DE NOVO DOMESTICATION

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DEPARTMENT OF AGROECOLOGY

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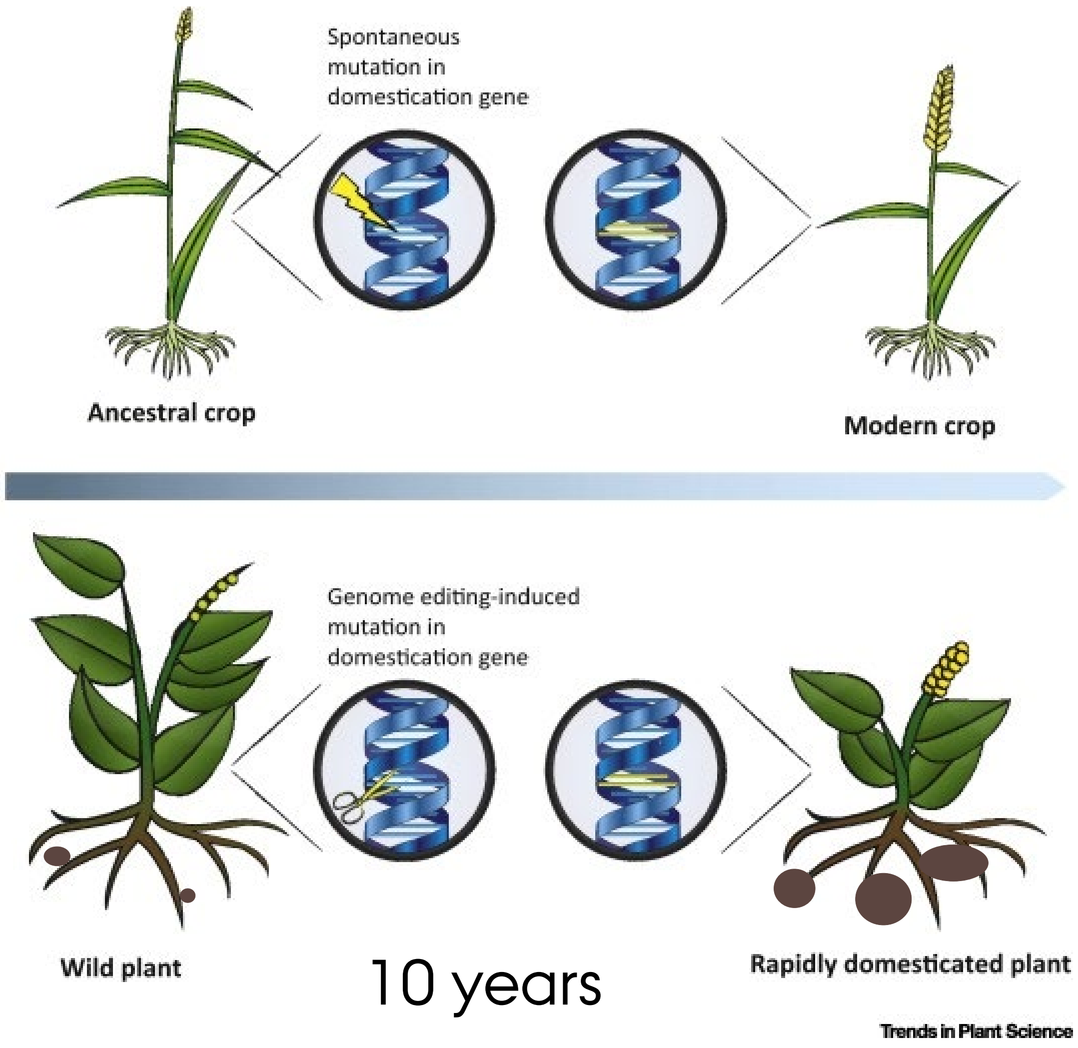
KIM HEBELSTRUP
ASSOCIATE PROFESSOR

100-1000s of years

Historic domestication



De novo domestication

10 years

Morphological traits

Physiological traits

Metabolic profiles

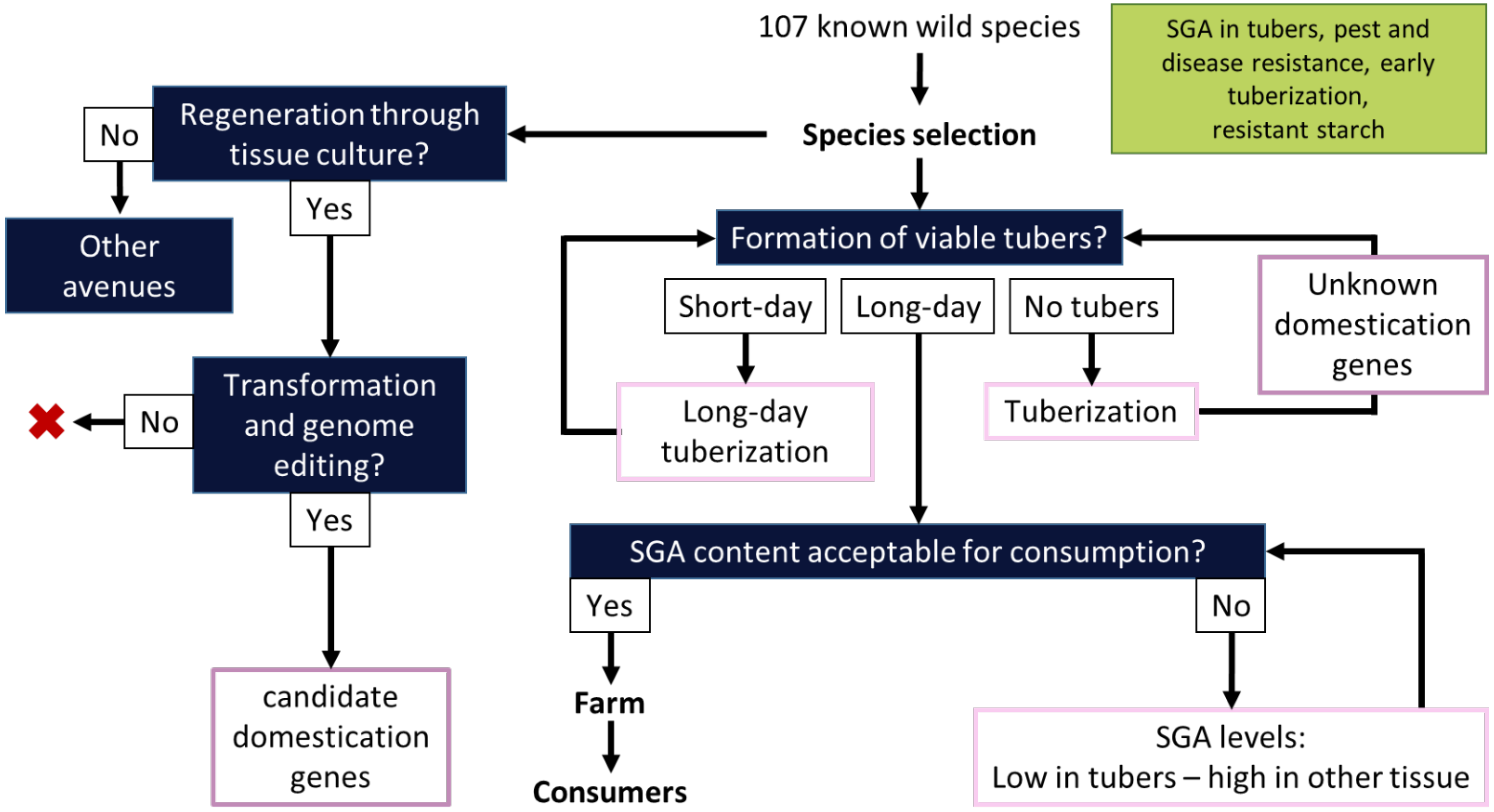
Selection of wild, abandoned or marginally cultivated species from archaeoethnobotanical studies

