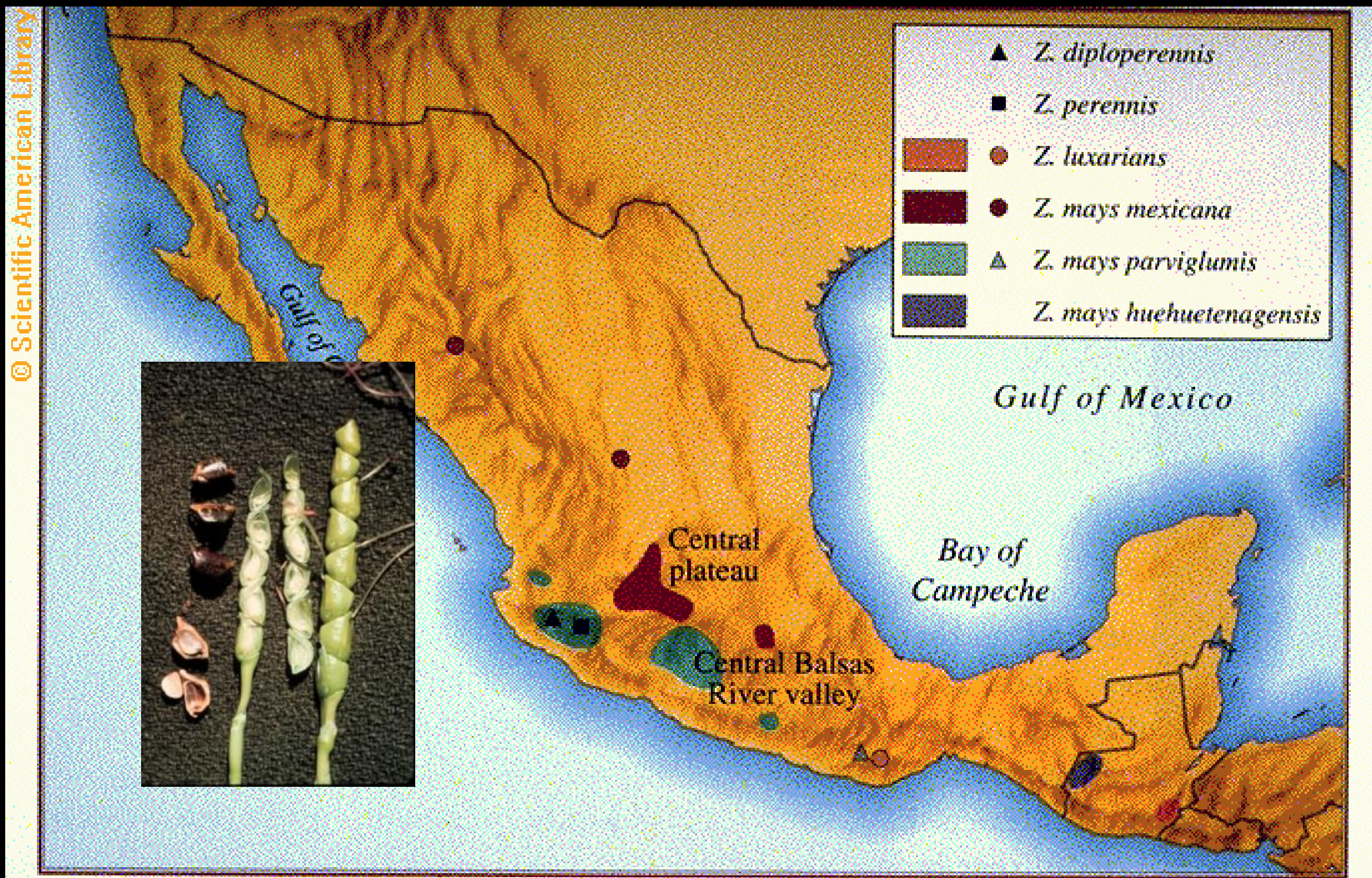
Modifikace nebo eliminace funkce ?

Kukuřice (*Zea mais* L.)

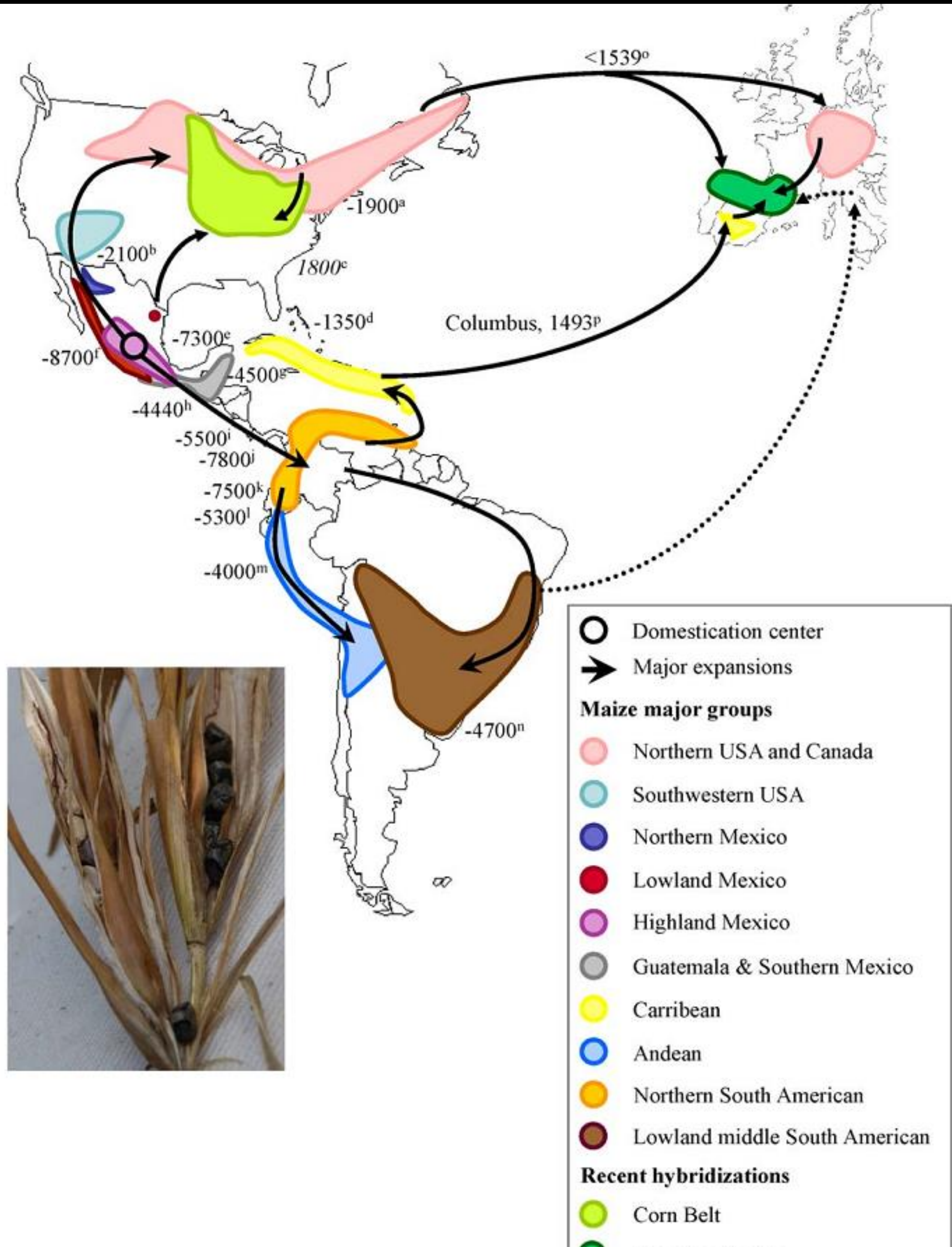
Domestikována v jižním Mexiku – před 7 tisíci lety
Poskytuje nyní přibližně 25% lidské výživy !
produkce 800 milionu tun



Planá kukuřice teosinta (*Zea mays ssp. parviglumis*)

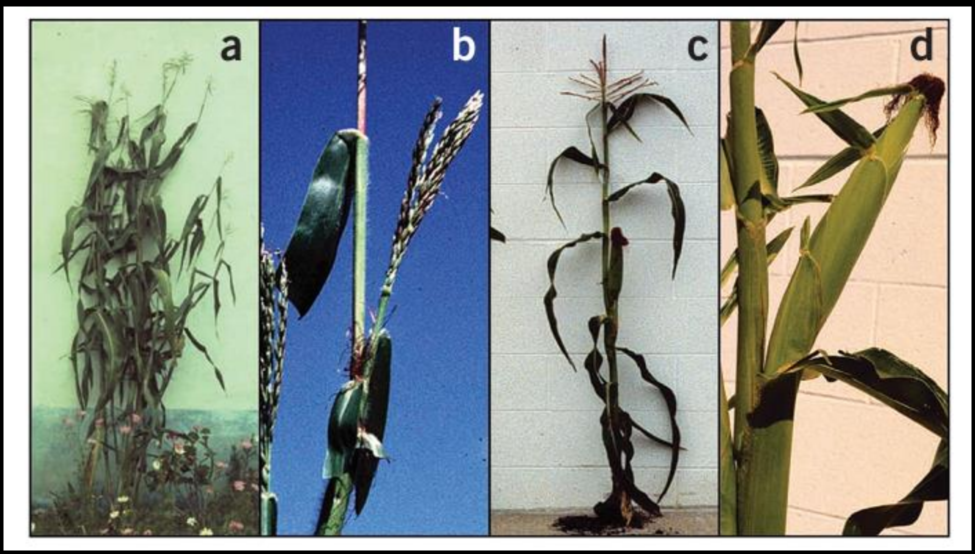


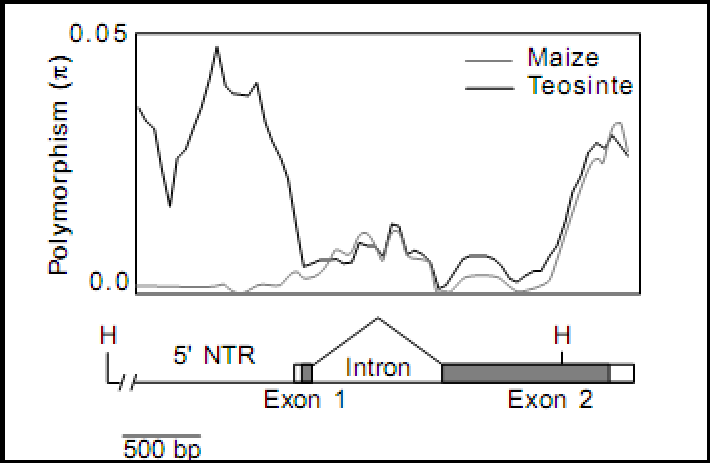
The modern geographical distribution of different teosintes in Mexico and Central America.

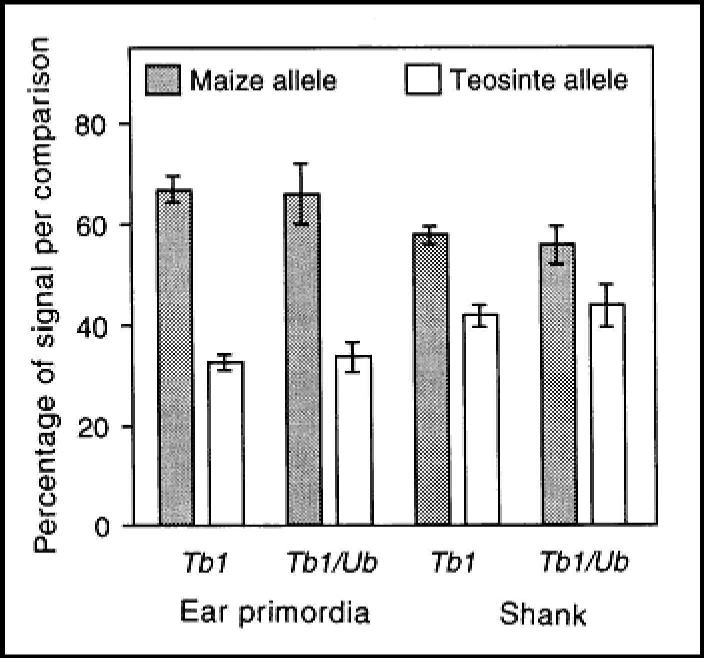

<1539o
-1900a
-2100b
1800c
-1350d
Columbus, 1493p
-7300e
-8700f
-4500g
-4440h
-5500i
-7800j
-7500k
-5300l
-4000m
-4700n
Domestication center
Major expansions
Maize major groups
Northern USA and Canada
Southwestern USA
Northern Mexico
Lowland Mexico
Highland Mexico
Guatemala & Southern Mexico
Carribean
Andean
Northern South American
Lowland middle South American
Recent hybridizations
Corn Belt
Pyrenées-Galicia

The limits of selection during maize domestication

Rong-Lin Wang*, Adrian Stec*, Jody Hey†, Lewis Lukens* & John Doebley*





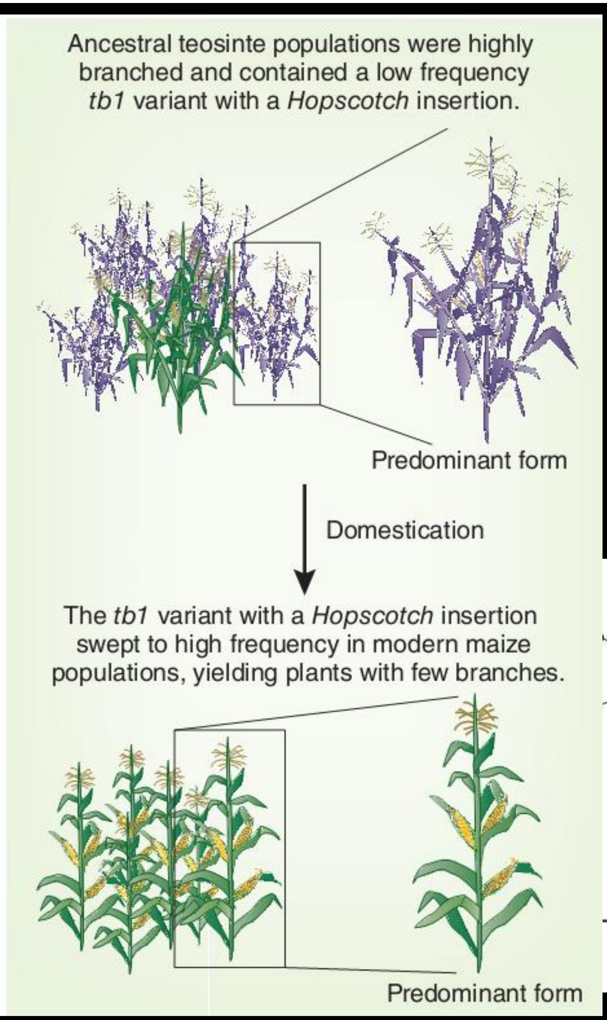


TEOSINTE BRACHED 1 *(tb1)*

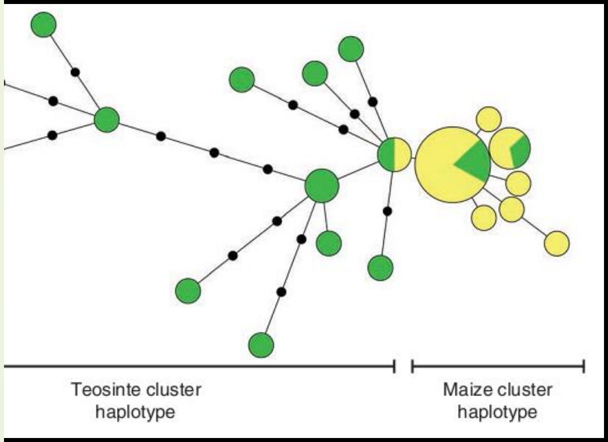
změna hladiny exprese

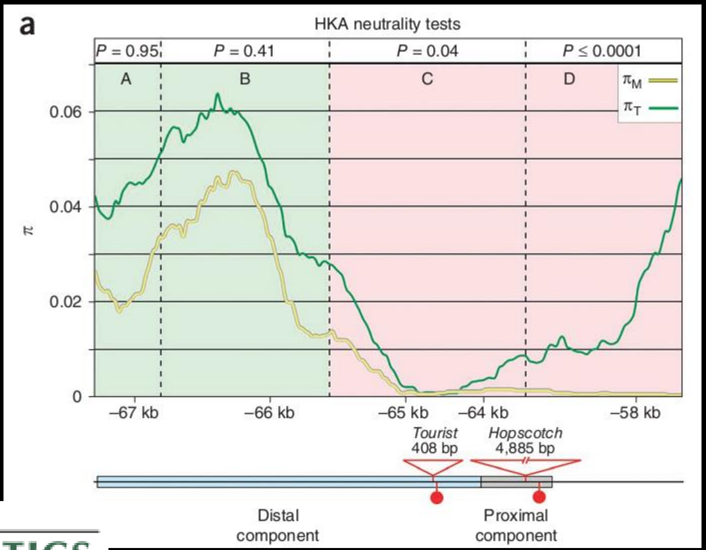
transkripční regulátor
represe buněčného cyklu

A transposon in *tb1* drove maize domestication

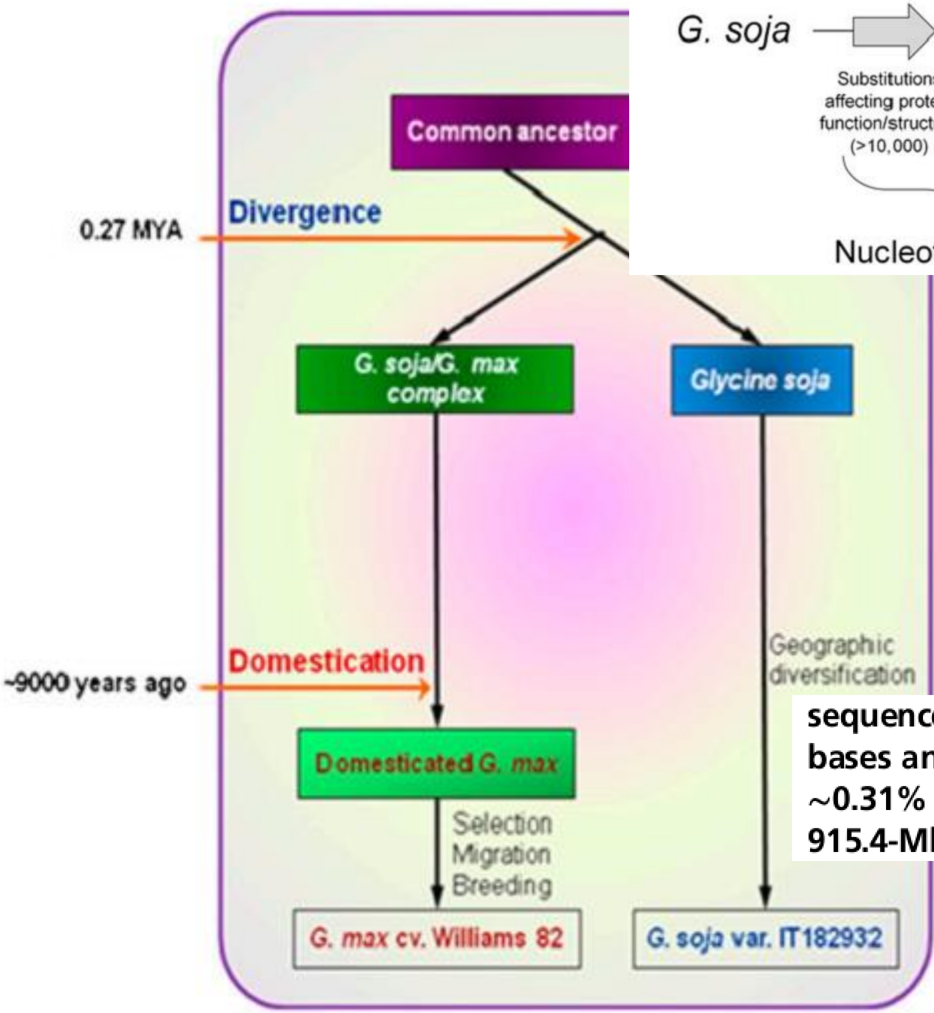


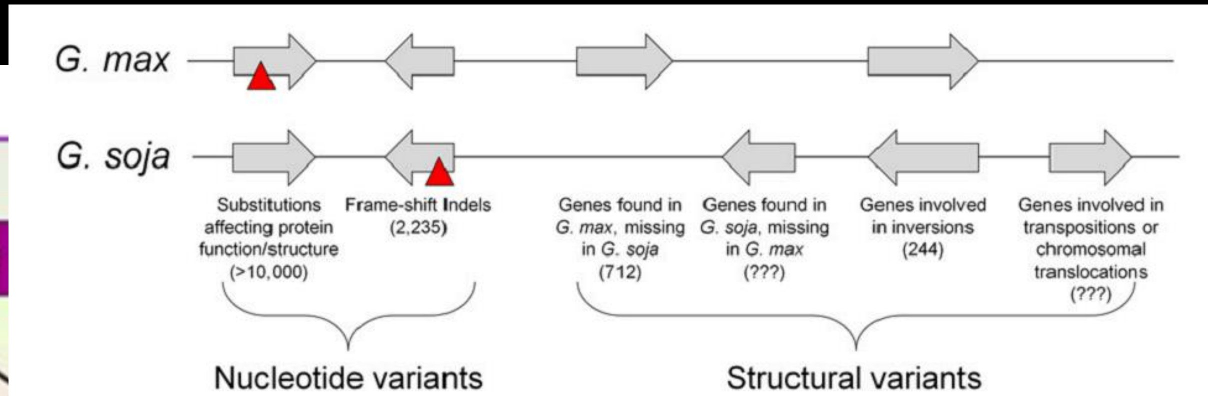
show that a transposable element (*Hopscotch*) inserted in a regulatory region of the maize domestication gene, *teosinte branched1* (*tb1*), acts as an enhancer of gene expression and partially explains the increased apical dominance in maize compared to its progenitor, teosinte. Molecular dating indicates that the *Hopscotch* insertion predates maize domestication by at least 10,000 years, indicating that selection acted on standing variation rather than new mutation.