Test of key agronomic parameters: e.g., yield, flowering, tuberization, brittleness, metabolic profiling for toxic compounds

Identification of target traits and target domestication genes from related domesticated crops

Establishment of transformation and regeneration protocols

De novo domestication by genome editing



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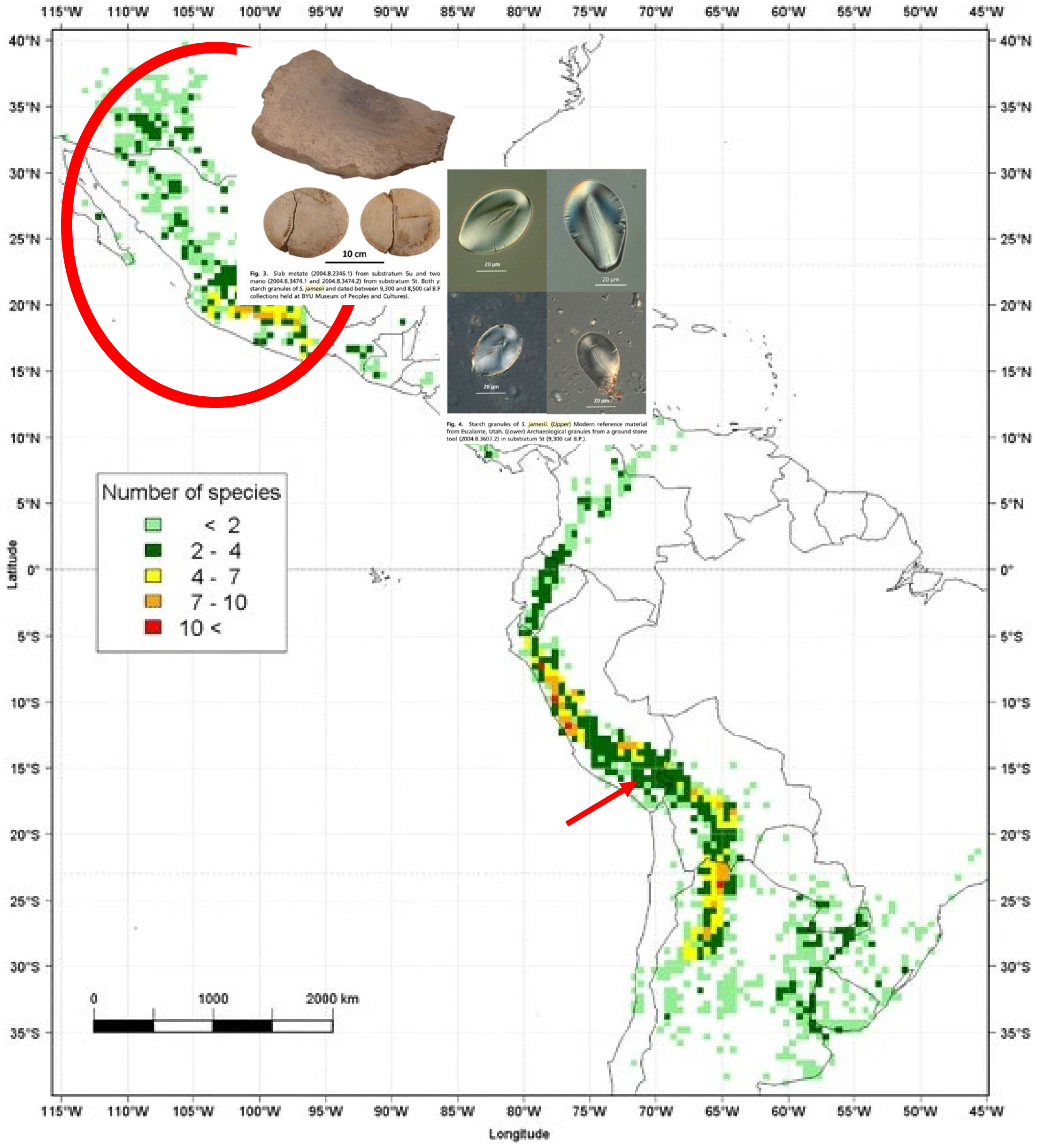


Number of wild potato species per half degree grid cell in the Americas.

The map shows five centers of species richness (from South to North): a northern Argentina, b Bolivia, c southern Peru, d northern Peru, and e) central Mexico (Spooner et al. 2014).

Geographic Correlates of Potato Systematics and Diversity

- **107 wild potato species**
- between 38 °N to 41 °S,
- between 0 and 5000 m altitude,
- within habitats from –1 °C to 26 °C annual average temperature,
- and with mean annual rainfall from less than 100 mm to more than 3700 mm (Hawkes, 1994; Hijmans & Spooner, 2001).