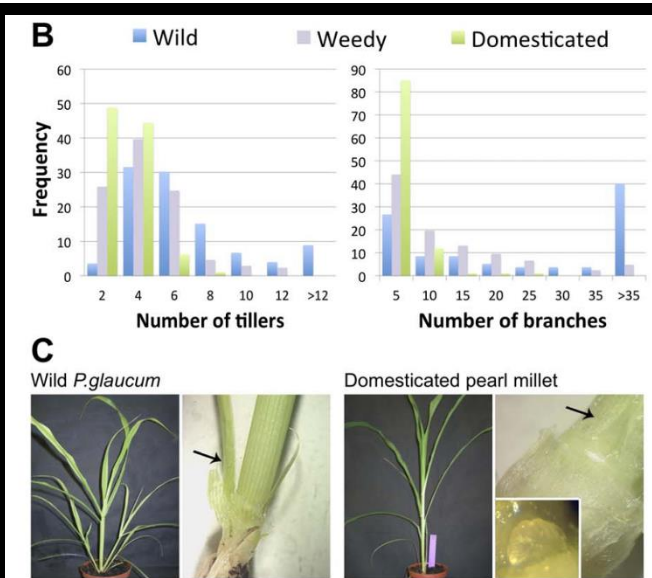
Domestikační historie sóji

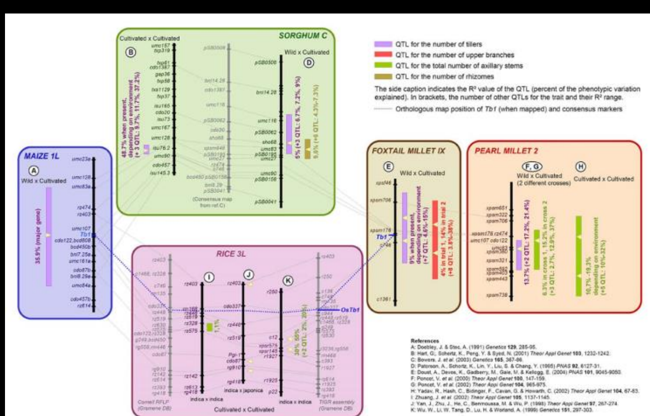


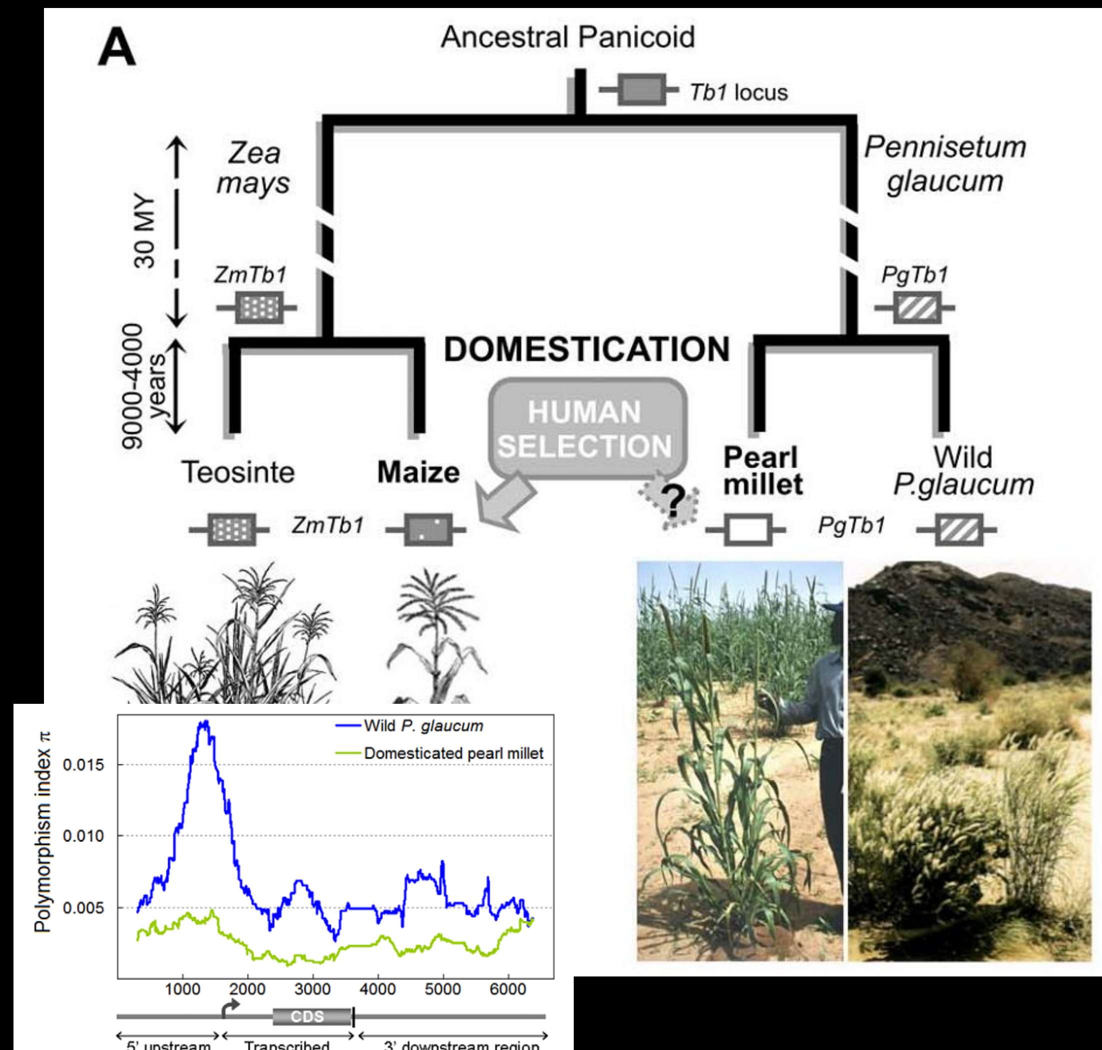


sequence of the *G. soja* genome, which contains 2.5 Mb of substitutec bases and 406 kb of small insertions/deletions relative to *G. max*, is ~0.31% different from that of *G. max*. In addition to the mappec 915.4-Mb consensus sequence, 32.4 Mb of large deletions and 8.3

Cereal Domestication and Evolution of Branching: Evidence for Soft Selection in the *Tb1* Orthologue of Pearl Millet (*Pennisetum glaucum* [L.] R. Br.)

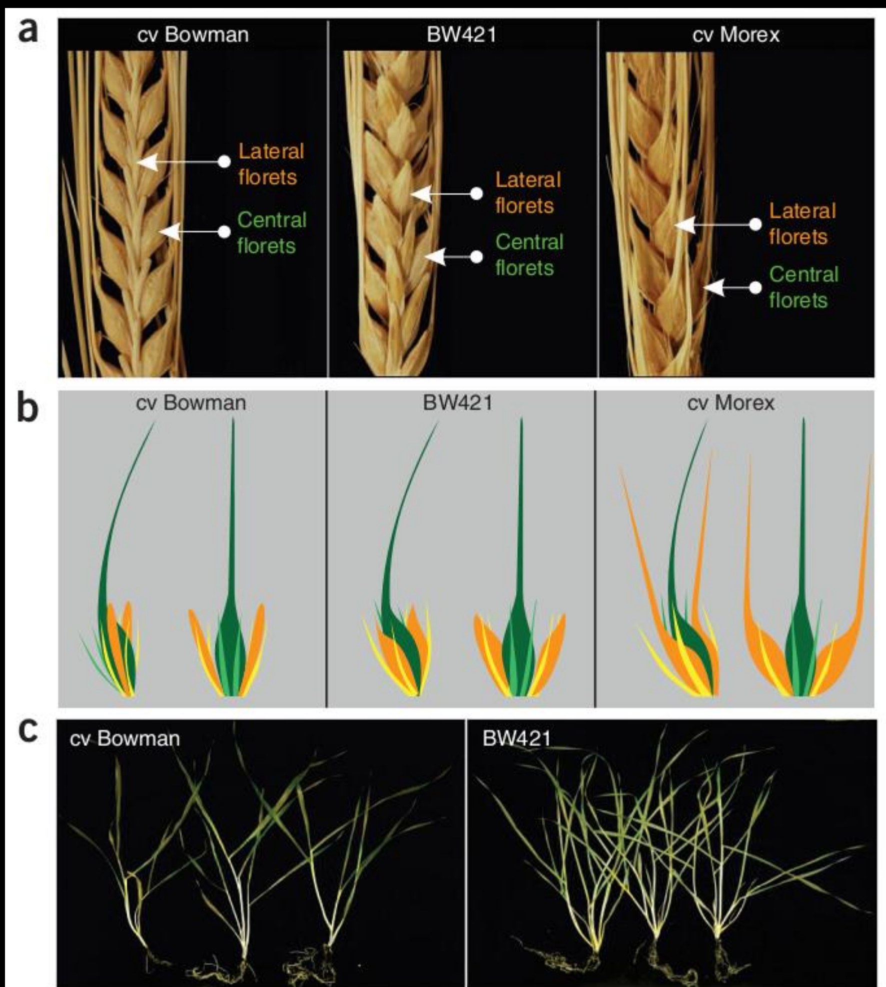


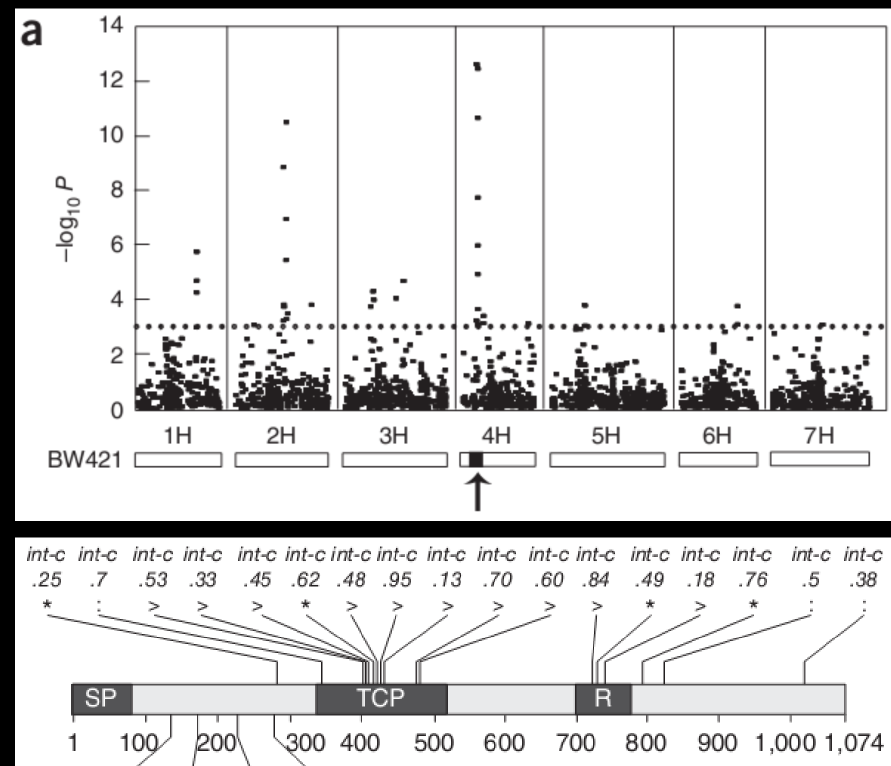




INTERMEDIUM-C, a modifier of lateral spikelet fertility in barley, is an ortholog of the maize domestication gene *TEOSINTE BRANCHED 1*

Dvouřadý **Šestiřadý**

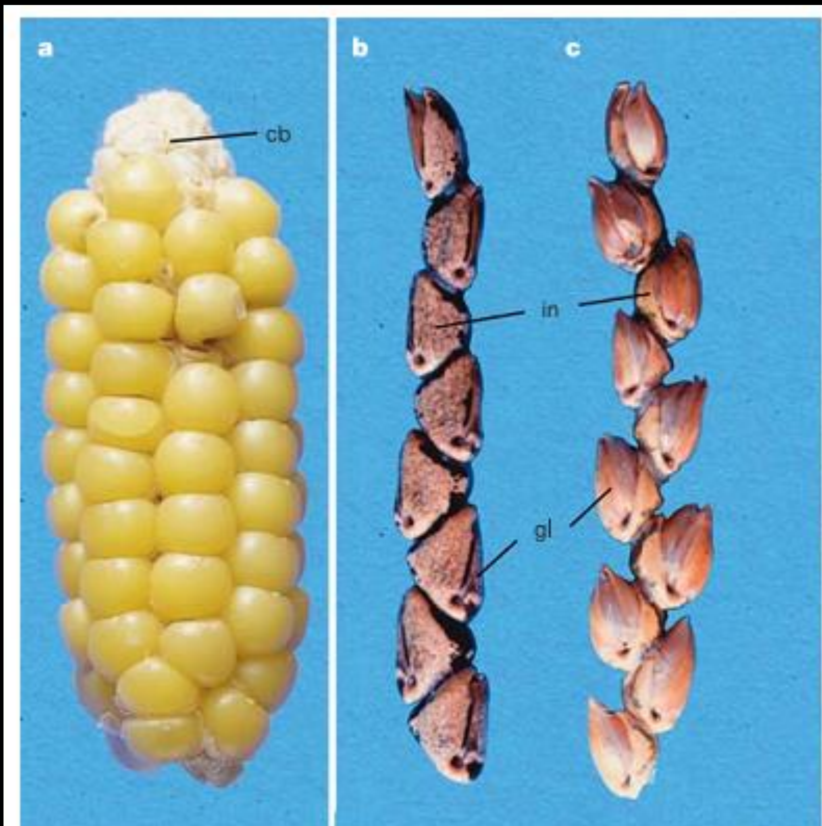


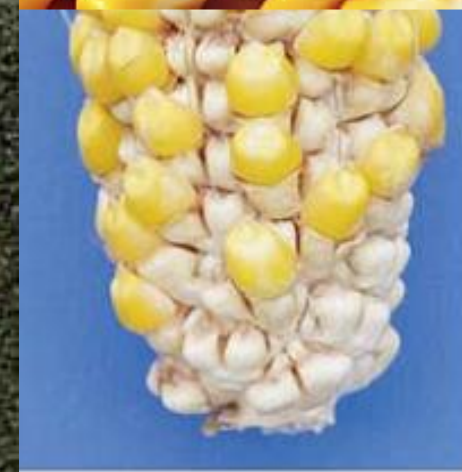


The origin of the naked grains of maize

Huai Wang[1*], Tina Nussbaum-Wagler[1*], Bailin Li[2], Qiong Zhao[1], Yves Vigouroux[1†], Marianna Faller[2], Kirsten Bomblies[1], Lewis Lukens[3] & John F. Doebley[1]

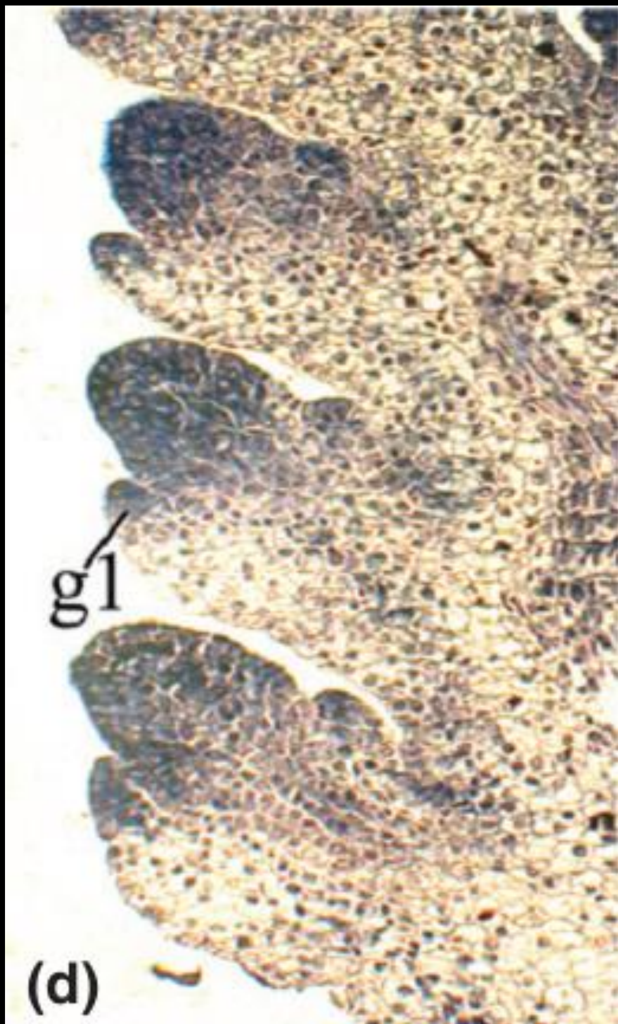
Nature 2005

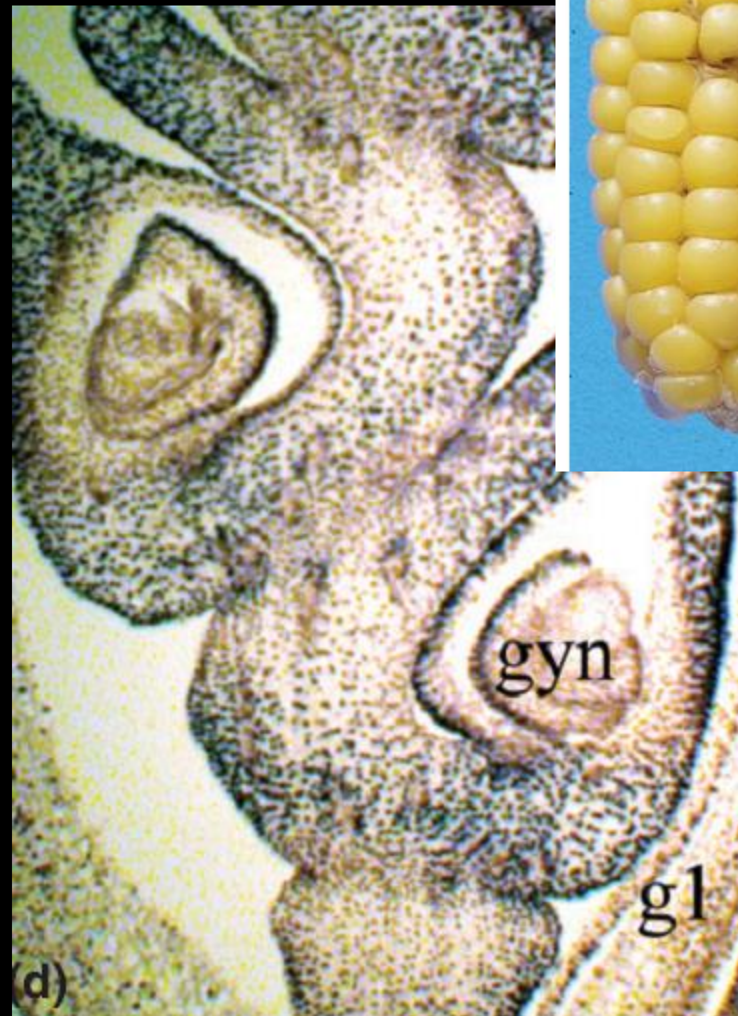


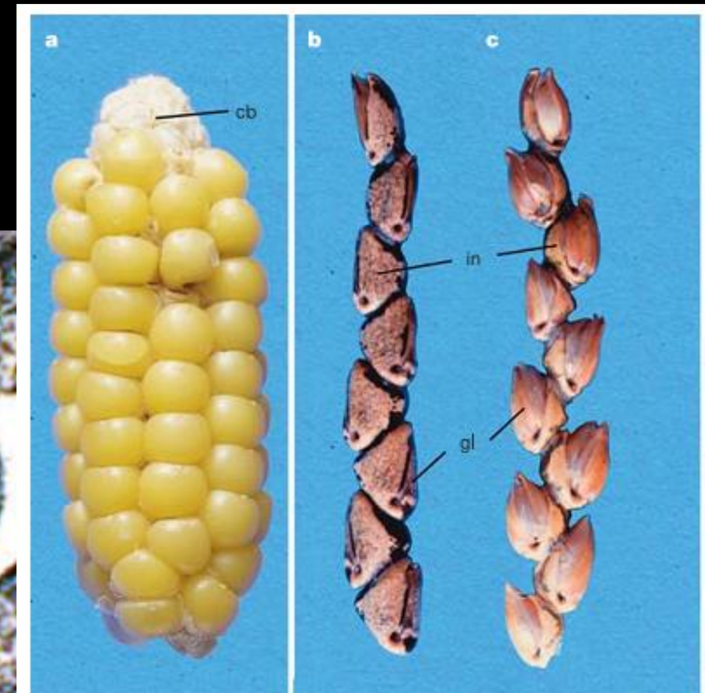


TEOSINTE GLUME ARCHITECTURE 1

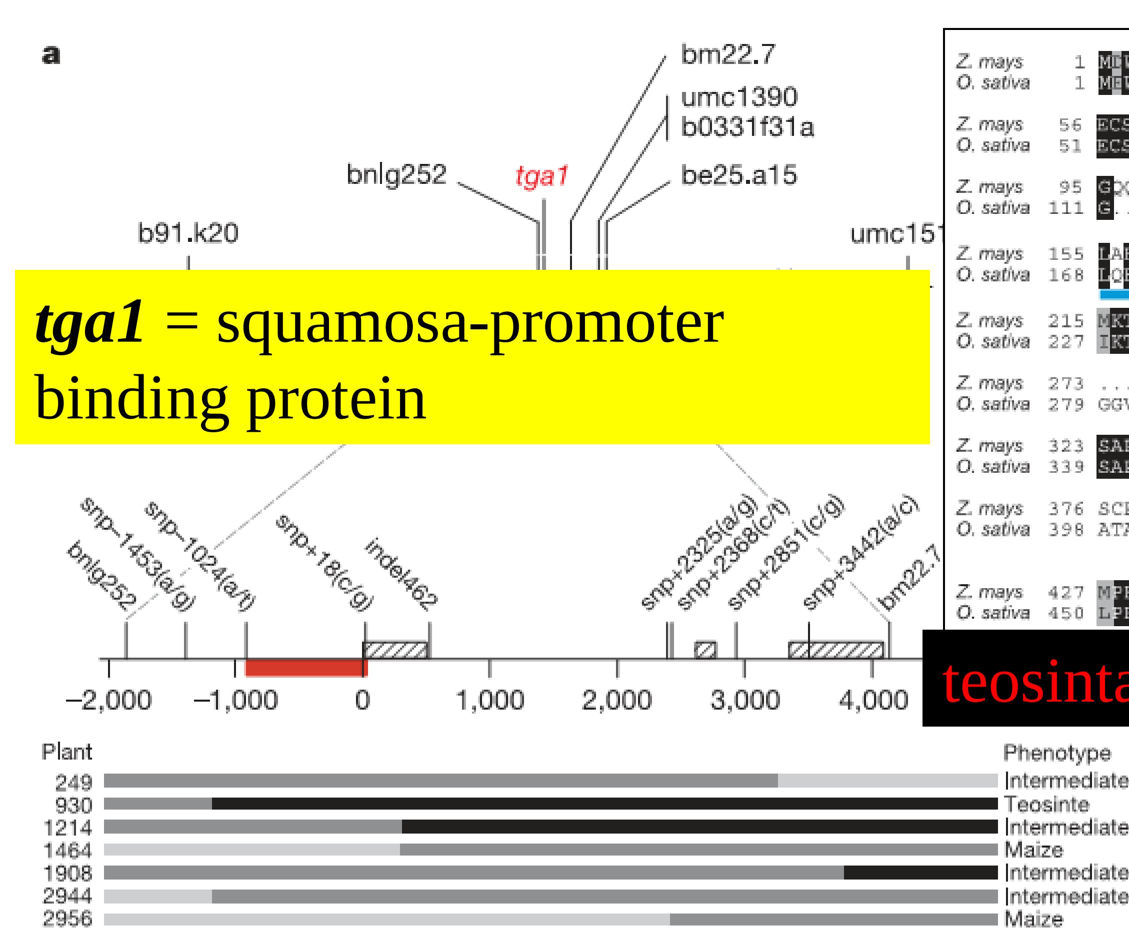
TEOSINTE GLUME ARCHITECTURE 1

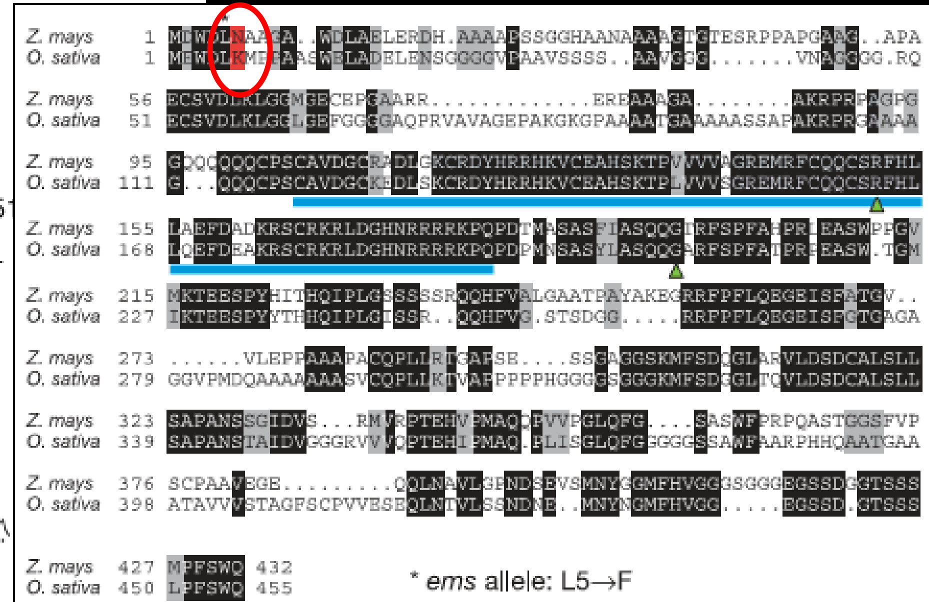




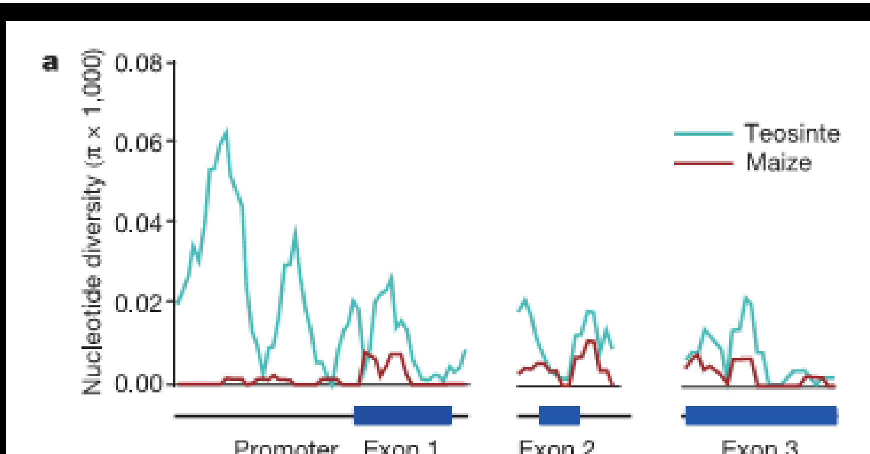


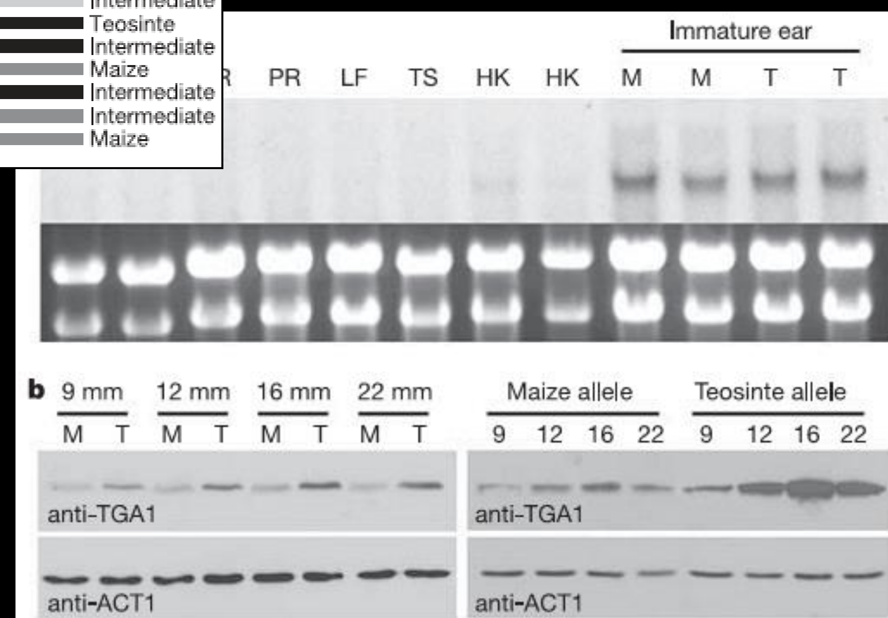
***tga1* = squamosa-promoter binding protein**





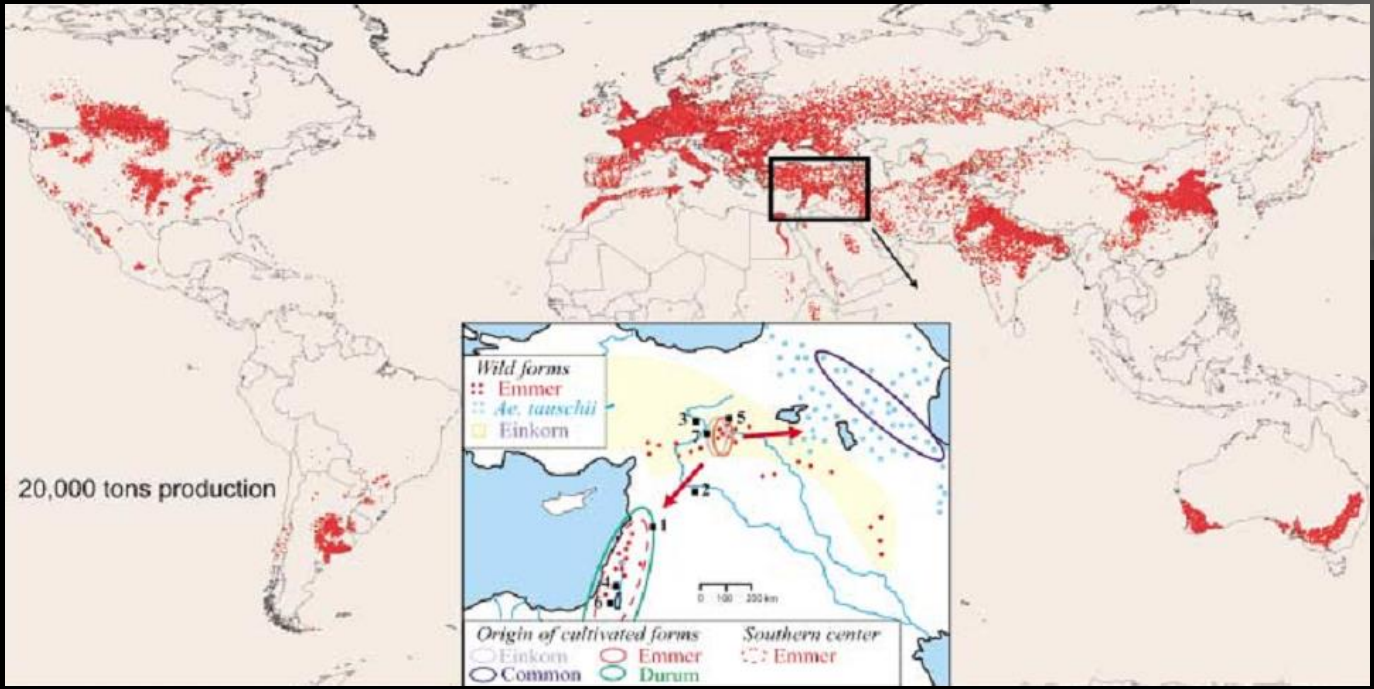
teosinta/ kukuřice (záměna K6N)



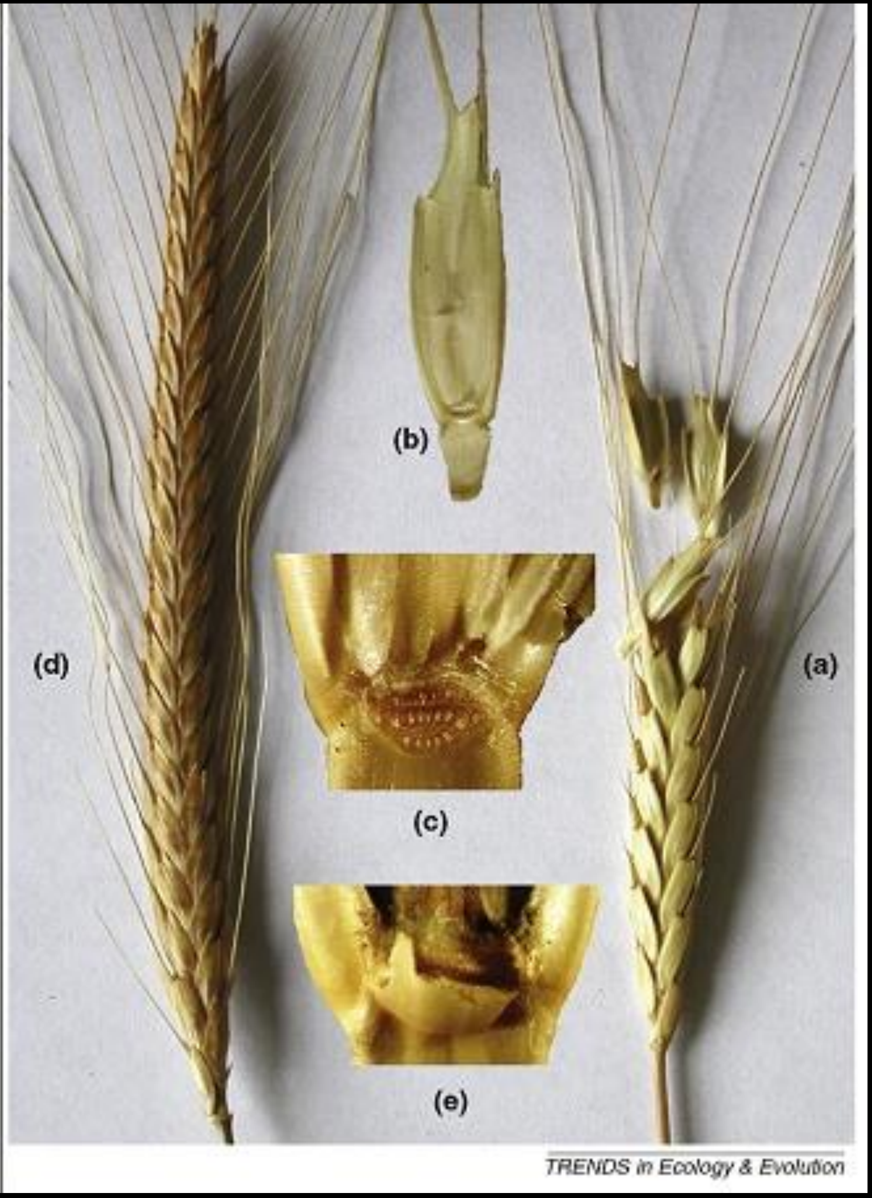


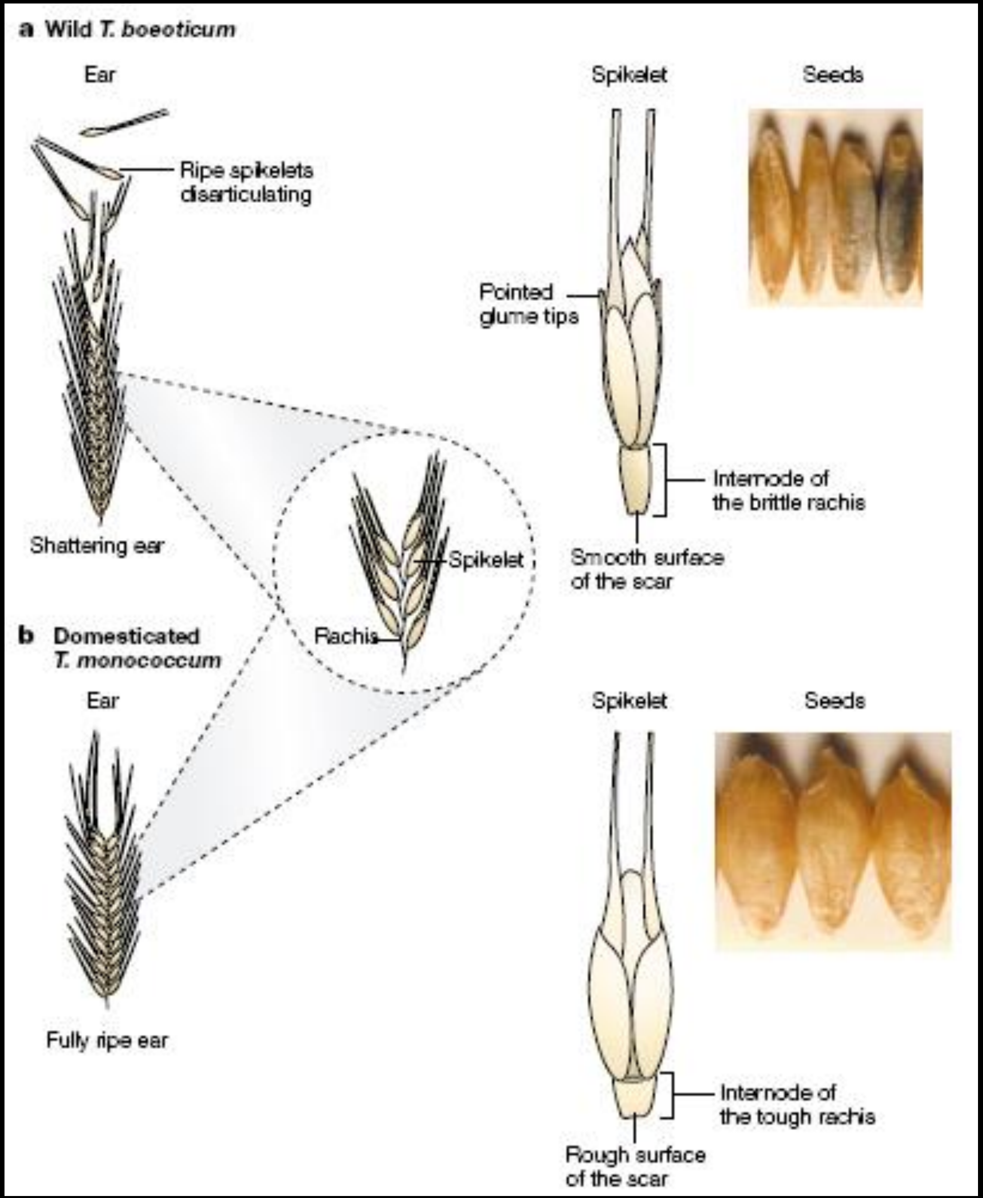
Pšenice (*Triticum aestivum* L.)

světová produkce 600 mil tun

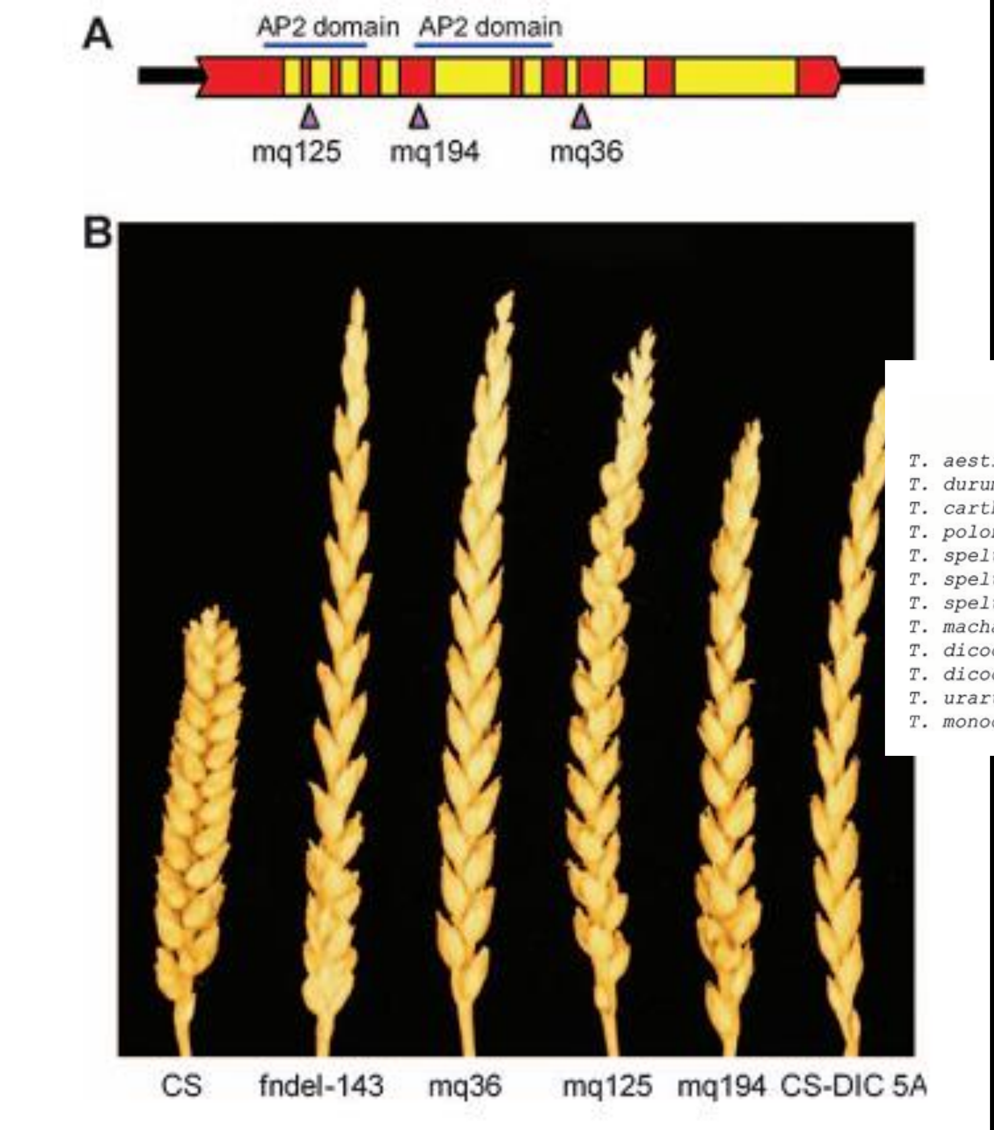


Rozpadavost klasu obilovin





Q gen – pšenice –volná obilka, rozpadavost klasu



APETALA-2
transkripční faktor

Exon – isoleucin 329

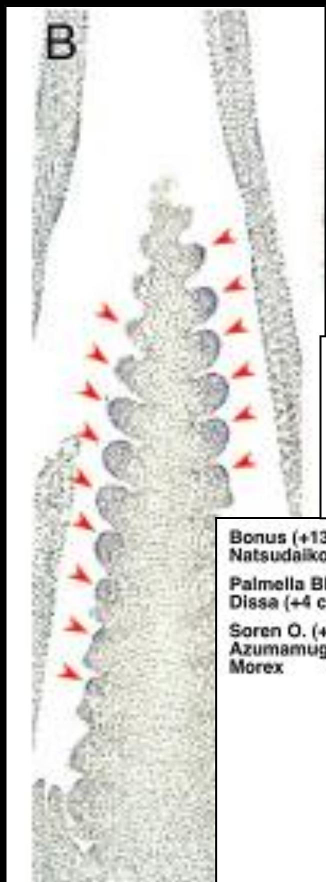
- tvar a pevnost plevy
- rozpadavost vřetene klasu
- délka klasu
- výška rostliny
- doba metání

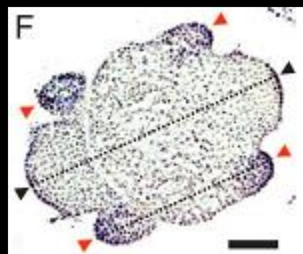
Simons et al. 2006 Genetics

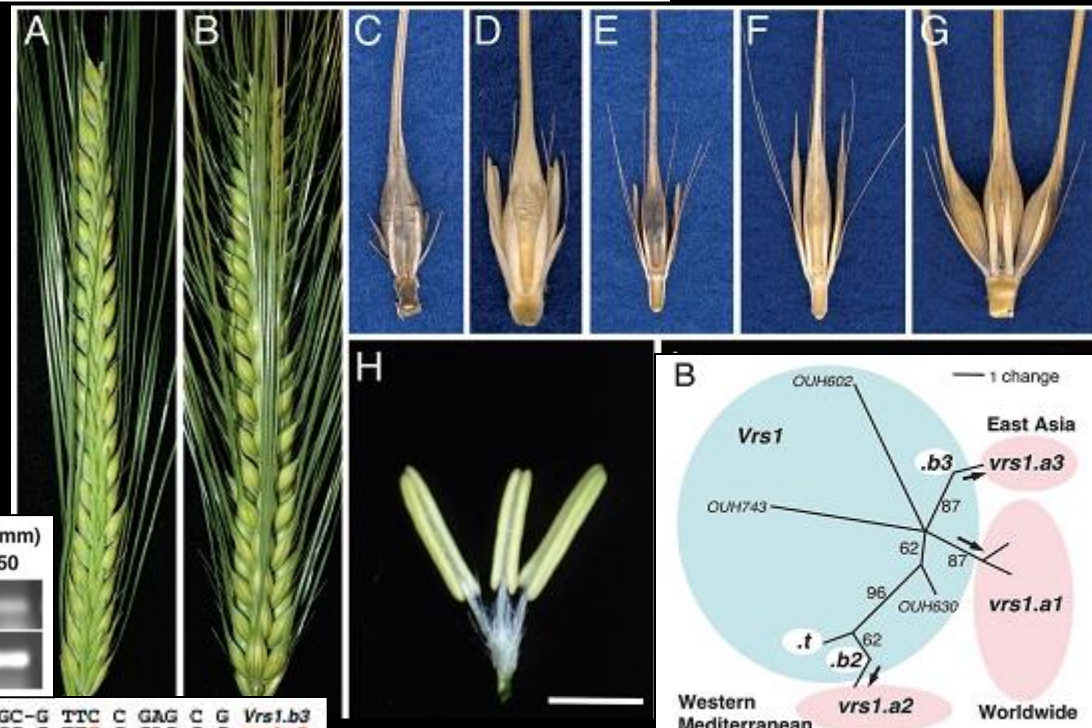
Six-rowed barley originated from a mutation in a homeodomain-leucine zipper I-class homeobox gene