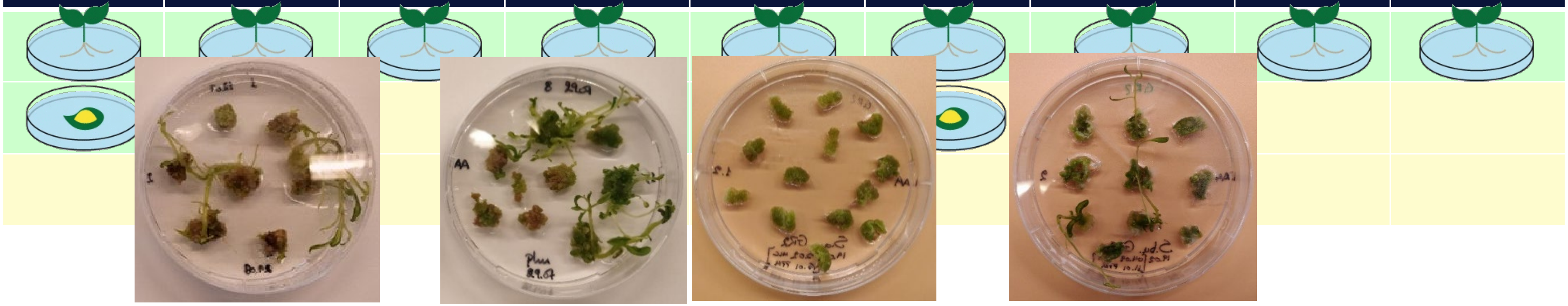
Species Name	Virus X	Virus Y	PLRV	Colorado beetle	Aphids	Nematodes	Blackleg	Bacterial wilt	Wart	Common scab	**Late blight**	Frost	Heat	Drought
S. acaule	++	++	++	+	++	+	++	++	++	NA	+	++	++	+
S. bulbocastanum	NA	+	-	+	++	++	++	-	NA	NA	++	-	++	++
S. demissum	-	++	++	+	++	++	++	++	++	NA	++	++	++	++
S. tu. ssp. *phureja*	++	++	++	-	++	++	++	++	++	++	++	+	+	-
S. pinnatisectum	-	++	++	++	+	-	++	++	NA	NA	++	++	-	NA
S. stoloniferum	-	++	-	++	++	+	++	-	NA	NA	++	-	++	++
S. tu. ssp. andigena	++	++	++	-	++	++	++	-	++	++	++	+	++	++
S. curtilobum	+	NA	NA	-	-	+	NA	++	++	NA	++	+	NA	+
S. stenotomum	NA	++	NA	-	++	++	++	++	++	+	++	+	-	++
S. jamesii	-	++	-	++	++	-	++	NA	+	NA	++	-	+	++

Various known resistances to pathogens in wild *Solanum* species. - (magenta) susceptible, + (light green) moderately resistance, ++ (dark green) highly resistant, NA (purple) no data available

(Bukasov and Naumov, 1938, Niederhauser and Mills, 1953, Rothacker, 1957, Dunnett, 1959, Graham et al., 1959, Rothacker, 1960, Niederhauser, 1961, Webb and Schultz, 1961, Ross and Rowe, 1965, Robinson, 1968, Thurston and Lozano, 1968, Sequeira and Rowe, 1969, Cockerham, 1970, Bagnall, 1972, Richardson and Weiser, 1972, Saltykova and Yakovleva, 1973, Martin and French, 1977, Mendoza and Estrada, 1979, Schmiediche et al., 1980, Smillie et al., 1983, Van Soest et al., 1984, Dellaert and Hoekstra, 1987, Chavez et al., 1988, Colon and Budding, 1988, Horvath et al., 1988, Radcliffe et al., 1988, Brown et al., 1989, Hanneman, 1989, Lojkowska and Kelman, 1989, Reynolds and Ewing, 1989, Turner, 1989, Brown et al., 1991, Midmore and Prange, 1991, Tozzini et al., 1991, Flanders et al., 1992, De Maine et al., 1993, Singh et al., 1994, Bamberg, 1995, Cañizares and Forbes, 1995, Querci et al., 1995, Rousselle-Bourgeois and Mugniery, 1995, Rousselle-Bourgeois and Priou, 1995, Vega and Bamberg, 1995, Bamberg et al., 1996, Janssen et al., 1996, Flanders et al., 1997, Horvath et al., 1997, Valkonen, 1997, Helgeson et al., 1998, Ruiz de Galarreta et al., 1998, Tommiska et al., 1998, Franco-Lara and Barker, 1999, Mihovilovich et al., 1999, Pelletier et al., 1999, Pérez et al., 1999, Douches et al., 2001, Fock et al., 2001, Di Vito et al., 2003, Chen et al., 2003, Hijmans et al., 2003, Salazar, 2006, Watkinson et al., 2006, Arvin and Donnelly, 2008, Ritter et al., 2008, Fréchette et al., 2010, Cai et al., 2011, Watanabe et al., 2011, Cabello et al., 2012, Khiutti et al., 2012, Rogozina et al., 2012, Zoteyeva et al., 2012, Ruiz de Galarreta et al., 2015, Kinder et al., 2017, Bachmann-Pfabe et al., 2019, Rogozina et al., 2019a, Rogozina et al., 2019b, Enciso-Maldonado et al., 2022, Perez et al., 2022, Dénes et al., 2023, Rogozina et al., 2023, He et al., 2024)

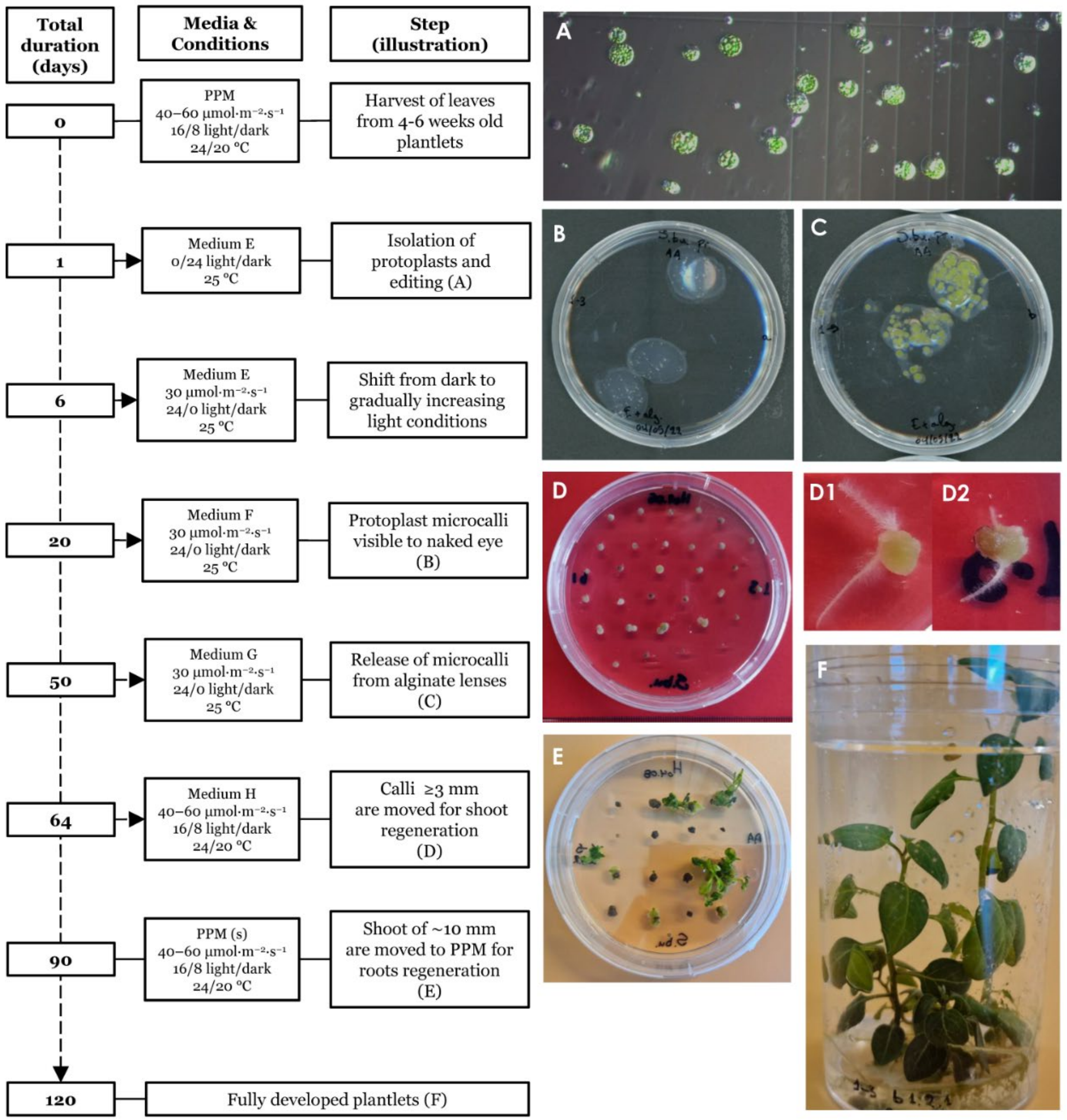
S. acaule	S. curtilobum	S. stenototum	S. tuberosum ssp. phureja	S. tuberosum ssp. andigena	S. demissum	S. bulbocastanum ssp. partitum	S. stoloniferum	S. pinnatisectum

S. acaule	*S. curtilobum*	*S. stenototum*	*S. tuberosum ssp. phureja*	*S. tuberosum ssp. andigena*	*S. demissum*	*S. bulbocastanum ssp. partitum*	*S. stoloniferum*	*S. pinnatisectum*



Timeline of regeneration protocol

Isolated protoplasts prior to transformation (A). Day 20 post protoplast isolation (ppi) showing protoplast embedded in alginate lenses (B). Day 50 ppi, prior to release from the alginate lenses (C). Day 64 ppi, hardened calli showing initiation of early plant growth (D). Calli with premature root emergence (D1,D2). Day 90 ppi, presence of shoots of ~10–20 mm length (E). Day ~120 ppi, fully regenerated plants grown in propagating medium (F).



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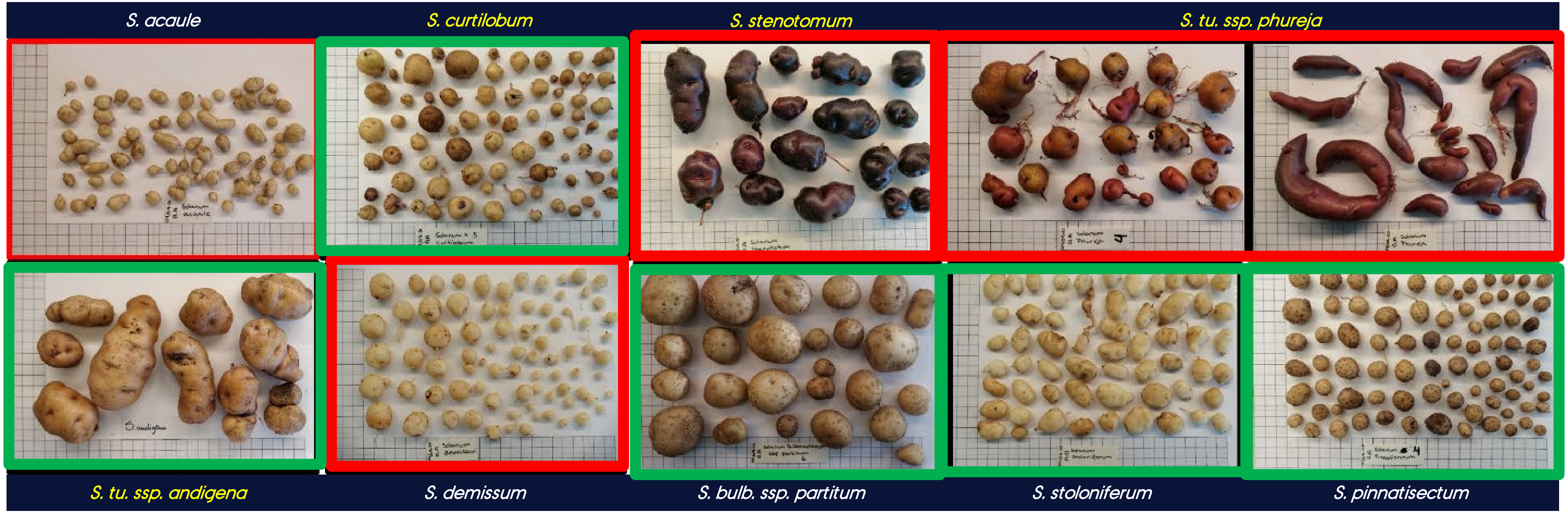
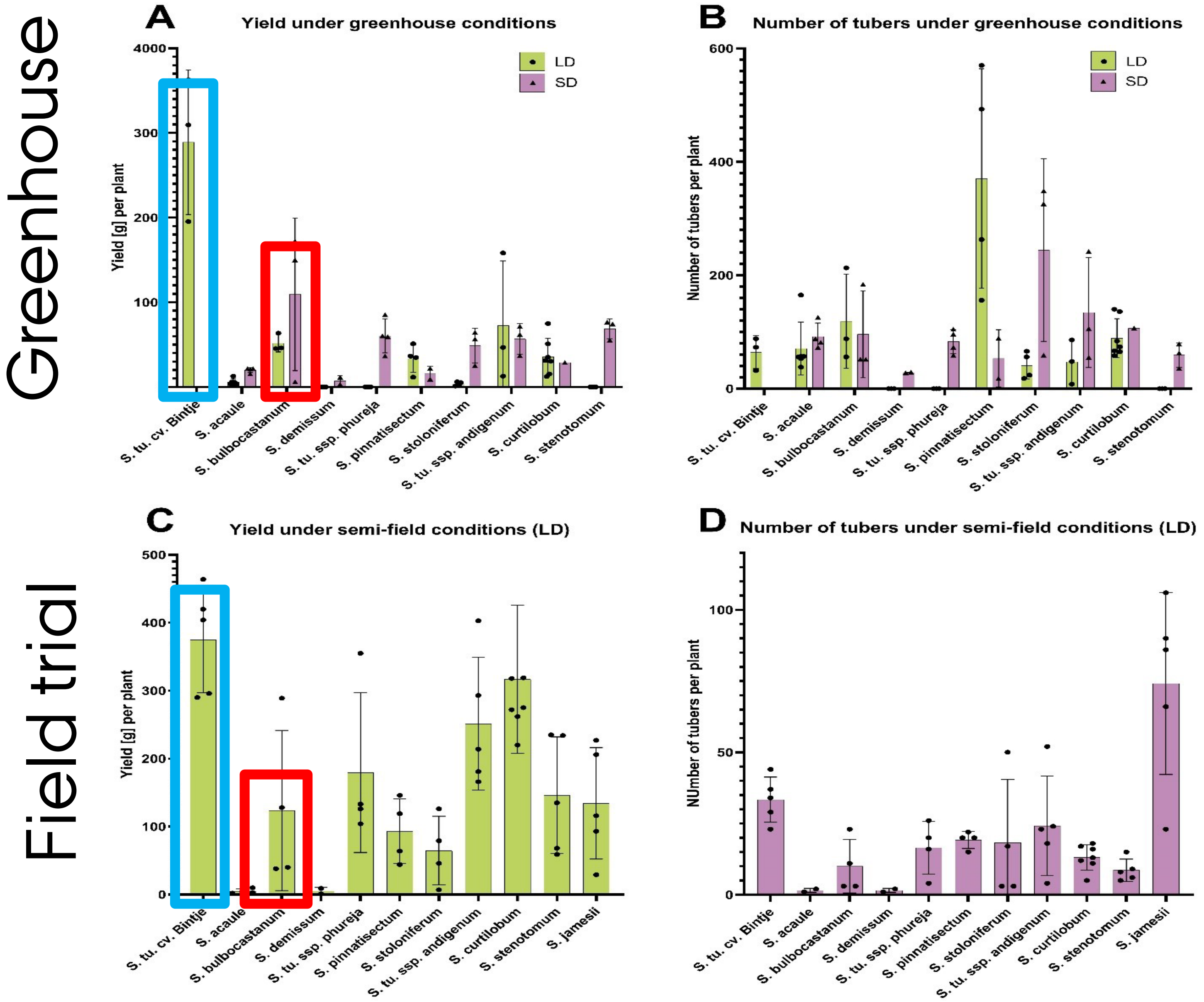
Production under both long days (16h light /8h dark) and short day