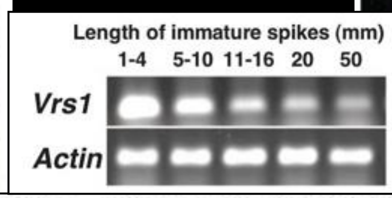
3x více semen

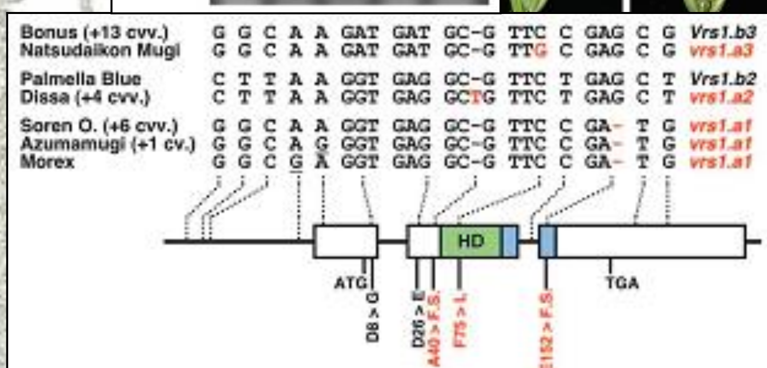
Komatsuda et al. 2007 PNAS

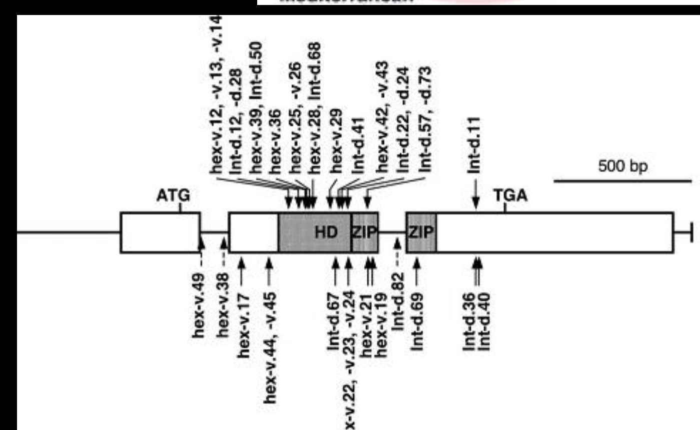










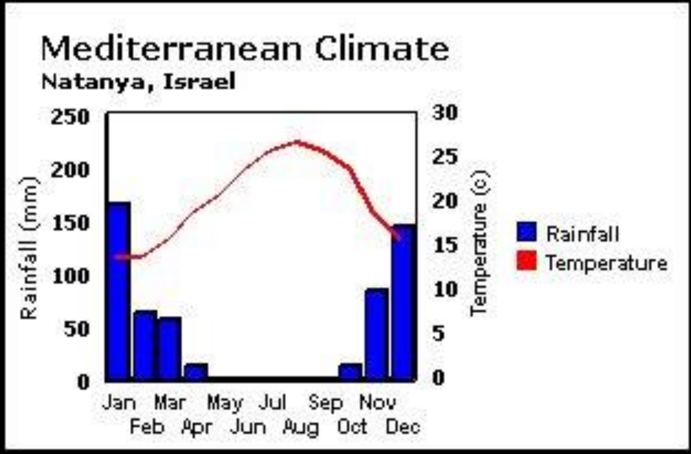


Modifikace nebo ztráta funkce **Vrs1** genu
Transkripčního represoru

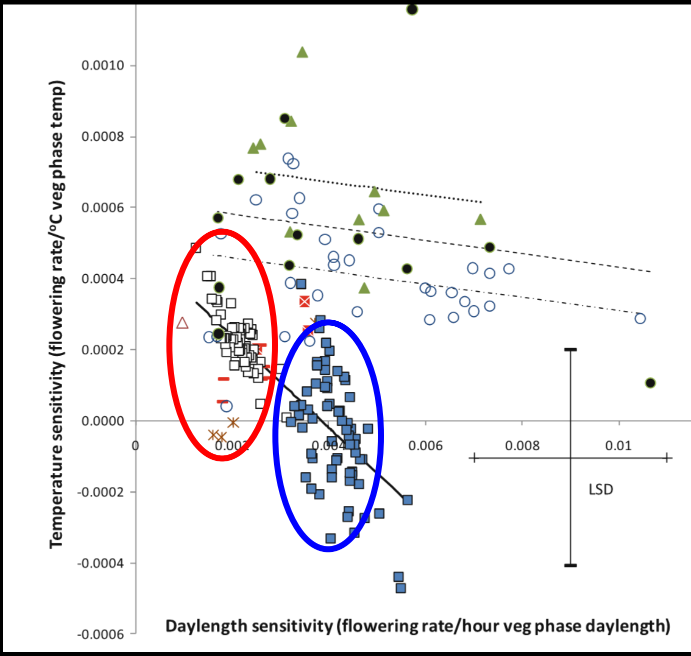
Středozemí a Blízký Východ

Hlavní srážky – podzim a zima

Potřeba využít toto období pro vegetativní fázi a následně oddálit nástup kvetení – **vernalizace a fotoperiodismus**

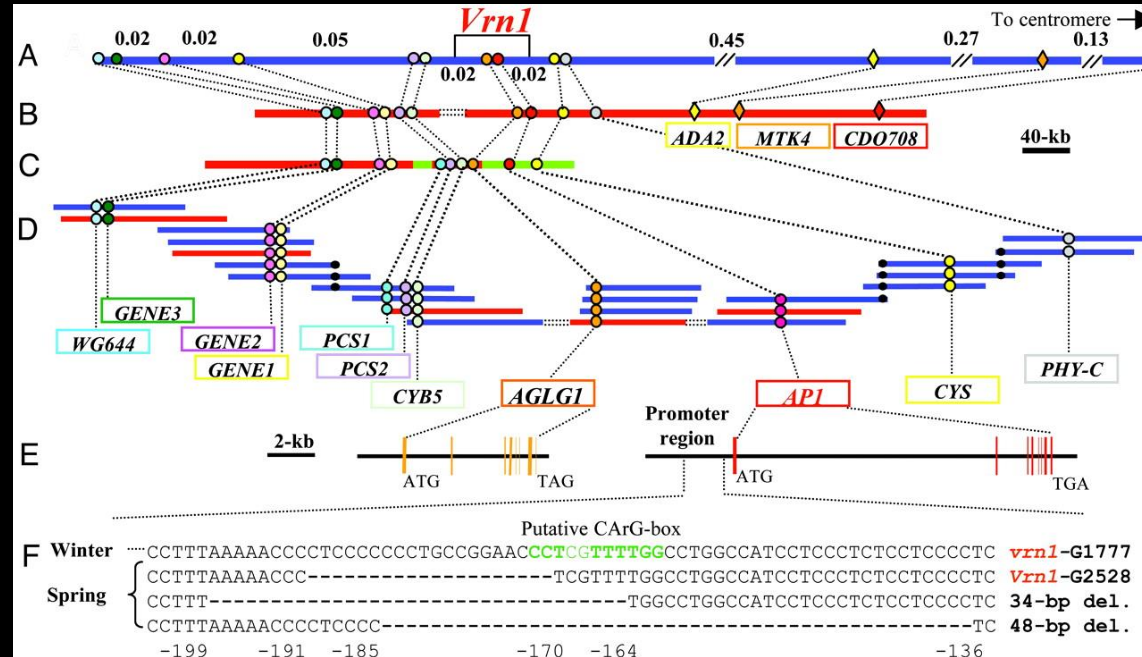


Dvouletá vegetační forma – ozimé formy



Pro prvotní nomadický styl, rozšíření zemědělství do Evropy a úrodnější oblastí – možnost dvou sklizní za rok

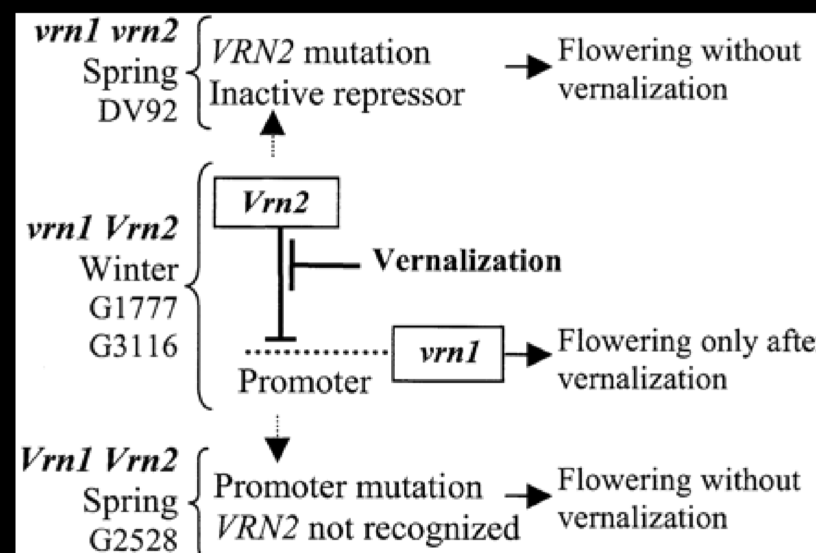
jednoleté – jarní formy



Ozimá pšenice vyžaduje vernalizaci - řízenou ***VRN1*, *VRN2* geny**

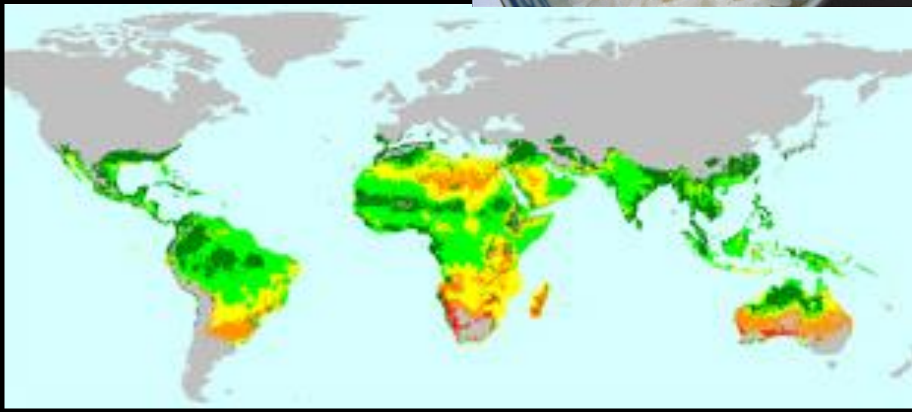
MADS-box faktory

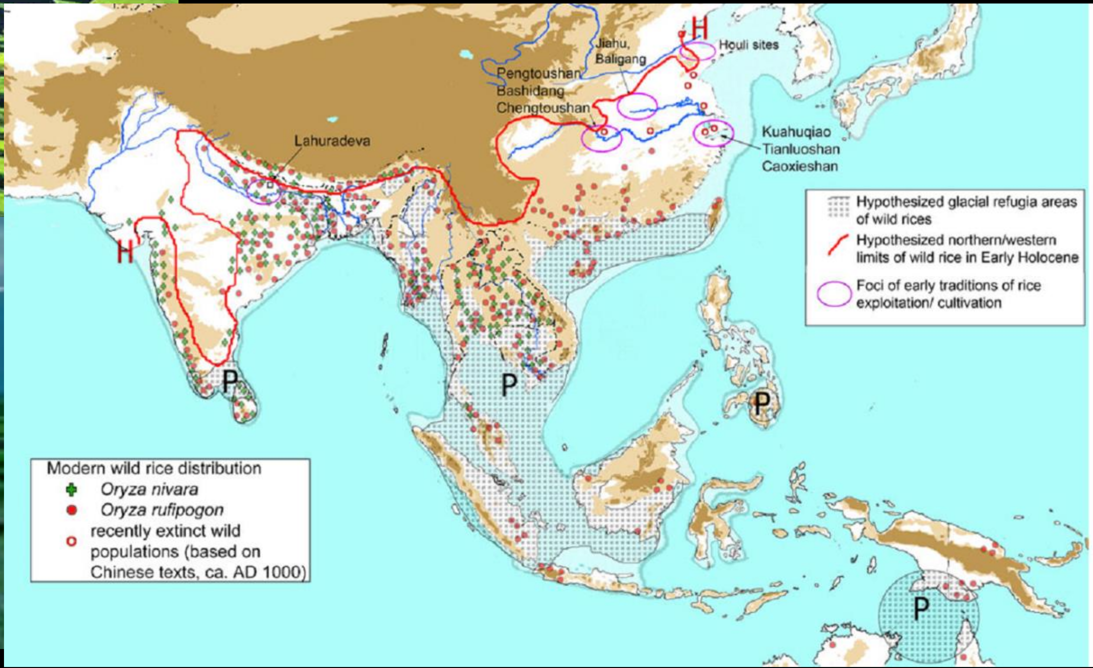
Yan et al. 2003 PNAS



Rýže (*Oryza sativa* L.)

světová produkce 600 mil tun





Domestikací modifikované znaky rýže

Zrno:

velikost, tvar, barva, vůně, obsah amylózy

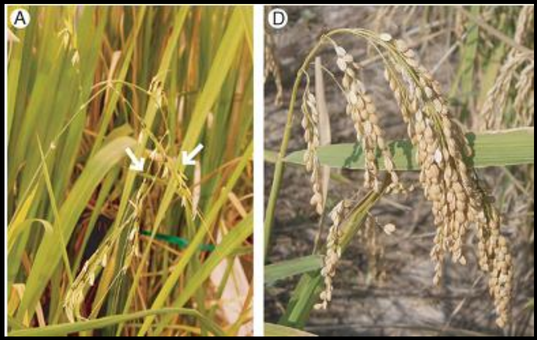
Klas:

rozpadavost, osinatost, velikost a tvar laty

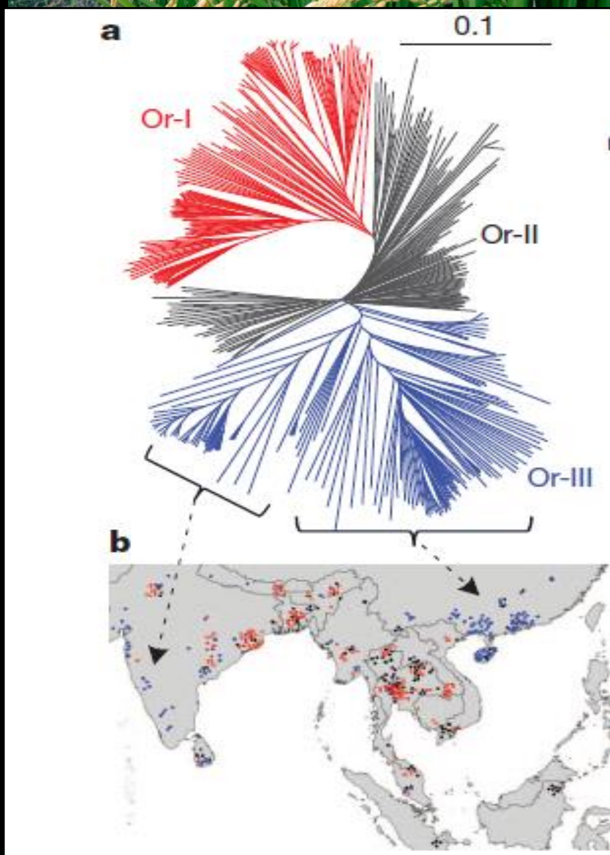
Rostlina:

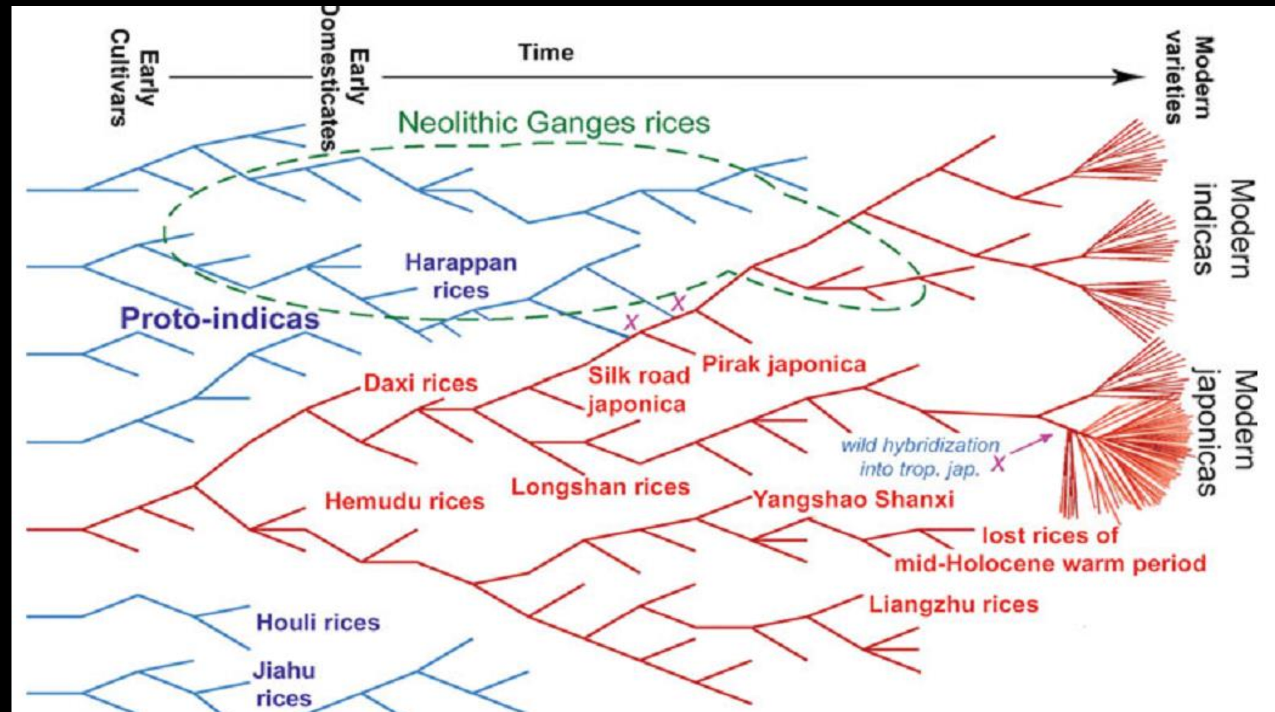
odnožování

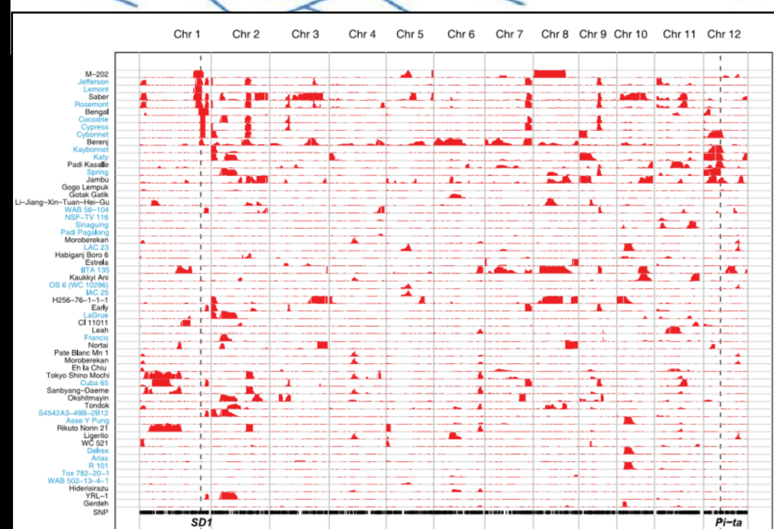
Gene	Chromosome	Trait affected
Gw2	2	Grain weight/ width
Gs3	3	Grain size/shape
qSW5	5	Grain size
Rc	7	Pericarp color
Sdr4	7	Seed dormancy
Badh2	8	Grain fragrance
Qsh1	1	Grain shattering
Qsh4	4	Grain shattering
Sh-h	7	Grain shattering
Waxy	6	Low amylose content
Ehd1	10	Heading date
Hd1	6	Heading date
Hd3a	6	Heading date
Hd6	3	Heading date
SE5	6	Heading date
Ehd2	10	Heading date

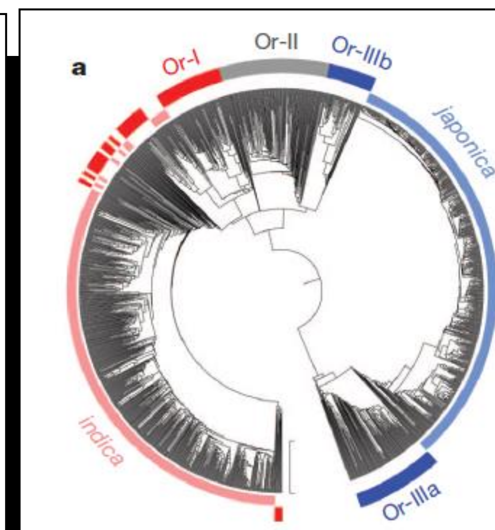


Vliv introgrese na vznik kulturní rýže









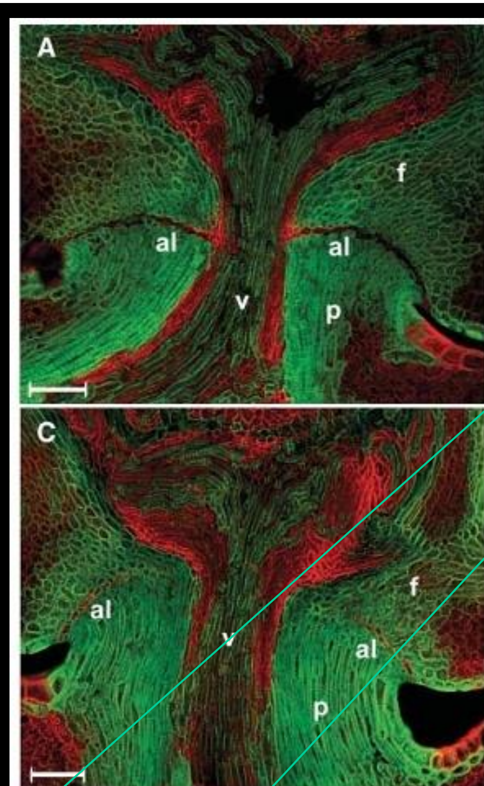
Rice Domestication by Reducing Shattering