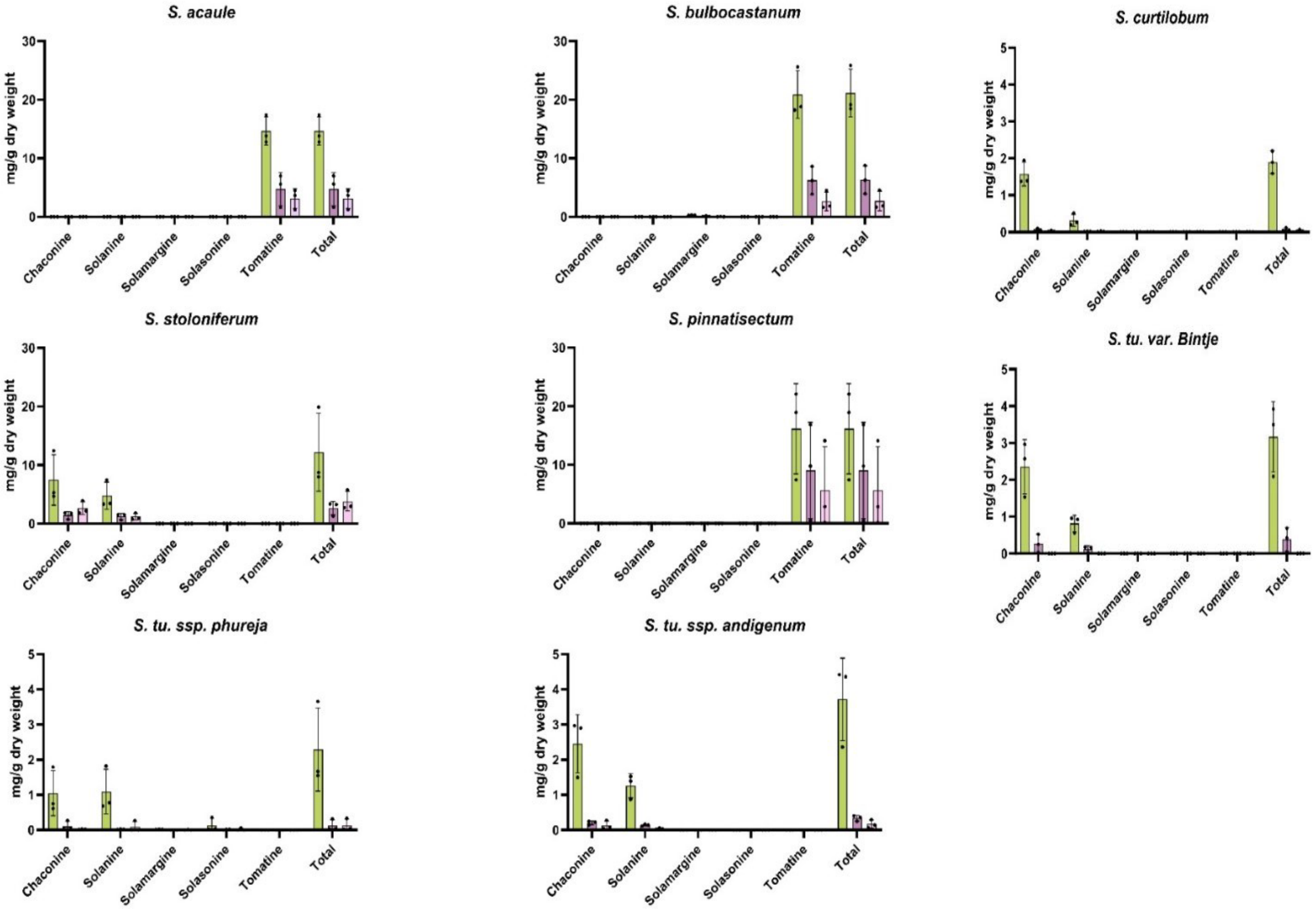
Only short days (8 h light /16h dark)

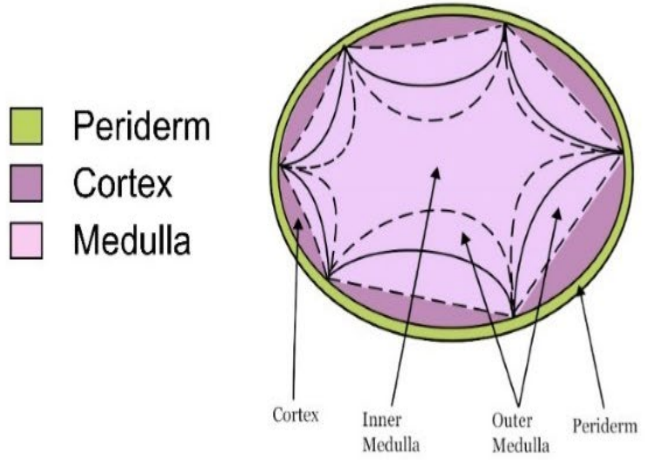


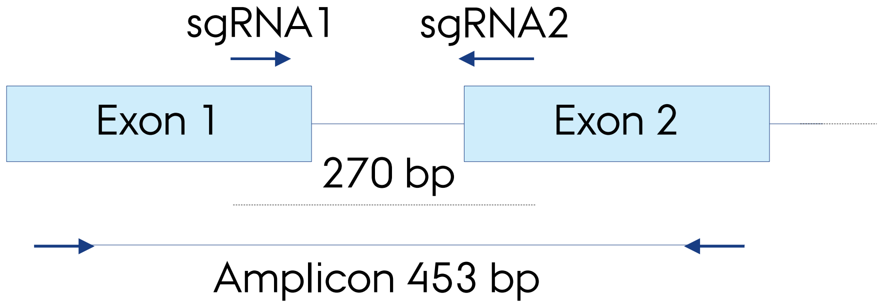


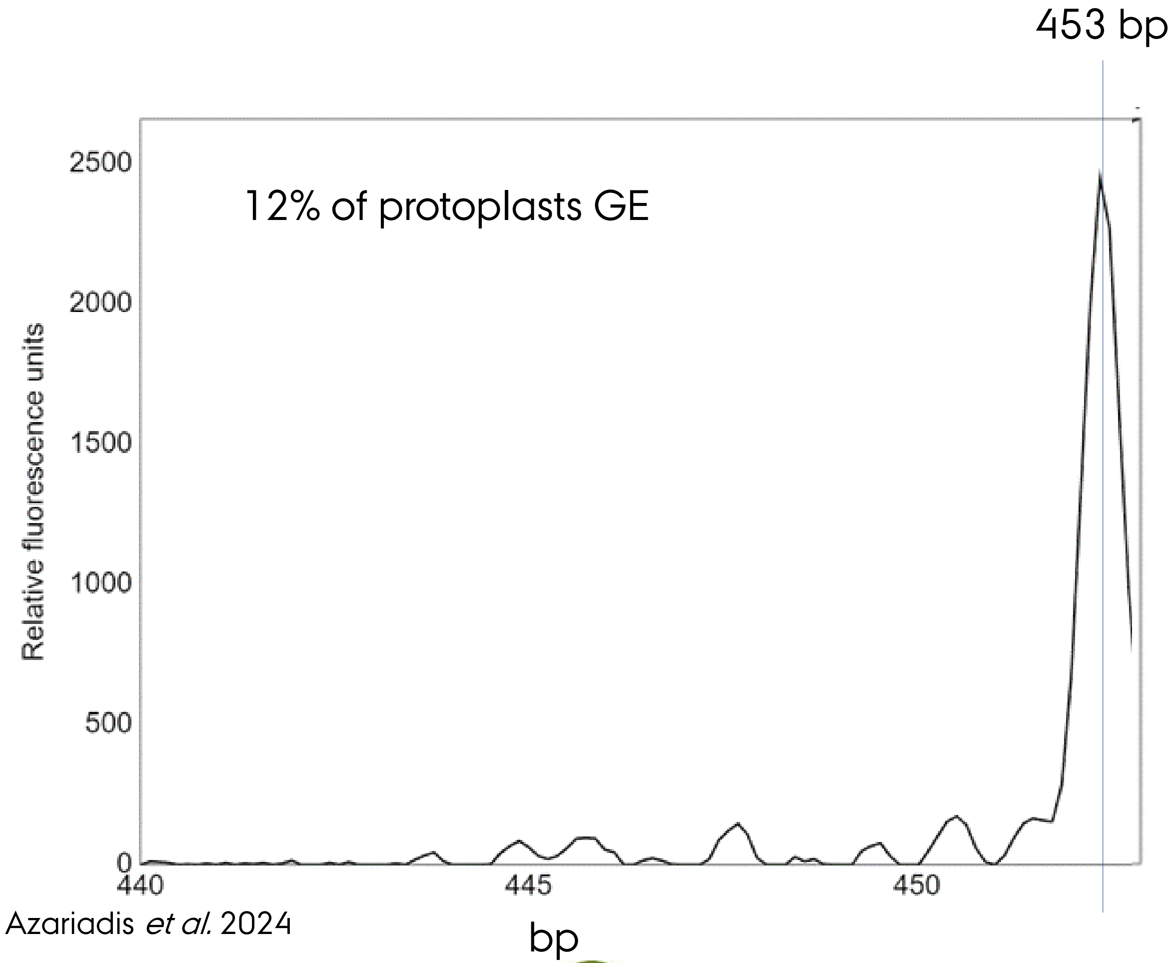
Tuber Yield under short and long-day conditions.

(**A, B**) Tuber production of individual plants in separate pots in the greenhouse under long-day (LD) or short-day (SD) conditions. (**C, D**) Tuber production under semi-field conditions. (**A, C**) Yield is given as fresh tuber mass per plant. (**B, D**) The number of tubers per plant. Some of the species did not produce any tubers under long days in the greenhouse.


S. acaule
S. bulbocastanum
S. curtilobum
S. stenotomum
S. stoloniferum
S. pinnatisectum
S. tu. var. Bintje
S. tu. ssp. phureja
S. tu. ssp. andigenum
mg/g dry weight
Chaconine
Solanine
Solamargine
Solasonine
Tomatine
Total