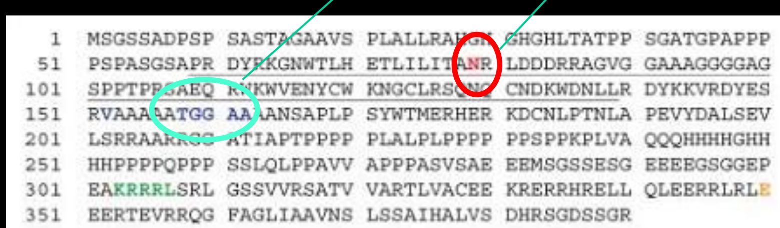
Li et al. Science 2006

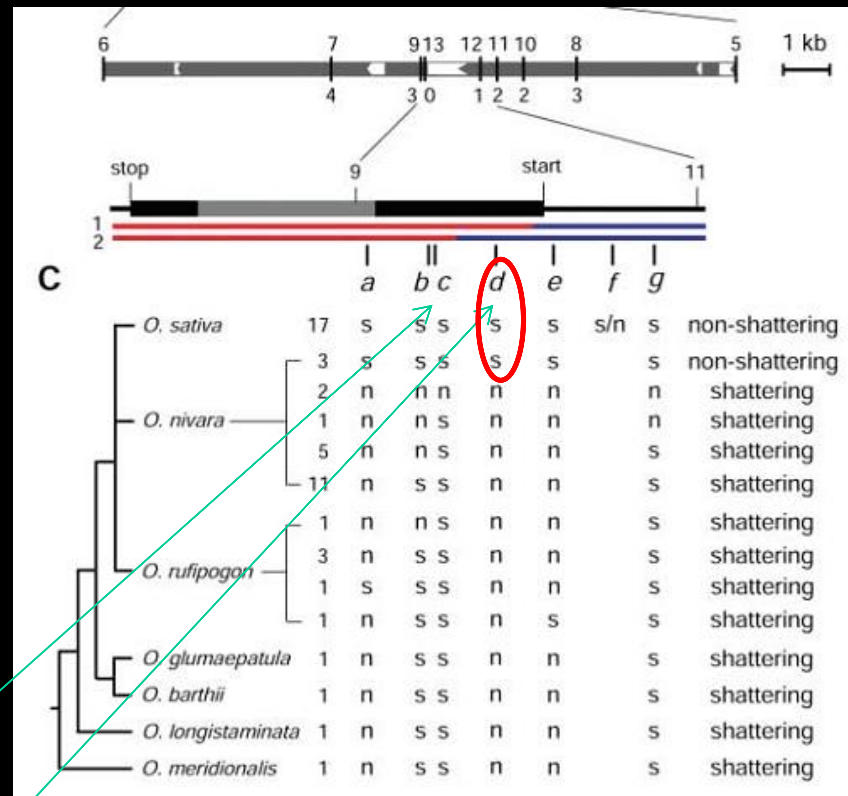
QTL 69%
***sh4* locus**

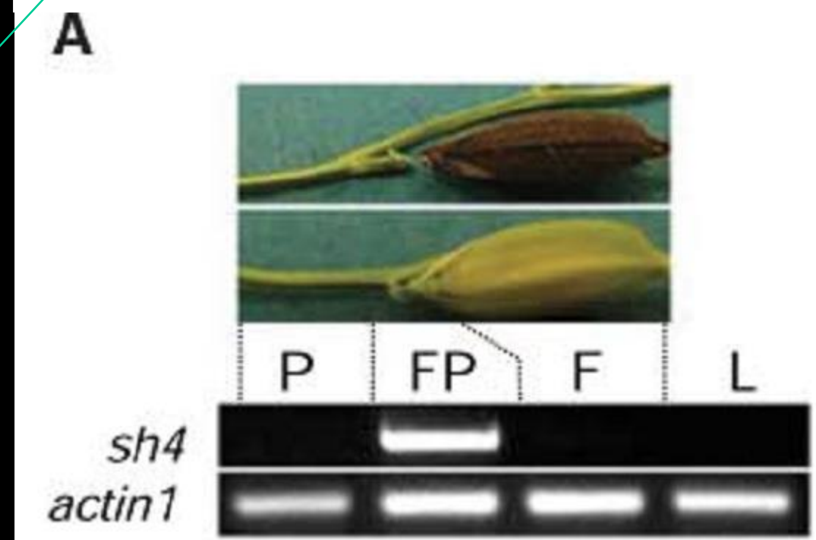
G to T substitution
Lys to Asp

Myb3 DNA binding domain





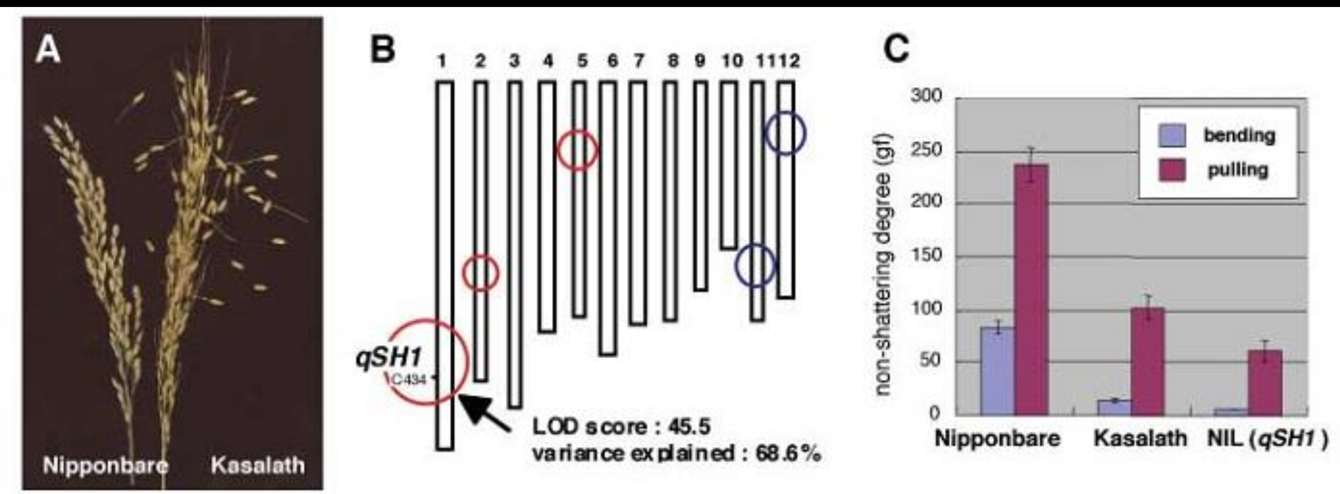


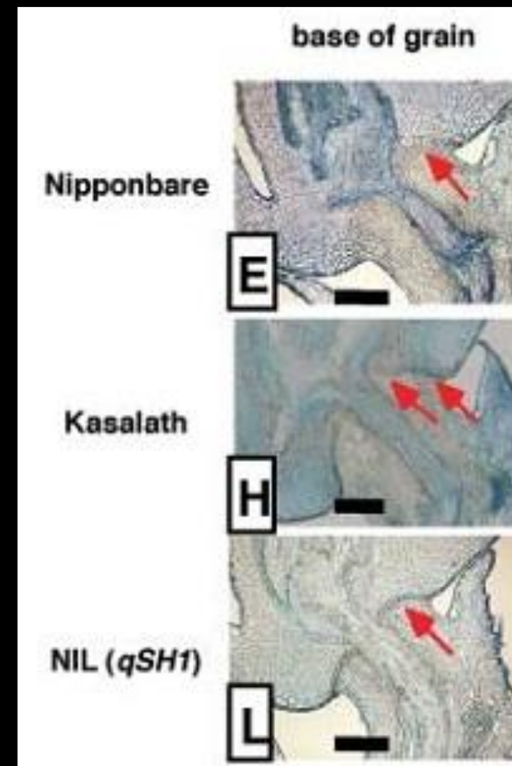


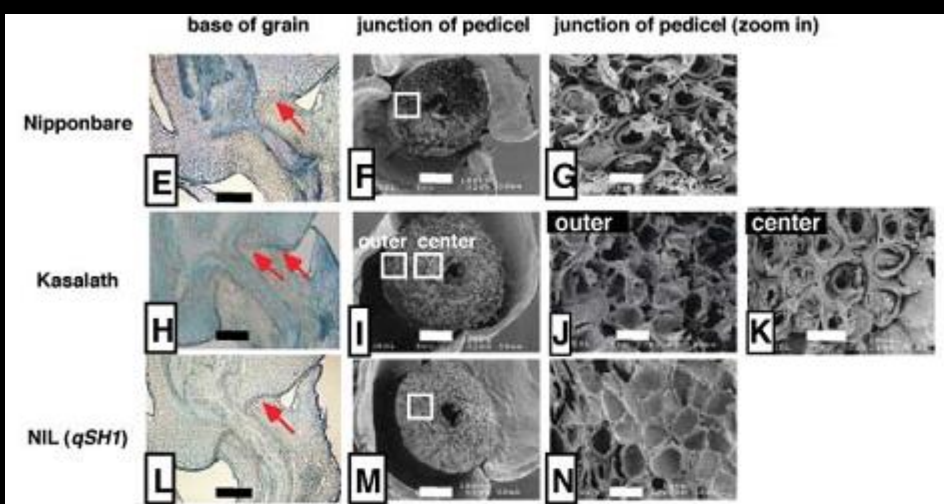
An SNP Caused Loss of Seed Shattering During Rice Domestication

qSH1

Saeko Konishi,[1*] Takeshi Izawa,[2*] Shao Yang Lin,[1†] Kaworu Ebana,[2] Yoshimichi Fukuta,[3] Takuji Sasaki,[2] Masahiro Yano[2‡]



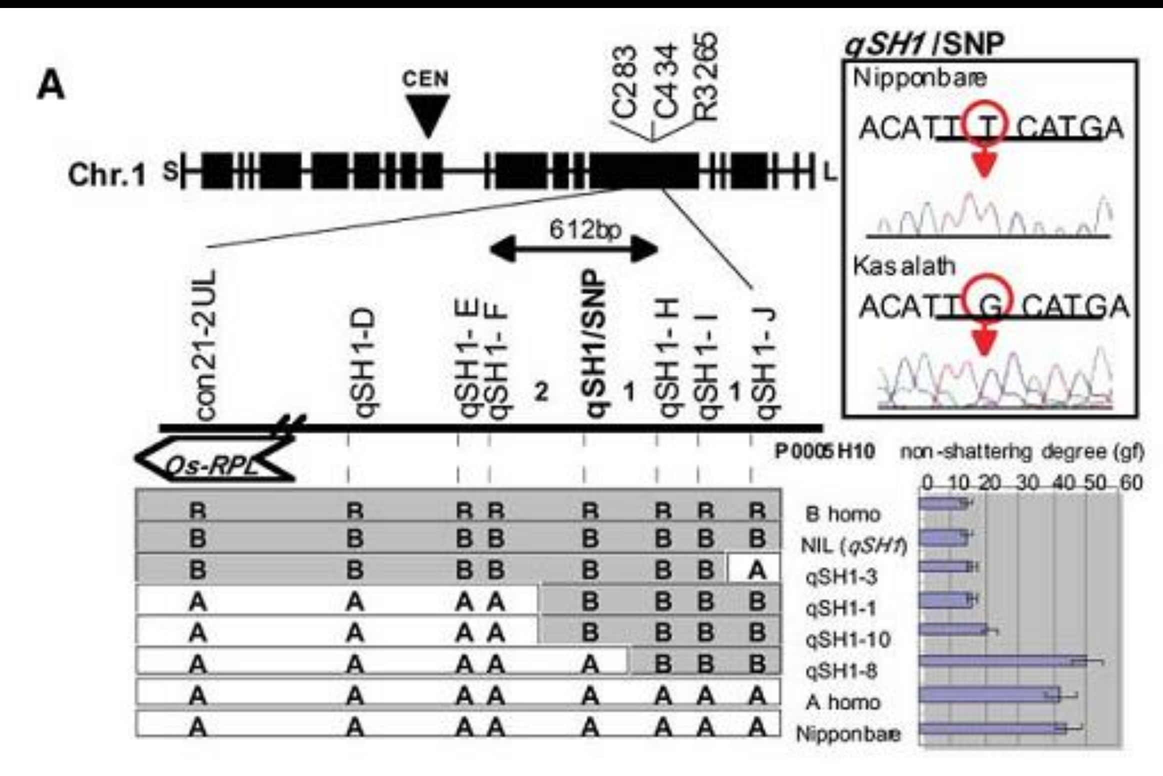


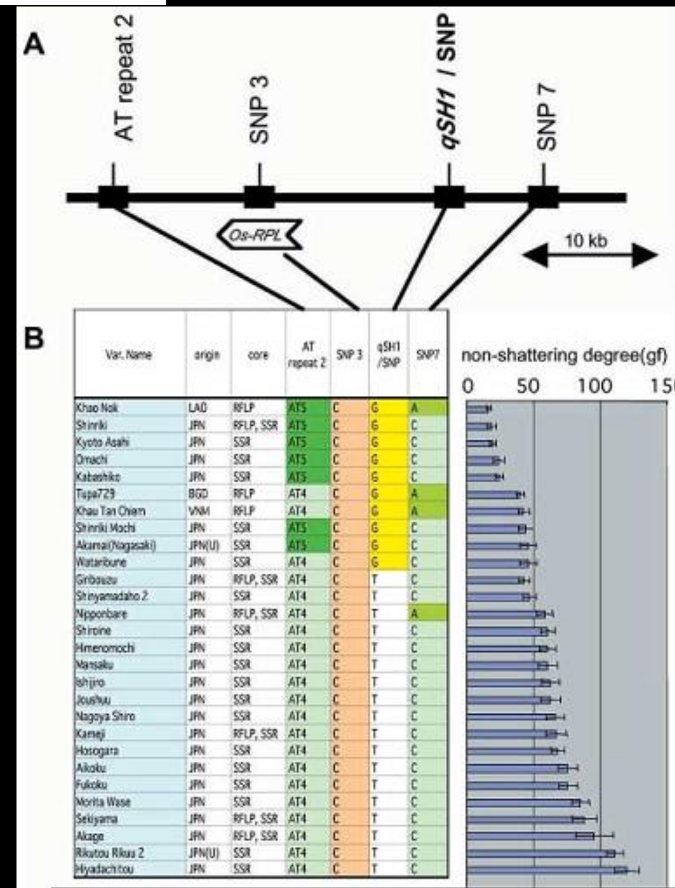


An SNP Caused Loss of Seed Shattering During Rice Domestication

Saeko Konishi,[1*] Takeshi Izawa,[2*] Shao Yang Lin,[1†] Kaworu Ebana,[2] Yoshimichi Fukuta,[3] Takuji Sasaki,[2] Masahiro Yano[2‡]

qSH1

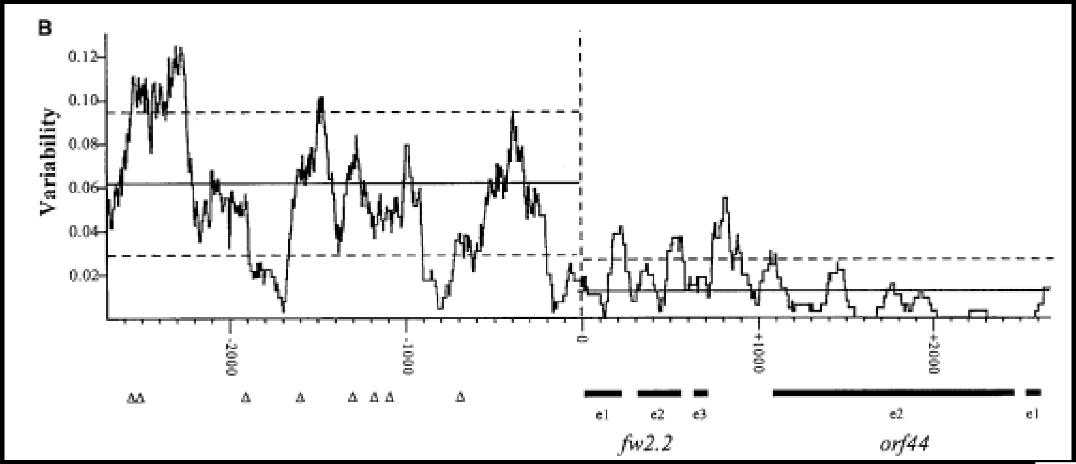




SNP !!! 12 kb od kódující sekvence , ovlivňující **expresi RPL genu**

BEL1-type homeobox gen, homolog *Arabidopsis* REPLUMLESS (RPL)

Rajče – velikost plodu fruitweight (*fw2.2* lokus)



(Frary et al. 2002 Science)
první klonovaný QTL

homologie k Ras family GTPase

Určuje 30% velikosti plodu

Mutace v promotorové oblasti

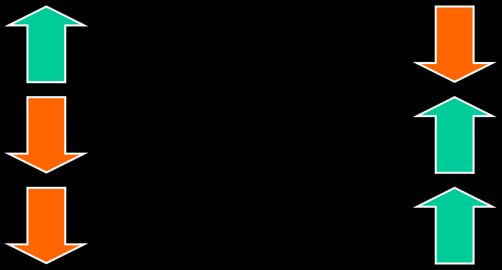
represor buněčného dělení

Interakce s beta podjednotkou CKII kinázy v membráně

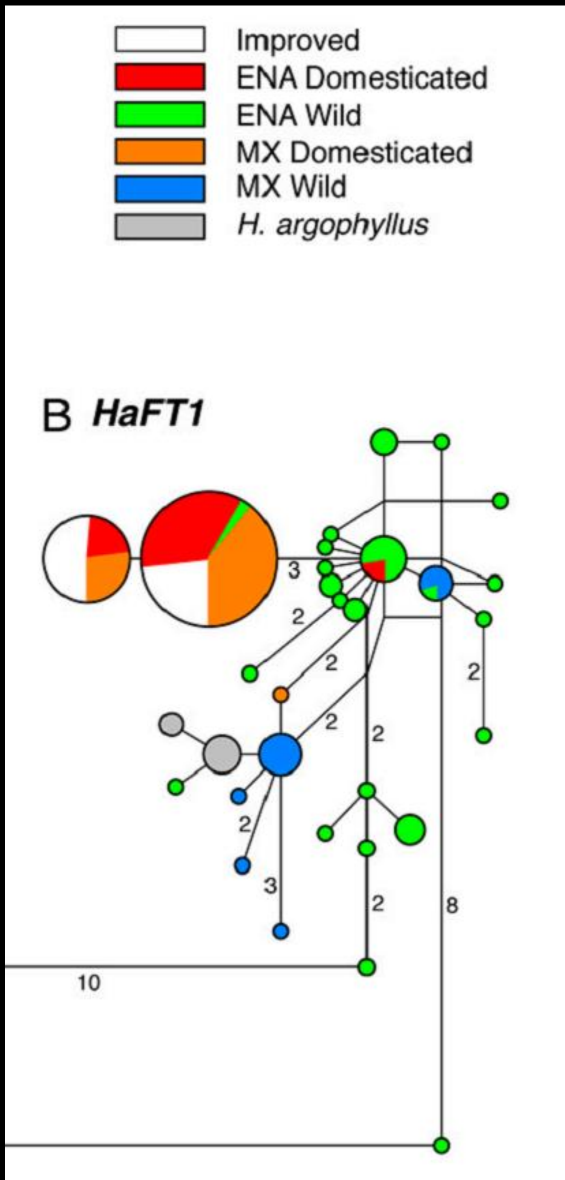
fw2.2

Buněčné dělení

Velikost plodu



Sunflower domestication alleles support single domestication center in eastern North America



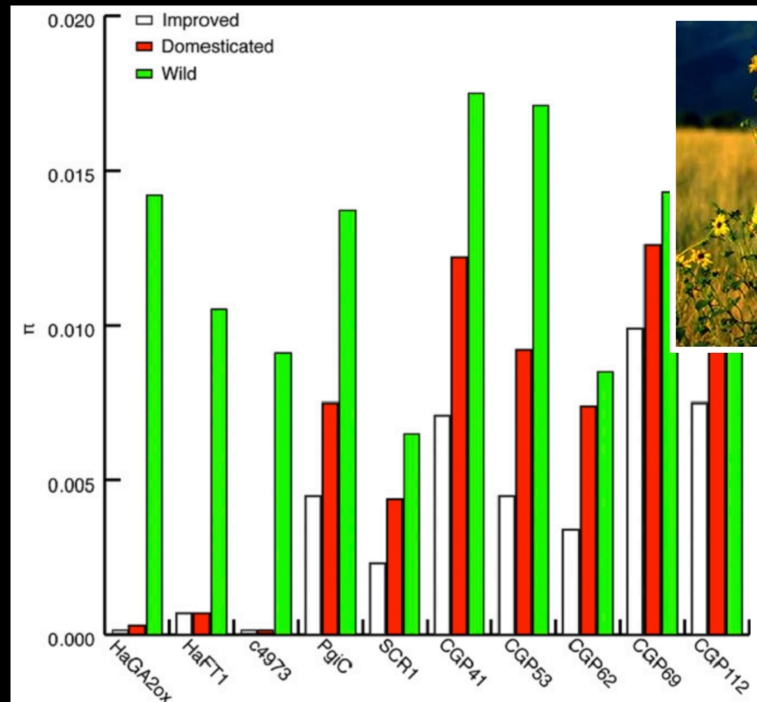


Table 1. Domesticated and wild allele frequencies in eastern North American landraces (ENA domesticated), American and Canadian wild populations (ENA wild), Mexican landraces (MX domesticated), and Mexican wild populations (MX wild)