Periderm
Cortex
Medulla
Cortex
Inner Medulla
Outer Medulla
Periderm





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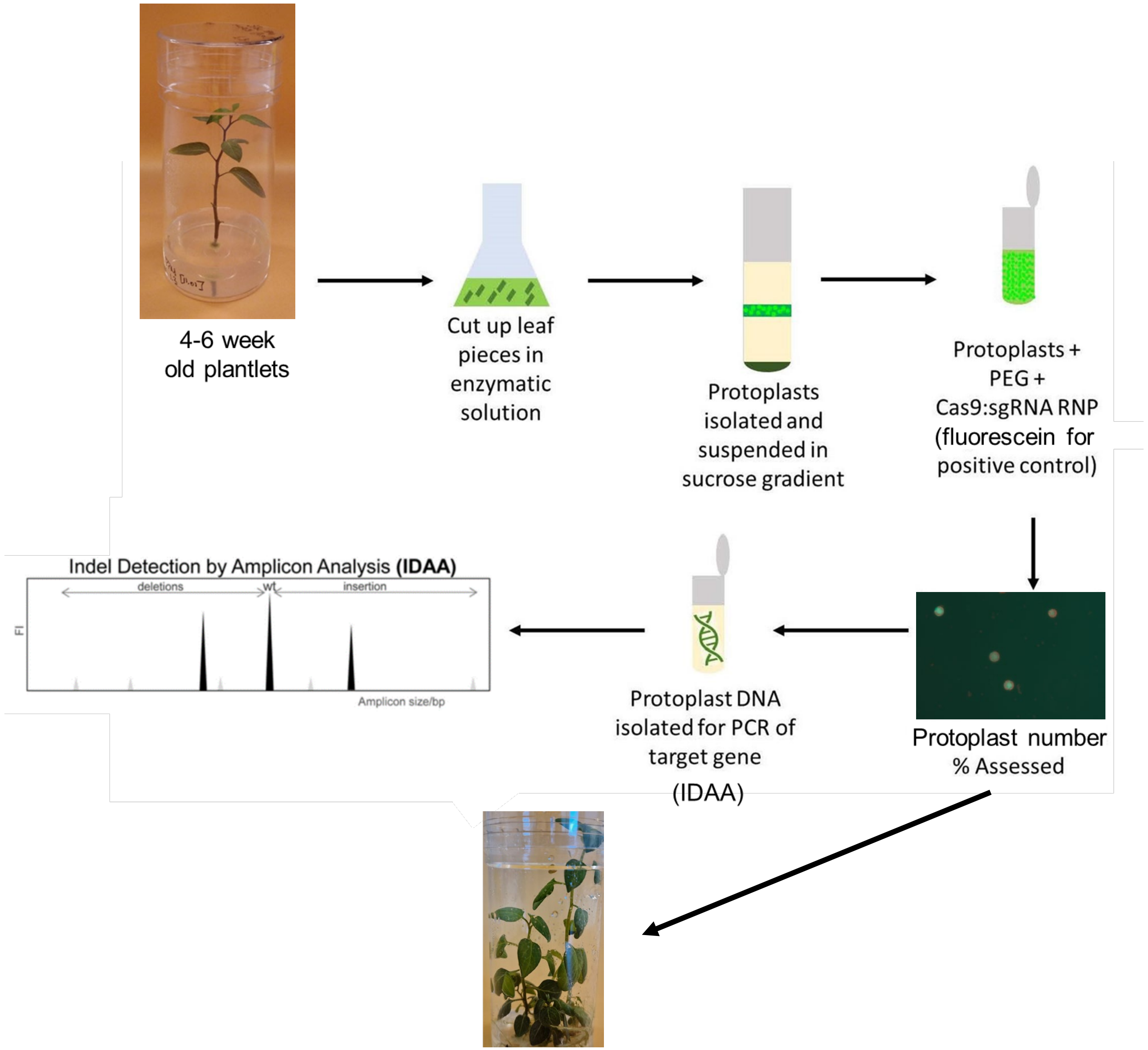

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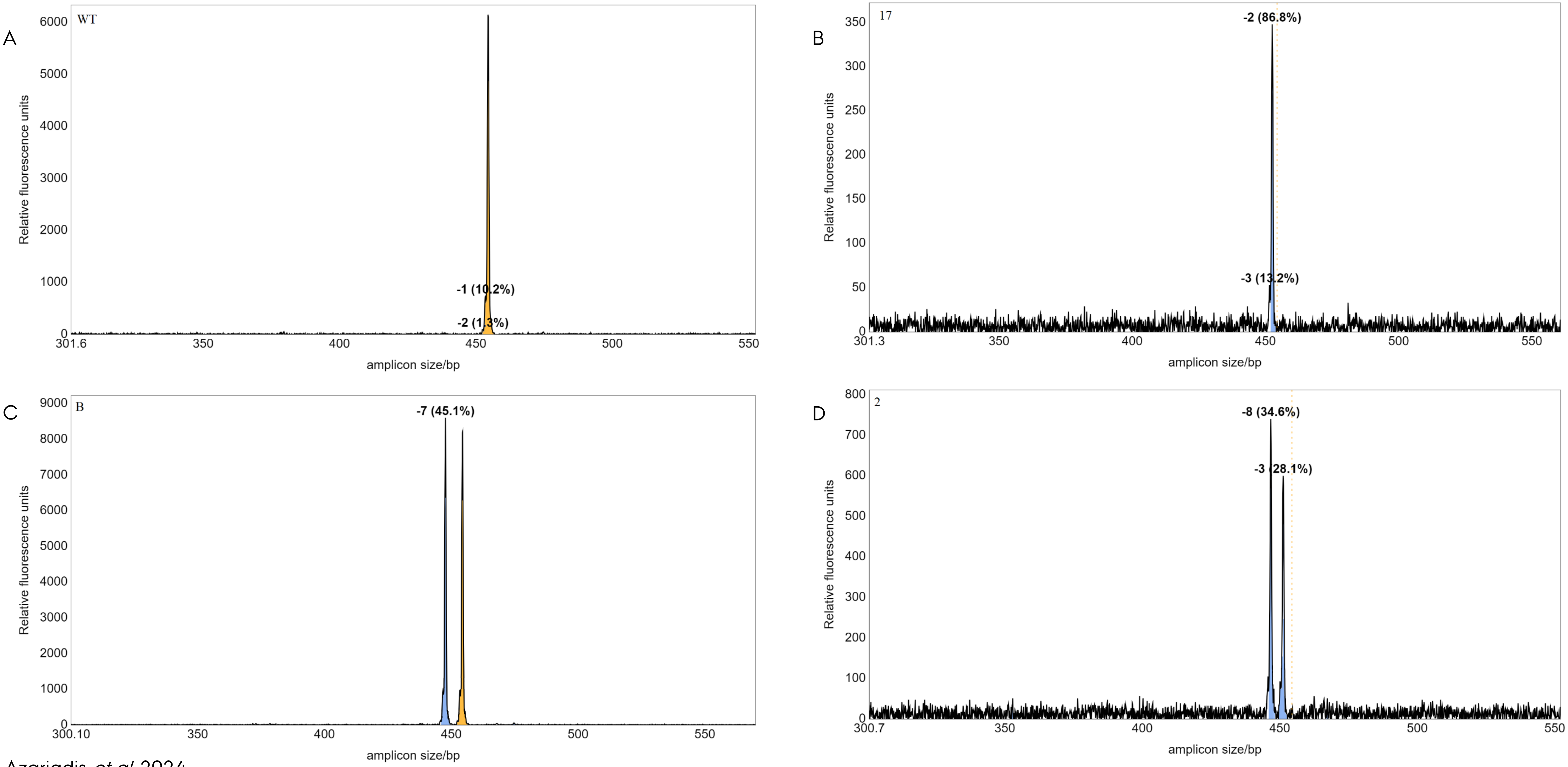