Gene	ENA domesticated	ENA wild	MX domesticated	MX wild
HaFT1				
Domesticated allele	95% (36)	5% (2)	98% (41)	0% (0)
Wild allele	5% (2)	95% (38)	2% (1)	100% (152)
	(38 total)	(40 total)	(42 total)	(152 total)
HaGa2ox				
Domesticated haplotype 1	95% (36)	7% (3)	100% (48)	0% (0)
Other domesticated haplotypes	5% (2)	2% (1)	0% (0)	0% (0)
Wild haplotypes	0% (0)	91% (42)	0% (0)	100% (152)
	(38 total)	(46 total)	(48 total)	(152 total)

Geny zodpovědné za domestikační vlastnosti

Gene	Crop	Trait	Causative change	Classification	Sel'n[a]	Prevalence
Domestication genes						
Vrs1 (*six-rowed spike 1*)	Barley	Inflorescence structure	Premature stop (insertion, deletion, or AA change)	Domestication	N.T.	Subset of domesticates
tb1 (*teosinte branched1*)	Maize	Plant and inflorescence structure	Regulatory change	Domestication	Yes	All domesticates
tga1 (*teosinte glume architecture 1*)	Maize	Seed casing	AA change	Domestication	Yes	All domesticates
sh4 (QTL 4 responsible for the reduction of grain shattering)	Rice	Shattering	Regulatory and AA change	Domestication	Yes	All domesticates
PROG1 (*PROSTRATE GROWTH 1*)	Rice	Plant structure	AA change	Domestication	Yes[b]	All domesticates
qSH1 (QTL for seed shattering on chromosome 1)	Rice	Shattering	Regulatory change	Domestication and improvement	No	Subset of domesticates
Rc (*red pericarp*)	Rice	Grain color	Premature stop (deletion or AA change)	Domestication and improvement	Yes	Subset of domesticates (most modern)
Sdr4 (*Seed dormancy 4*)	Rice	Seed dormancy	Regulatory change	Domestication	N.T.	Subset of domesticates
Style2.1 (QTL for style length on chromosome 2)	Tomato	Autogamy	Regulatory change	Domestication	N.T.	All domesticates
fw2.2 (QTL for fruit weight on chromosome 2)	Tomato	Fruit weight (fruit size)	Regulatory change	Domestication and improvement	N.T.	Subset of domesticates (most modern)
fas (*fasciated*)	Tomato	Locule number (fruit size)	Regulatory change	Domestication and improvement	N.T.	Subset of domesticates (most modern)
Q	Wheat	Shattering and free-threshing	Regulatory and AA change	Domestication	N.T.	All domesticates

Norman Borlaug (1914 - 2009)
„Green Revolution“

pšenice Norin 10

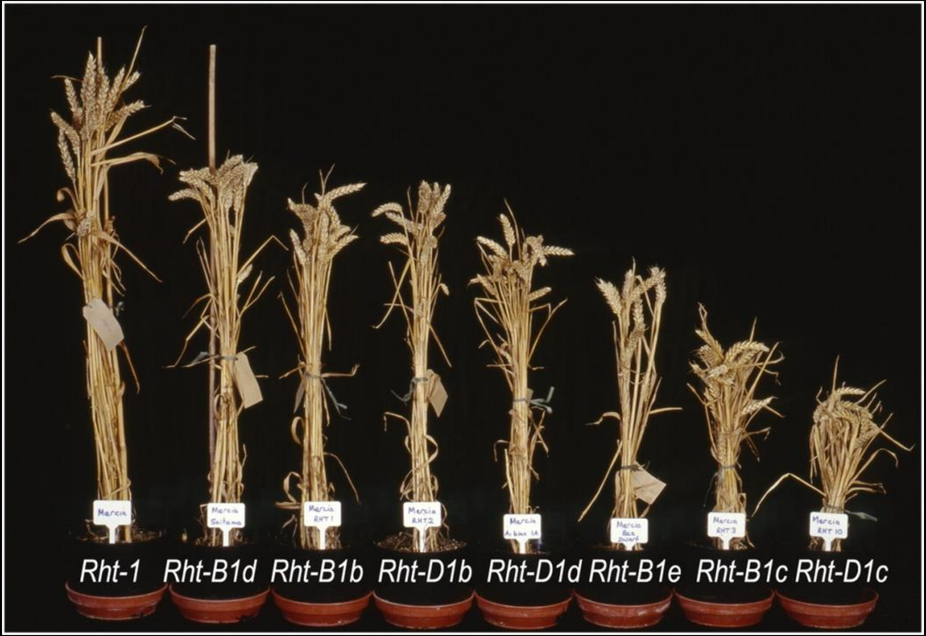
Mutant v genu pro kratší internodia

Rýže IR8 (Miracle Rice)

Nobelova cena míru 1970

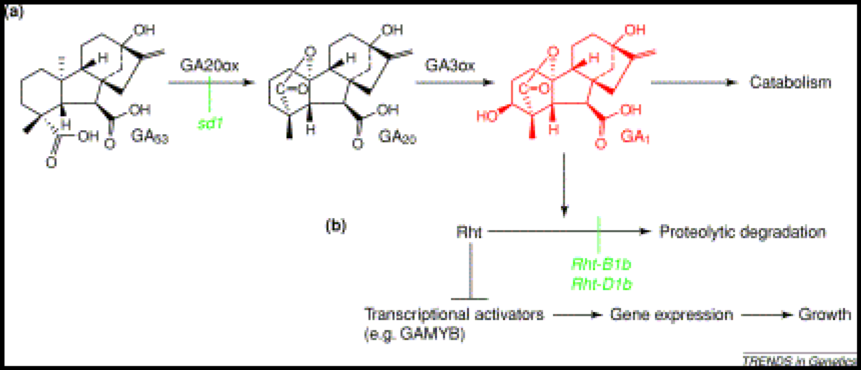
positiva (potravinová soběstačnost, vysoce produktivní odrůdy)
negativa (snížení diversity, zvýšení užití pesticidů, hnojiv, zavlažování, mechanizace, proměna venkova)

Zelená revoluce a geny zakrslosti - pšenice



Původně rostliny musely soutěžit s plevely
Většinou neoptimální výživa (N, P)
Robustní, vysoké

Používání umělých hnojiv a pesticidů
Potřeba redukce výšky (1950-60)



Rhbt-B1b (chromosom 4B)
Rhbt-D1b (chromosom 4D)

ortolog *Ath* GAI proteinu v signální dráze giberelinů

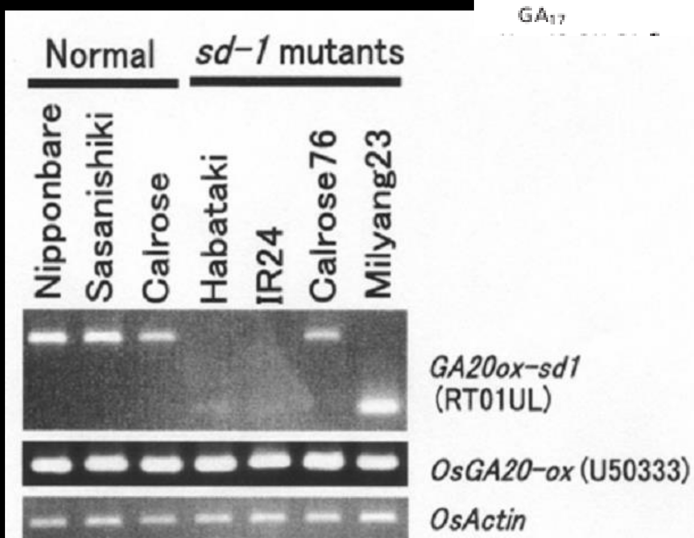
Mutantní protein postrádá N-terminální DELLA doménu – konstitutivní represor růstu

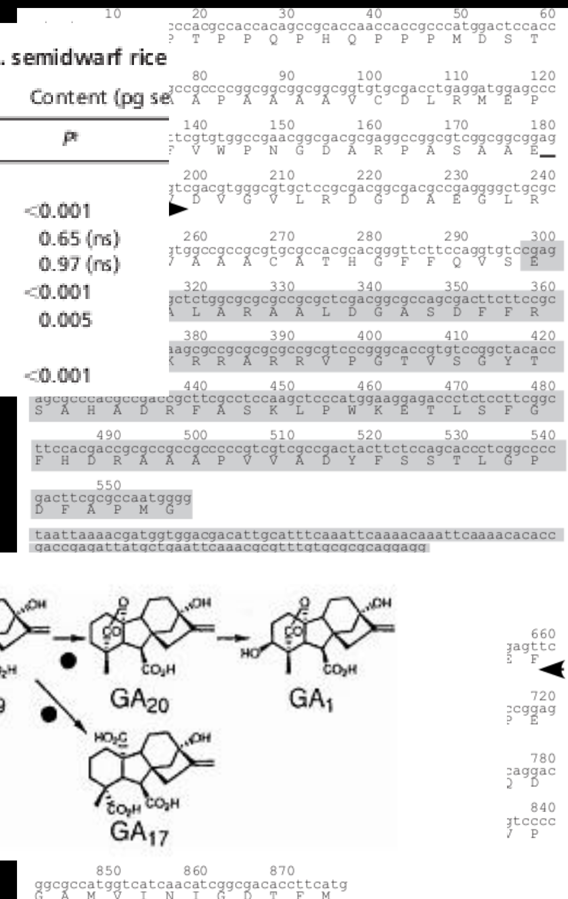
Zelená revoluce a geny zakrslosti - rýže

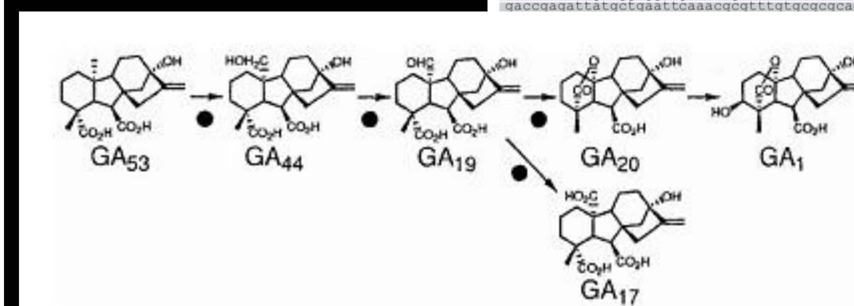
Semidwarf (*sd-1*), "green revolution" rice, contains a defective gibberellin 20-oxidase gene

Table 1. Contents of GAs in equivalent stem segments of tall vs. semidwarf rice

Compound	Content (pg se		
	Kyeema (tall)	Doongara (dwarf)	P*
13-OH GAs†			
GA_{53}	802 ± 54	2546 ± 133	<0.001
GA_{44}	687 ± 34	661 ± 42	0.65 (ns)
GA_{19}	4092 ± 269	4108 ± 401	0.97 (ns)
GA_{20}	178 ± 13	73 ± 4	<0.001
GA_1	146 ± 8	96 ± 6	0.005
GA_8	<dl‡	<dl‡	
GA_{17}	395 ± 13	109 ± 20	<0.001







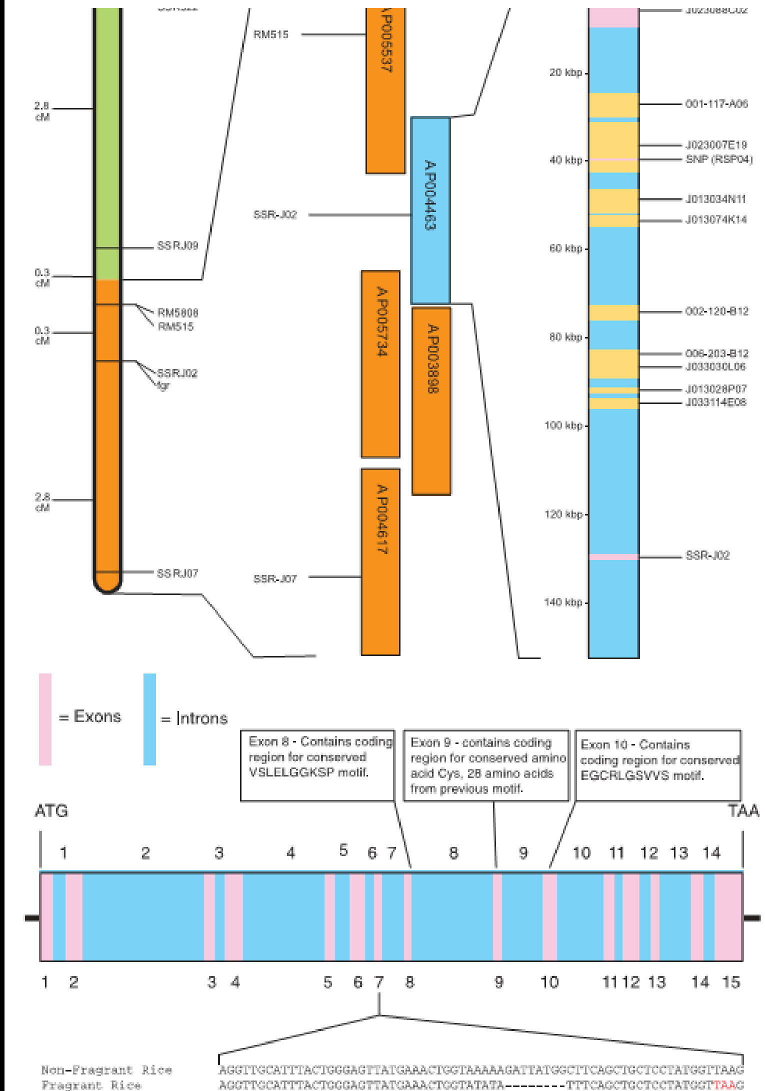
Enzym biosyntetické dráhy syntézy giberelinů - GA20 oxidáza

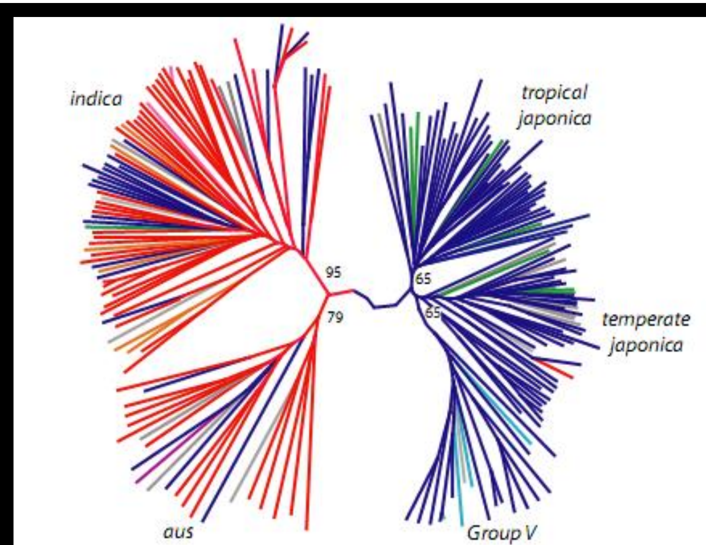
Geny zodpovědné za specifické vlastnosti

Aroma semene rýže
Barevnost semene rýže
Lepivost/konzistence rýže
Krátkostébelnost rýže
Žlutosemenost kukuřice

The origin and evolution of fragrance in rice (*Oryza sativa* L.)

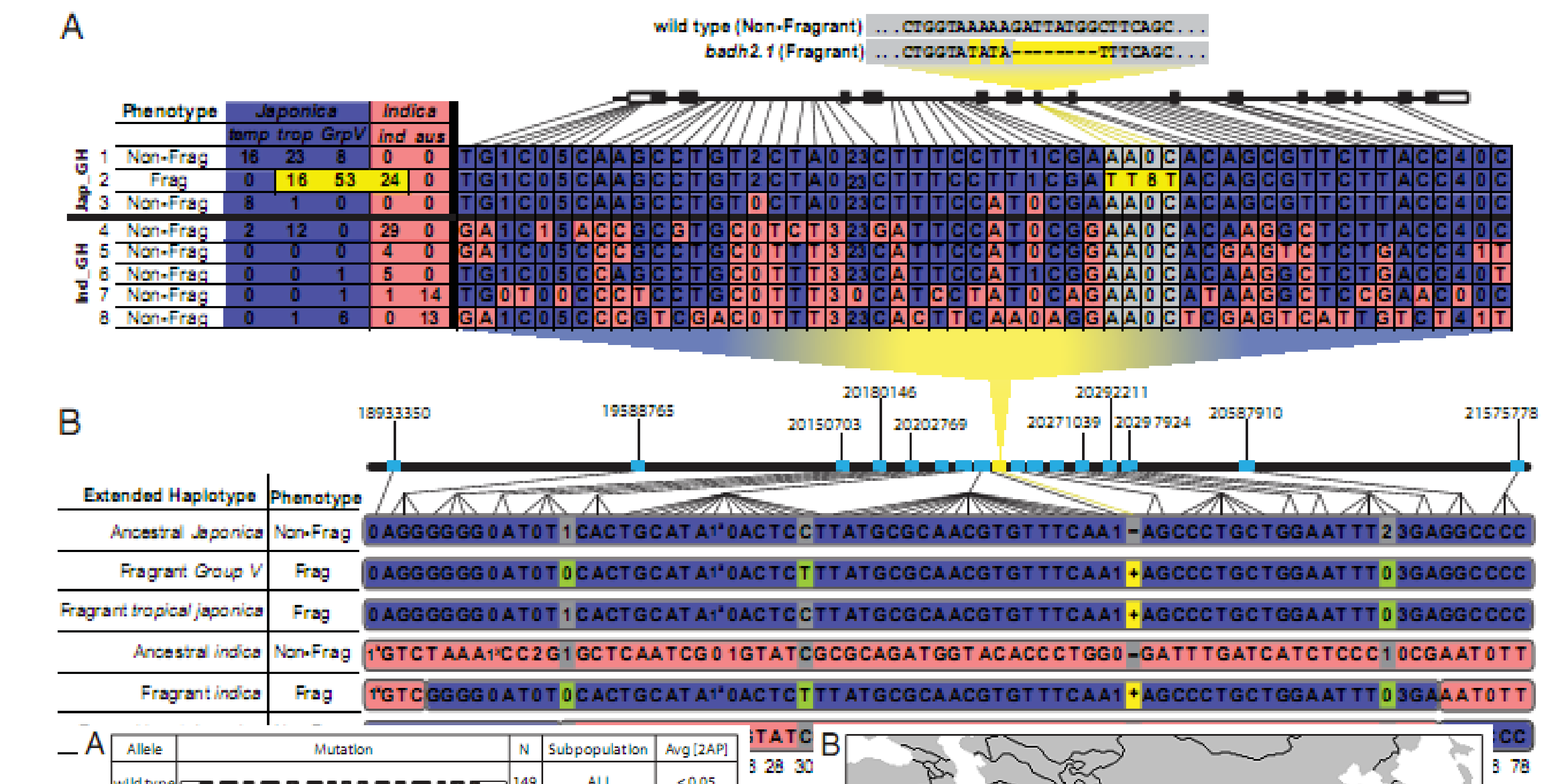
Michael J. Kovach[a], Mariafe N. Calingacion[b], Melissa A. Fitzgerald[b], and Susan R. McCouch[a,1]



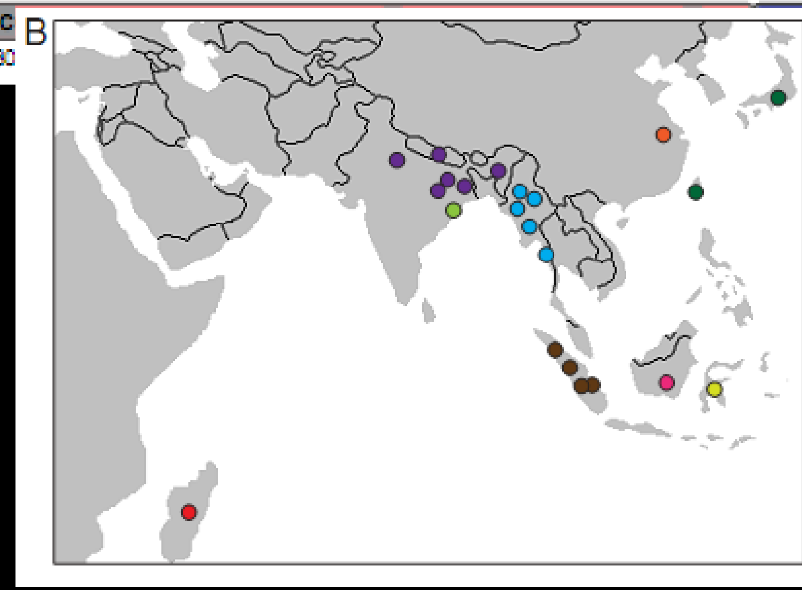


betain-aldehyd dehydrogenáza (BADH2)

akumulace
2-acetyl-1-pyrroline (2AP)



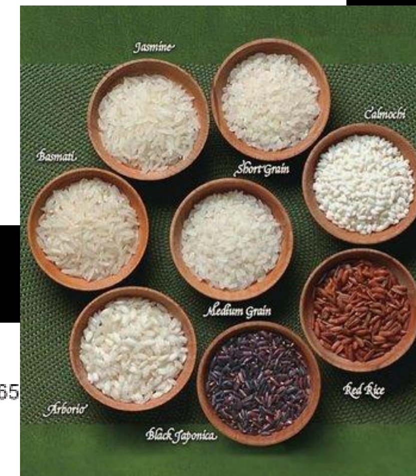
Allele	Mutation	N	Subpopulation	Avg [2AP]
wild type		149	ALL	< 0.05
badh2.1	FNP	93	*Group V, indica, tropical japonica*	0.70 ± 0.41
badh2.2	7bp deletion	1	*tropical japonica*	0.66
badh2.3	2bp deletion	1	*tropical japonica*	0.74
badh2.4	1bp insertion	1	*tropical japonica*	0.59
badh2.5	1bp deletion	1	*indica*	0.70
badh2.6	G→T SNP	1	*aus*	0.41
badh2.7	1bp insertion	6	*aus*	0.43 ± 0.17
badh2.8	3bp insertion	5	*Group V*	0.36 ± 0.14
badh2.9	G→T SNP	6	*tropical japonica*	0.18 ± 0.08
badh2.10	C→T SNP	2	*tropical japonica*	0.35



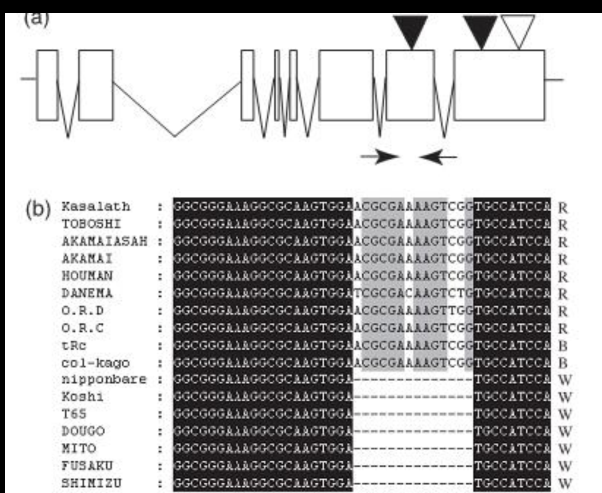
OPEN ACCESS Freely available online
PLoS GENETICS

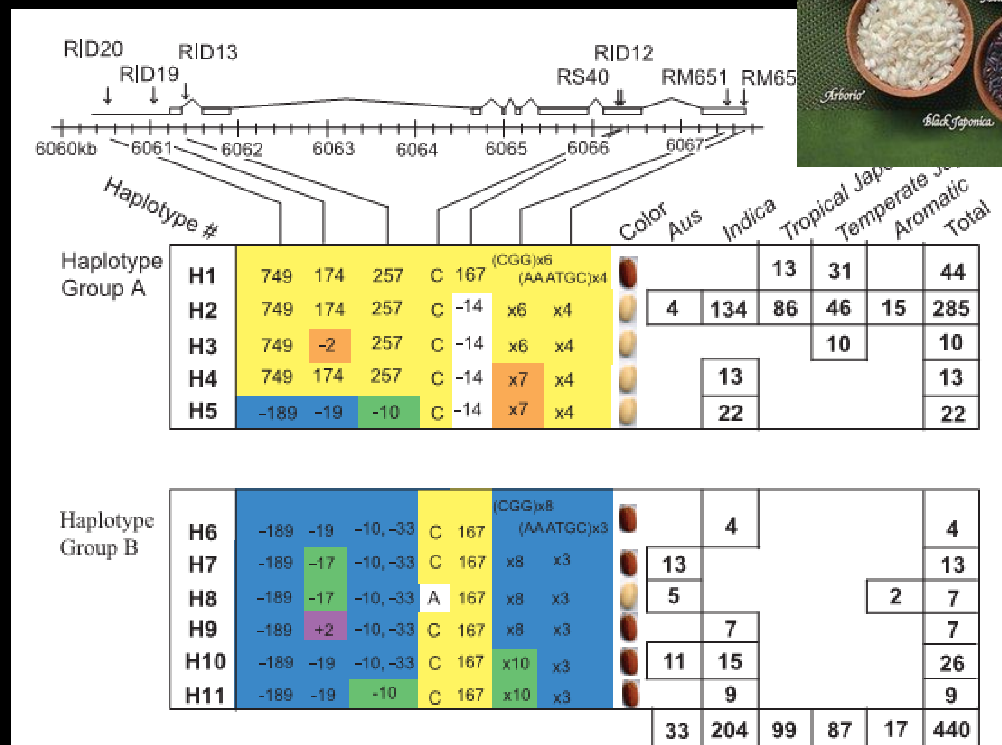
Global Dissemination of a Single Mutation Conferring White Pericarp in Rice

Megan T. Sweeney[1], Michael J. Thomson[2,3], Yong Gu Cho[4], Yong Jin Park[5], Scott H. Williamson[6], Carlos D. Bustamante[6], Susan R. McCouch[1*]



frame-shift delece uvnitř Rc genu - basic helix-loop-helix protein





1 Mb *japonica* DNA se „svezlo“ s rc alelou do většiny *indica* variet

Improvement and diversification genes in rice						
GIF1 (*GRAIN INCOMPLETE FILLING 1*)	Rice	Grain filling	Regulatory change	Improvement	Yes	All domesticates (survey not complete)
GS3 (QTL for grain size and length on chromosome 3)	Rice	Grain size and length	Premature stop (deletion)	Improvement	Yes	Subset of domesticates
qSW5 (QTL for seed width on chromosome 5)	Rice	Grain width	Deletion	Improvement	Yes[b]	Subset of domesticates
GW2 (QTL for grain weight on chromosome 2)	Rice	Grain width and weight	Premature stop (deletion)	Improvement	N.T.	Subset of domesticates (survey not compl
BADH2 (*BETAINE ALDEHYDE DEHYDROGENASE 2*)	Rice	Fragrance	Premature stop (deletion or AA change)	Diversification	Yes	Subset of domesticates
Ghd7 (QTL for grain number, plant height, and heading date)	Rice	Grain number, plant structure and flowering date	Several unique alleles with different effects; some premature stop and deletion alleles	Improvement	N.T.	Subset of domesticates
Phr1 (*Phenol reaction 1*)	Rice	Grain discoloration (oxidation)	Premature stop (insertion or deletion)	Diversification	Yes	Subset of domesticates
Waxy	Rice	Grain quality (starch)	Intron splicing defect (non-functional)	Diversification	Yes	Subset of domesticates
Gn1a (QTL for grain number on chromosome 1, a)	Rice	Grain number	Premature stop (deletion)	Improvement	N.T.	Subset of domesticates
sd1 (*semidwarf1*)	Rice	Plant structure	Premature stop (deletion) or AA change	Improvement	Yes	Subset of domesticates

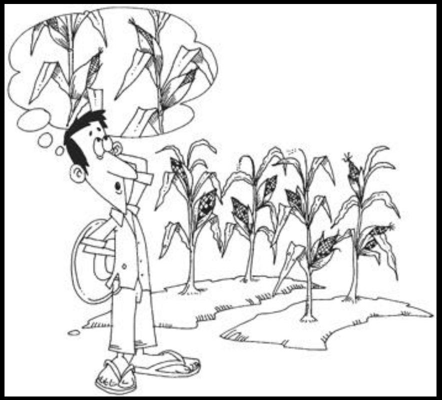
- **pro proteiny, enzymy biosyntetických dráh**
- **specifické**
- **eliminace funkce**

Domestikace a co dál ?

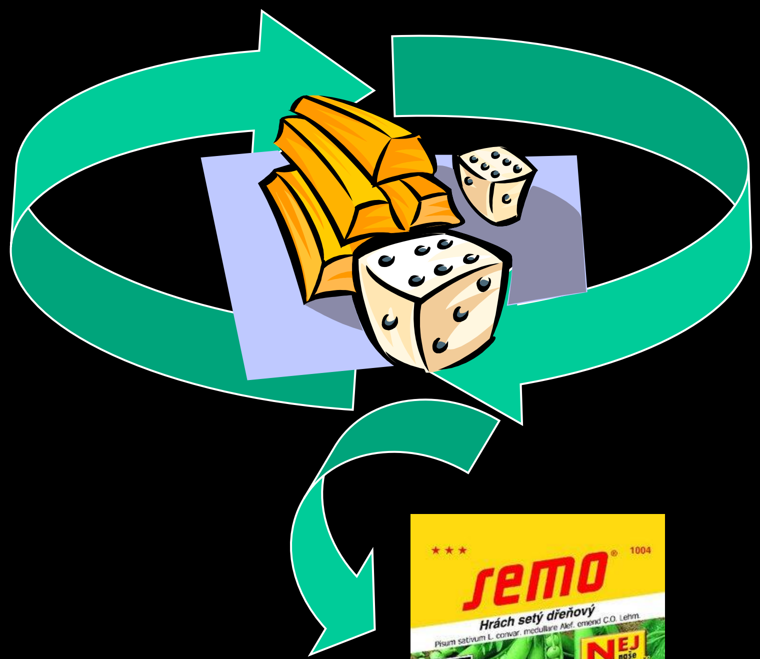
Super domestikace
Transgenose …

- modifikace charakteru-využití plodin
- domestikace nových druhů
- „ztracené druhy“
- superdomestikace

Šlechtění – umění a věda (ale také obchod)



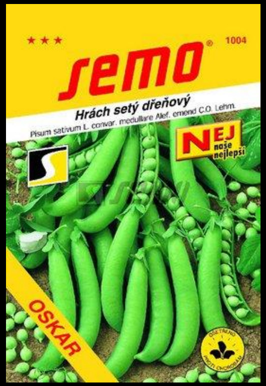
Genetická variabilita



křížení

výběr

Nová odrůda



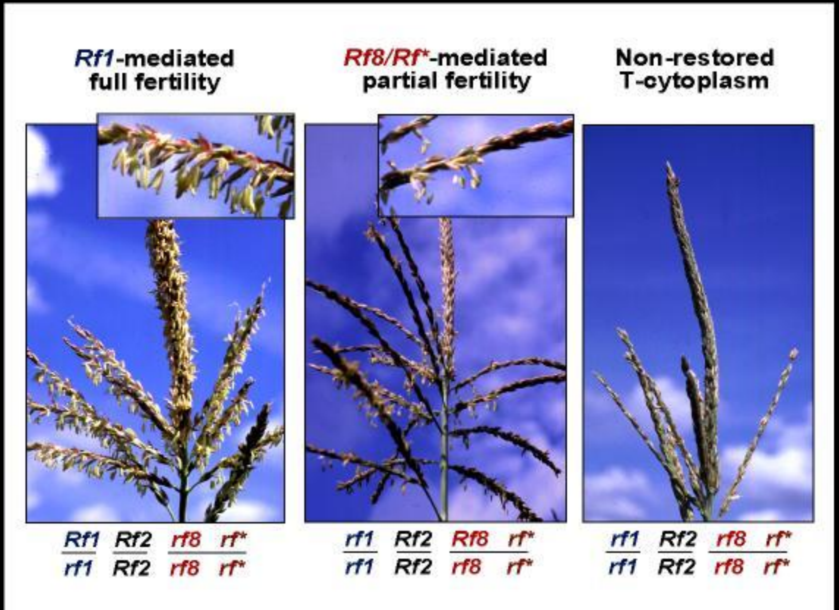
Heterose -"hybridní síla F1"

1930-1997: zvýšení výnosu kukuřice z 1 na 8 tun/ha
za což z 50-70% odpovídá heterózní efekt

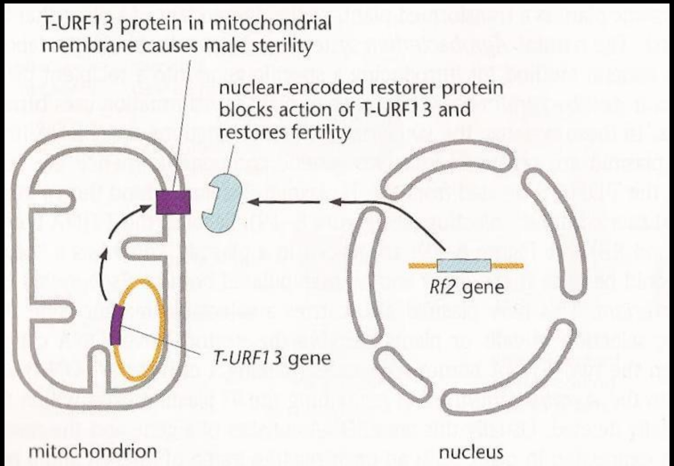
Cytoplasmatická samčí sterilita

- neschopnost produkce funkčního pylu
- samčí sterility je agronomicky výhodná pro produkci hybridních semen

fertilní květ sterilní květ



Web Fig. F. Maize tassel phenotypes mediated by different restorer loci

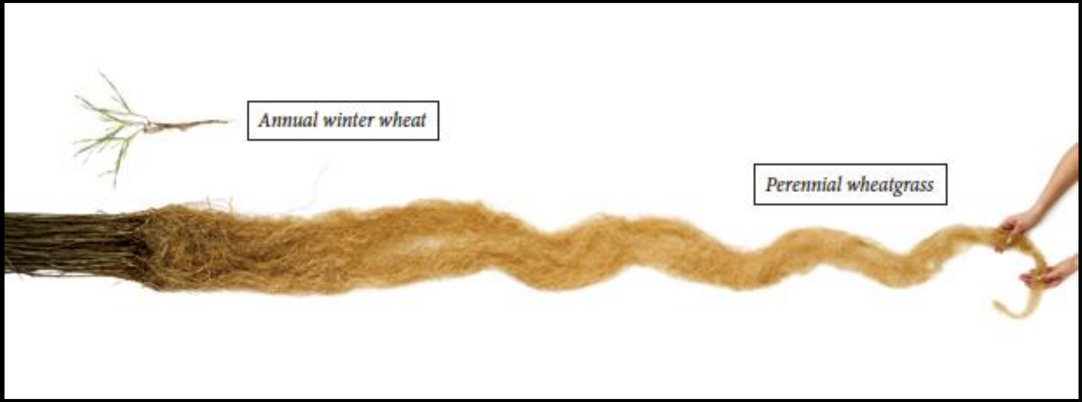


reorganizace mtDNA
CMS Texas (T) cytoplasma kukuřice

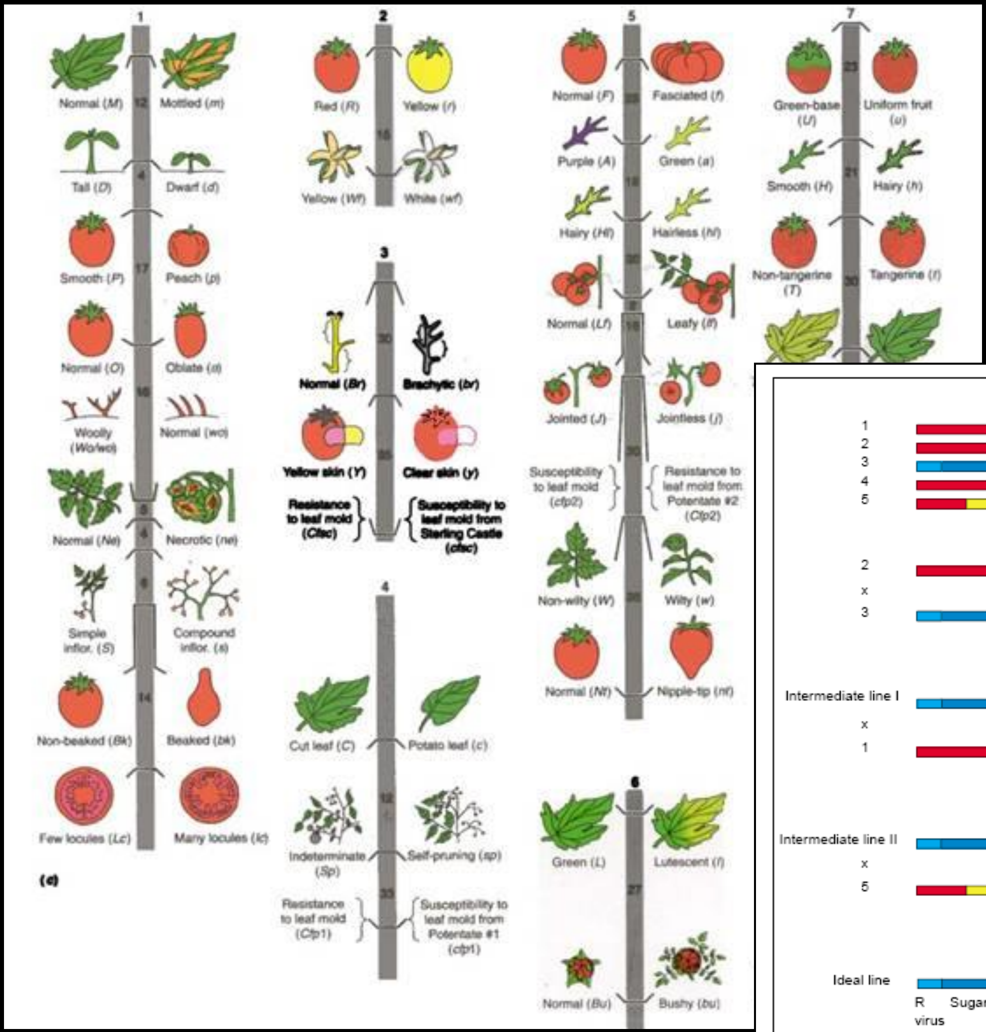
fúze promotoru ATP6 k části RRN2 genu – vznik nového membránového proteinu T-URF13

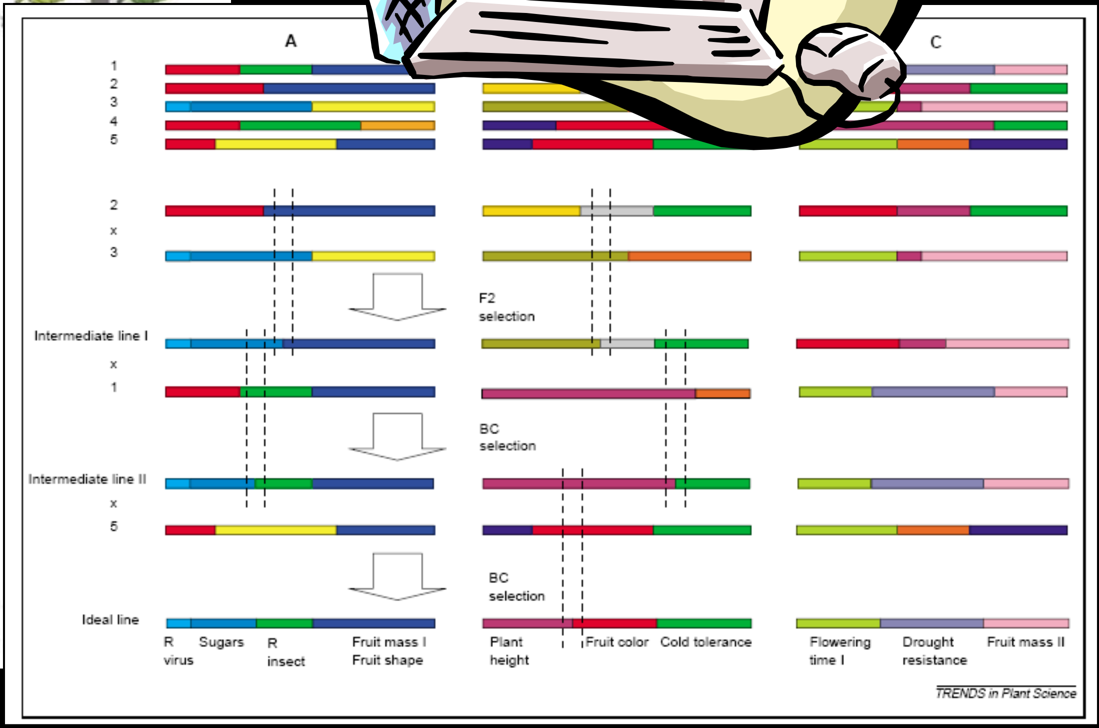
Změna zpět na vytrvalé druhy (traviny)

Annual grains feed the world, but they create problems. Perennials are thrifty. Their long roots hold on to soil, water, and fertilizer, which means less pollution.

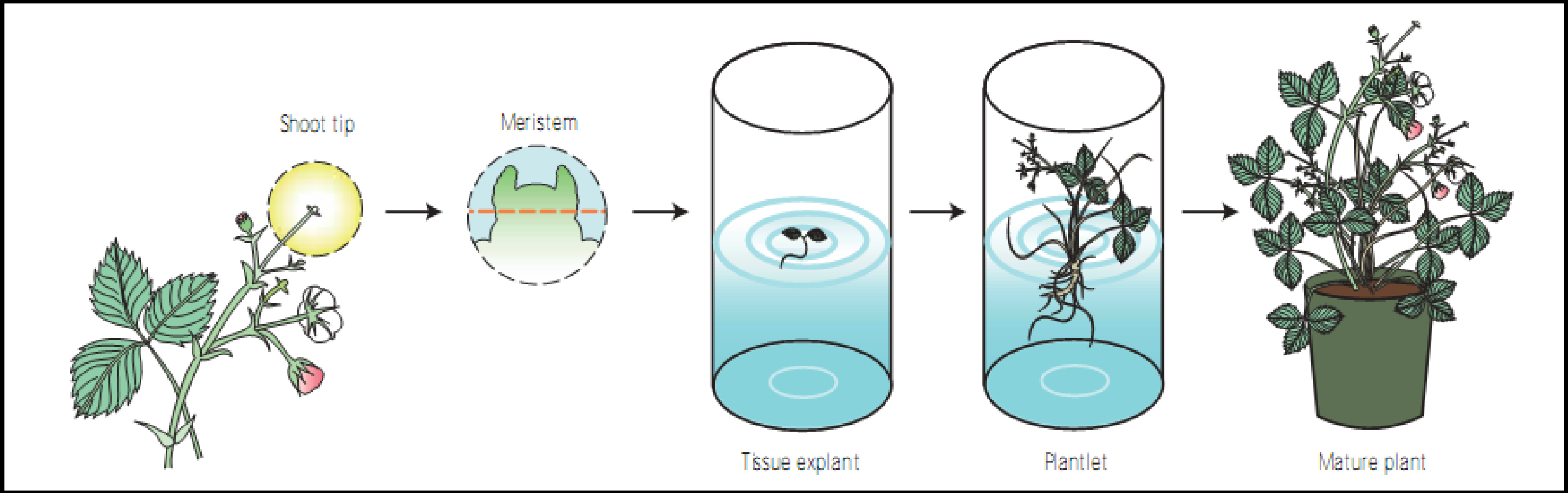


Pyramidování genů - Breeding by design

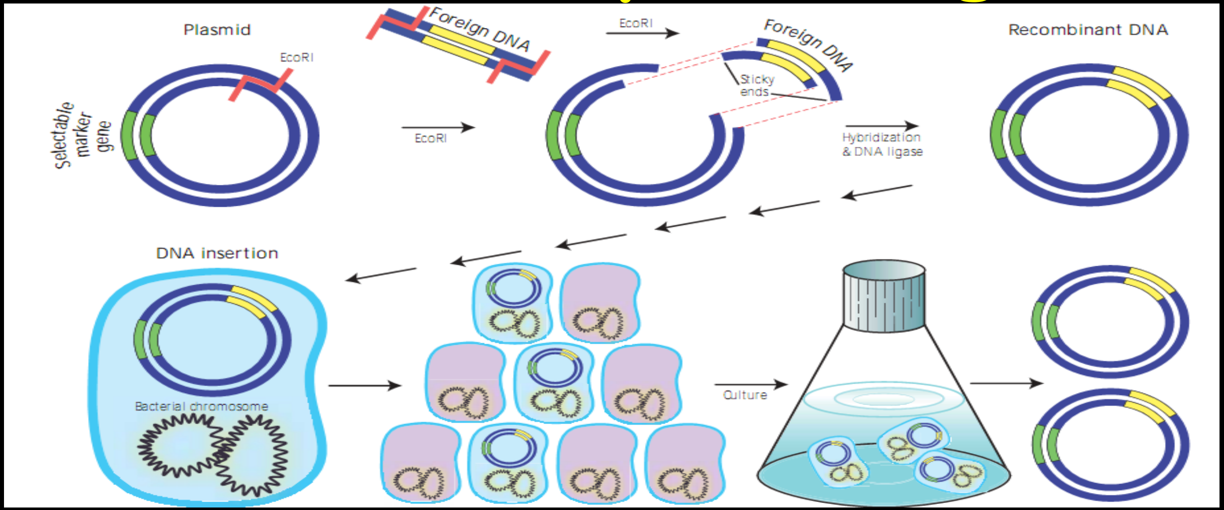




Biotechnologie a šlechtění rostlin



od *in vitro* kultur po transgenozi



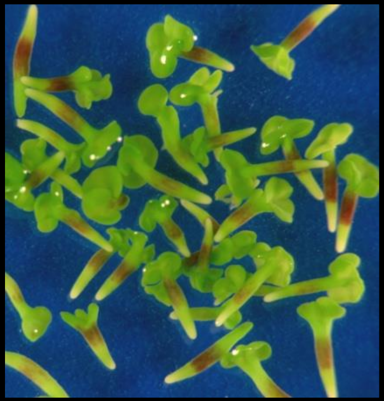
P. Smýkal

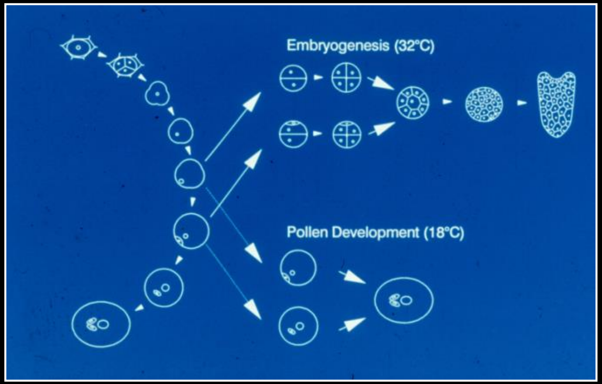
Dihaploidie
cesta získání homozygotních linií

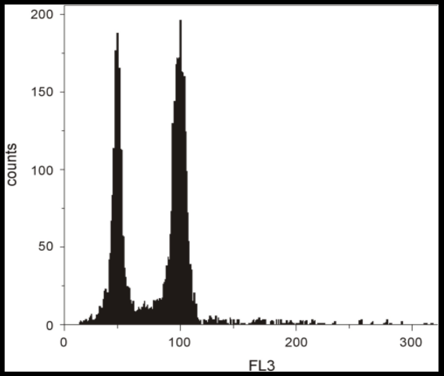
2n = Aa

n = A / a

2n = AA/ aa



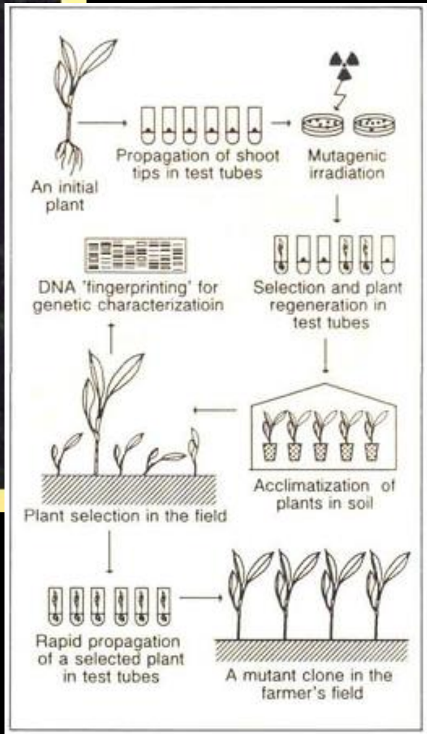




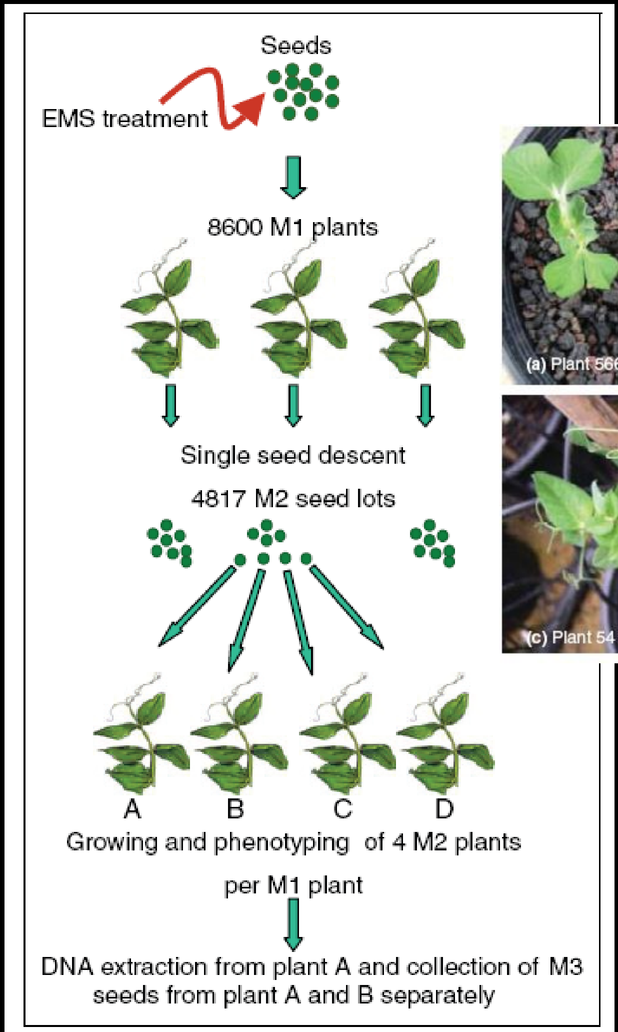
P. Smýkal

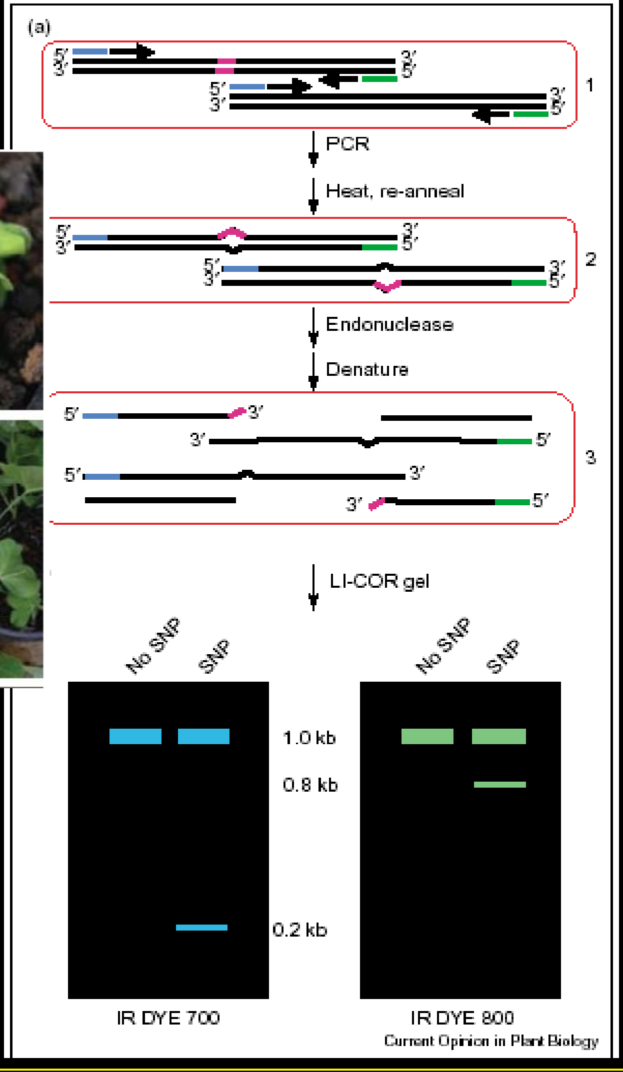
Mutační šlechtění

- fyzikální
- chemická
- transposony
- T-DNA

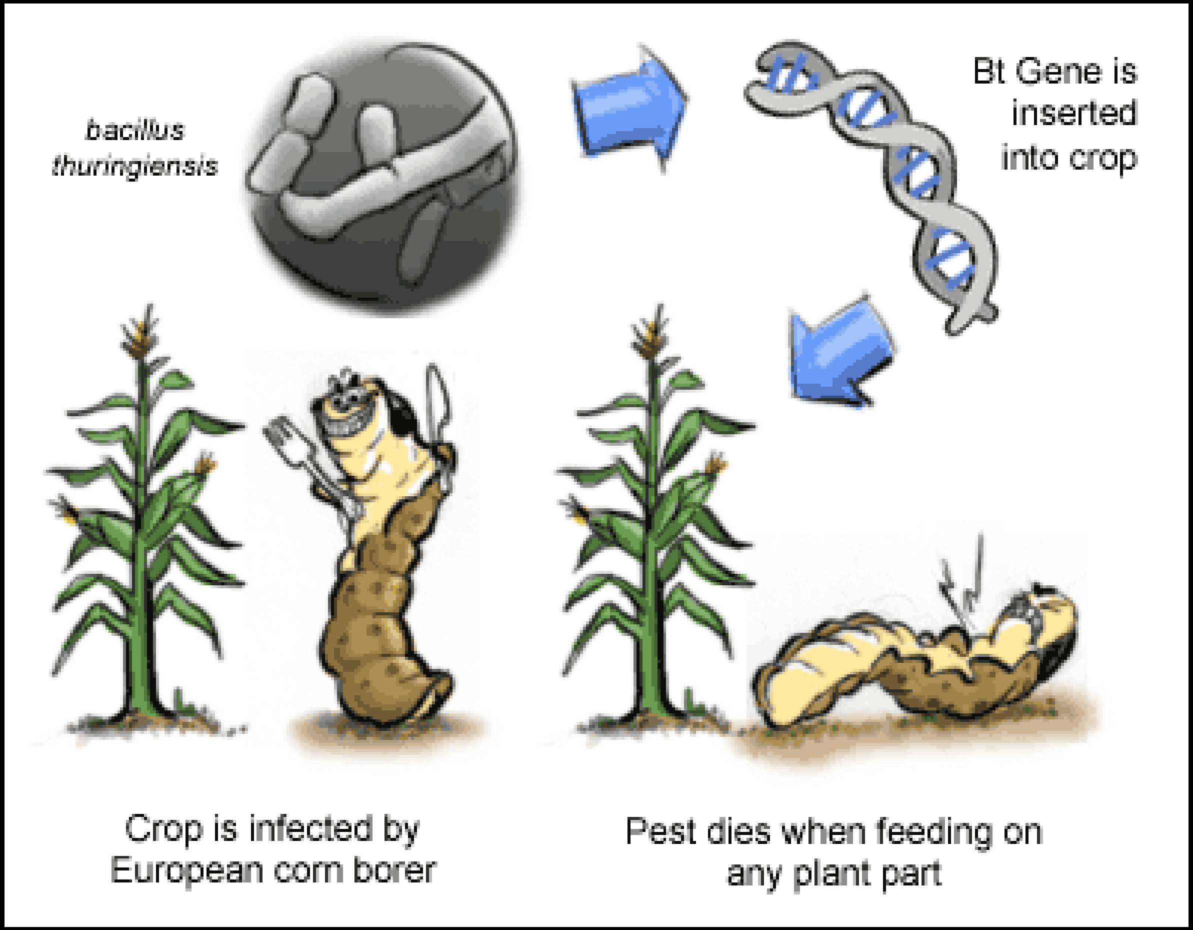


TILLING aneb mutageneze v novém
(Targeting Induced Local Lesions In Genomes)





Transgenose (GMO)
mezi vědou, etikou a politikou



Pěstování GMO rostlin

Globální stav GM plodin v roce 2008

■ 25 zemí pěstujících GM plodiny

V roce 2008 byla globální plocha s biotechnologickými plodinami 125 mil. ha, což představuje nárůst o 9,4 % proti roku 2007 (+ 10,7 mil. ha)

Zdroj: Clive James, ISAAA, 2009

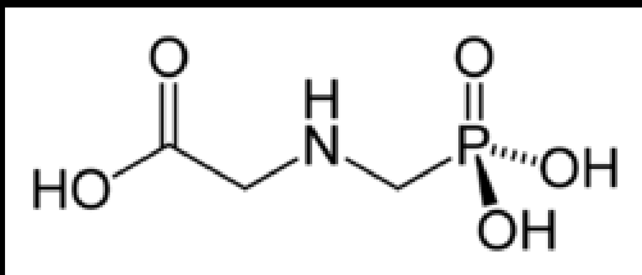
více než 50 000 ha (v mil. ha)

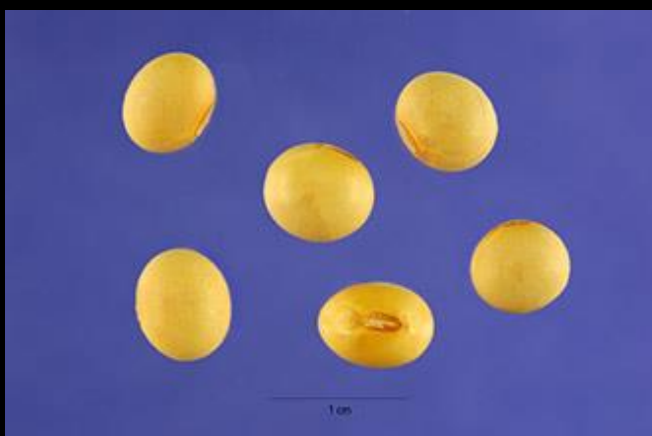
USA	62,5
Argentina	21,0
Brazílie	15,8
Indie	7,6
Kanada	7,6
Čína	3,8
Paraguay	2,7
Jižní Afrika	1,8
Uruguay	0,7
Bolívie	0,6
Filipíny	0,4
Austrálie	0,2
Mexiko	0,1
Španělsko	0,1

méně než 50 000 ha

Chile	Portugalsko
Kolumbie	Německo
Honduras	Polsko
Burkina Faso	Slovensko
ČR	Egypt
Rumunsko	

Roundup Ready ®
- glyphosate story

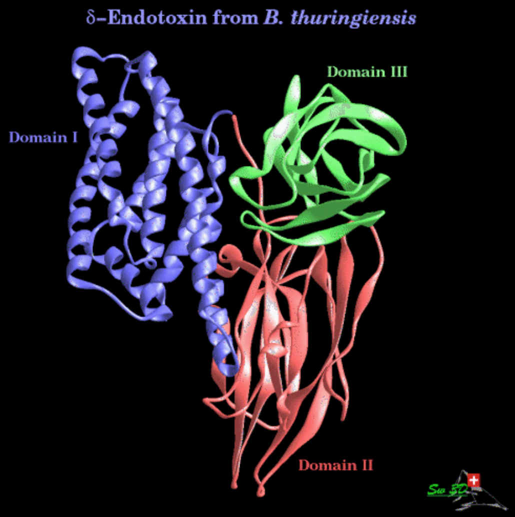




MONSANTO

Bt kukuřice (MON 810) - komerční story by

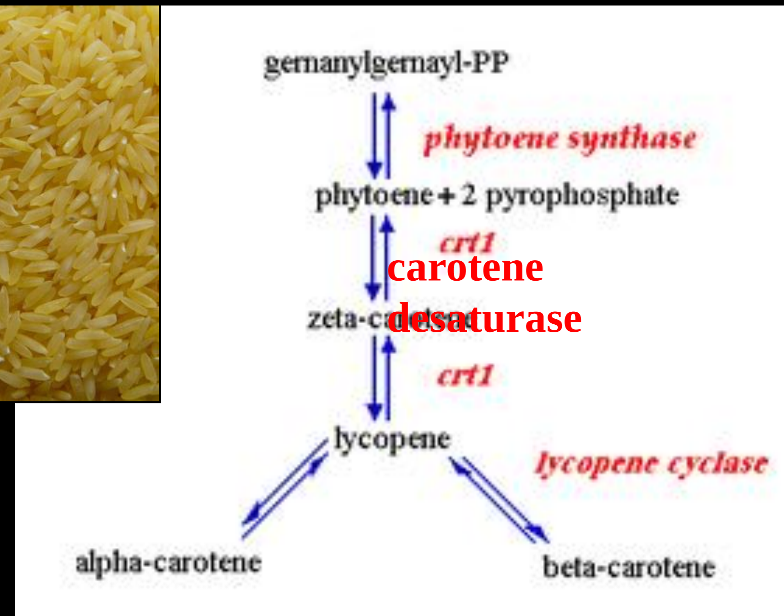
B. thuringiensis
objeveno v roce 1901 v Japonsku
1911 v Německu
Ernst Berliner nemoc housenek motýlů (Schlaffsucht)



cry **gen - protein**

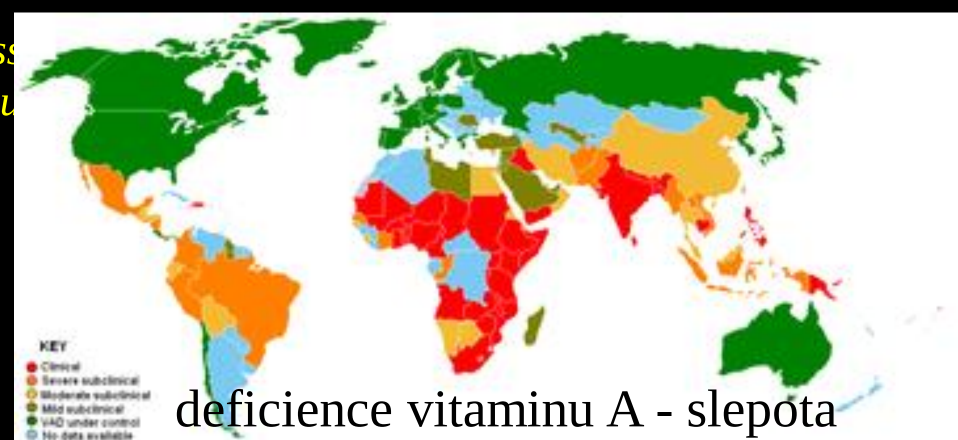
StarLink ® kukuřice (Aventis crop Science) 2002

Golden rice story



β- karoten
1-3 μg/g
10-30 μg/g

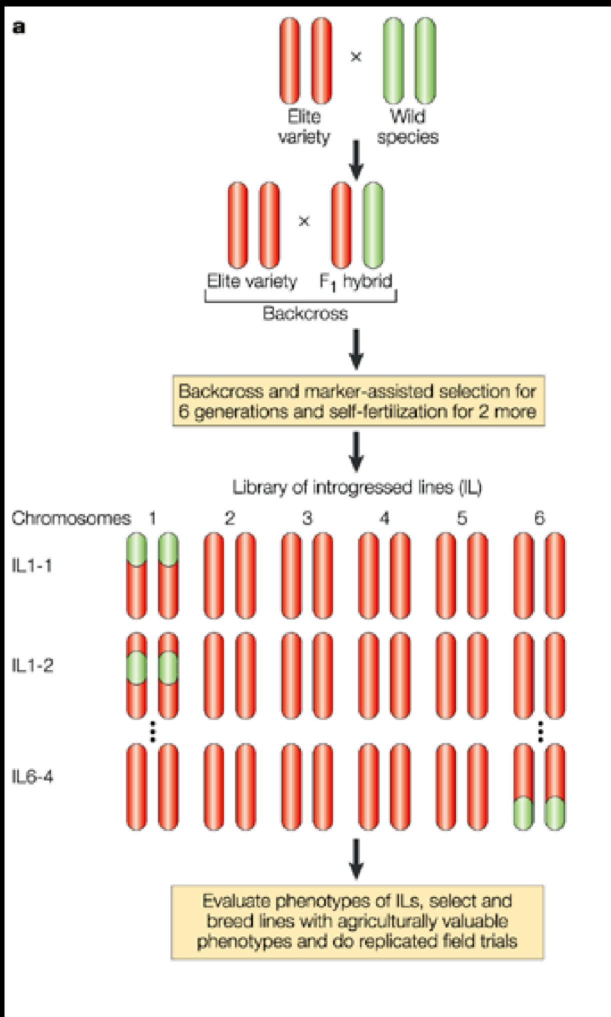
- **psy** **(phytoene synthase)** (*Narcissus pseudonarciss*
- **lyc** **(lycopene cyclase)** (*Narcissus pseudonarcissu*
- **crt1** - z půdní bakterie *Erwinia uredovora*

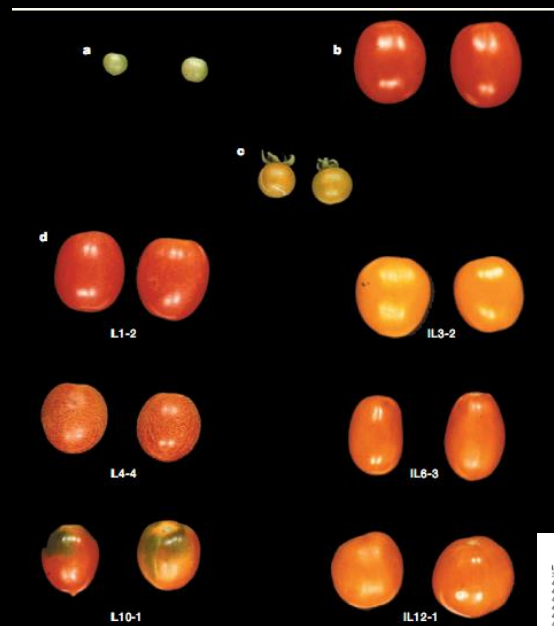


deficience vitaminu A - slepota

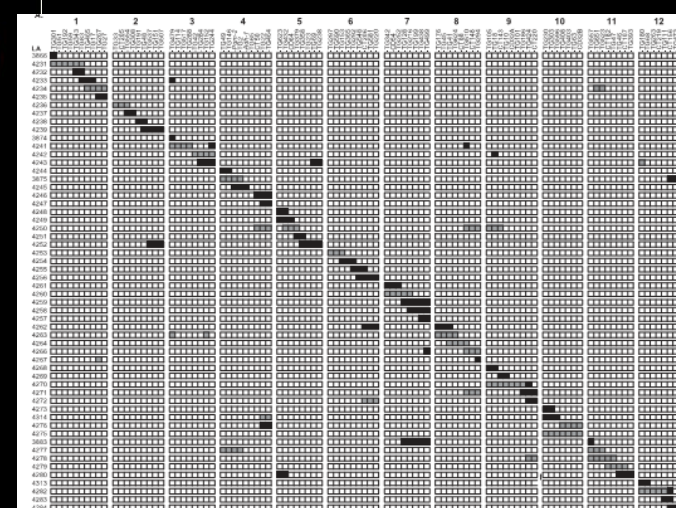
http://www.goldenrice.org

Rozšíření užitných vlastností introgrese





návrat k planým druhům
využití nových vlastností



Po většinu své existence lidstvo žilo v těsném kontaktu s přírodou, půdou

- lovci – sběrači 300 000 generací
- zemědělci 600
- industriální 8 – 10 generací