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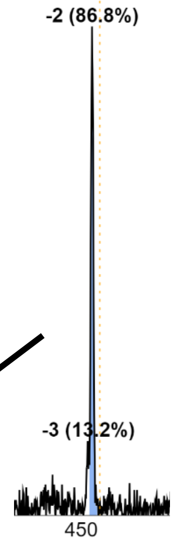
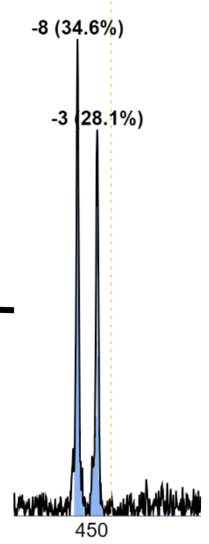
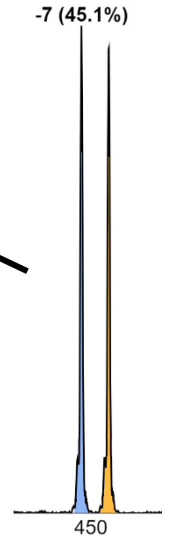
	sgRNA1	sgRNA2
WT	AAGTAGAAAAAAAGG	TGTTGGA
17	AAGTAGAA--AAAGG	TGTTGGA
2	AAG---------TGG	TGTTGGA
2	AAGTAGAAAAAAAGG	TG---GA
18	AAGT--------AGG	TGTTGGA
18	AAGTAGAAAAAAAGG	TGTTGGA







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Selection of wild, abandoned or marginally cultivated species from archaeoethnobotanical studies

Test of key agronomic parameters: e.g., yield, flowering, tuberization, brittleness, metabolic profiling for toxic compounds

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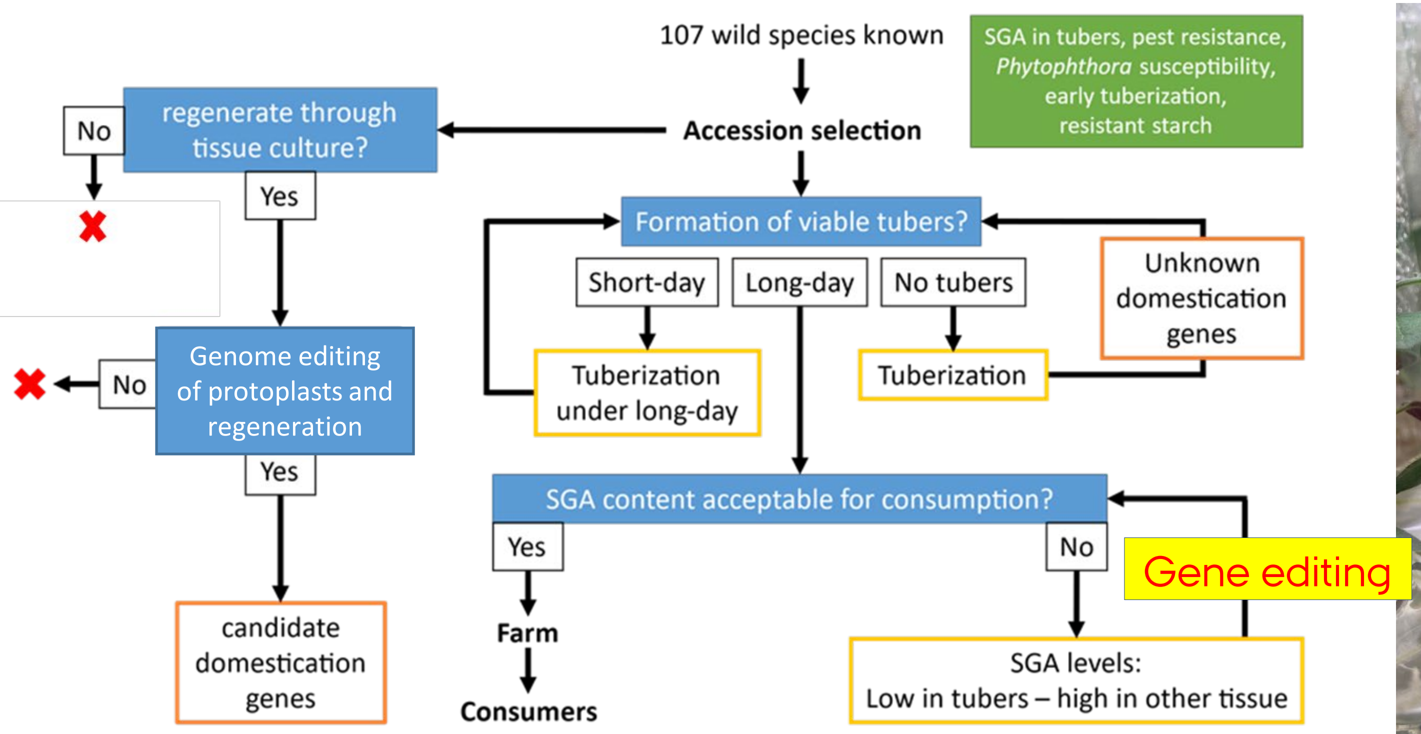
107 wild species known
SGA in tubers, pest resistance, *Phytophthora* susceptibility, early tuberization, resistant starch
Accession selection
regenerate through tissue culture?
No
Yes
Genome editing of protoplasts and regeneration
No
Yes
candidate domestication genes
Formation of viable tubers?
Short-day
Long-day
No tubers
Unknown domestication genes
Tuberization under long-day
Tuberization
SGA content acceptable for consumption?
Yes
No
Gene editing
Farm
Consumers
SGA levels: Low in tubers – high in other tissue

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PNAS

Late Archaic–Early Formative period microbotanical evidence for potato at Jiskairumoko in the Titicaca Basin of southern Peru

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Edited by Huw Barton, University of Leicester, United Kingdom, and accepted by Editorial Board Member James O'Connell October 12, 2016 (received for review March 15, 2016)

The data presented in this paper provide direct microbotanical evidence concerning the early use of potato (*Solanum tuberosum*) within its botanical locus of origin in the high south-central Andes. The data derive from Jiskairumoko, an early village site in the western Titicaca Basin dating to the Late Archaic to Early Formative **periods (~3,400 cal y BC to 1,600 cal y BC).** Because the site reflects the transition to sedentism and food production, these data may relate to potato domestication and early cultivation. **Of 141 starch microremains recovered from 14 groundstone tools from Jiskairumoko, 50 are identified as consistent with cultivated or domesticated potato, based on reference to published materials and a study of wild and cultivated potato starch morphology.** Along with macro- and microbotanical evidence for chenopod consumption and grinding tool data reflecting intensive use of this technology throughout site occupation, the microbotanical data reported here suggest the intensive exploitation, if not cultivation, of plant resources at Jiskairumoko. Elucidating the details of the trajectory of potato domestication is necessary for an overall understanding of the development of highland Andean agriculture, as this crop is central to the autochthonous agricultural suite. A paucity of direct botanical evidence, however, has hindered research efforts. The results of the modern and archaeological starch analyses presented here underscore the utility of this method in addressing questions related to the timing, mode, and context of potato origins.

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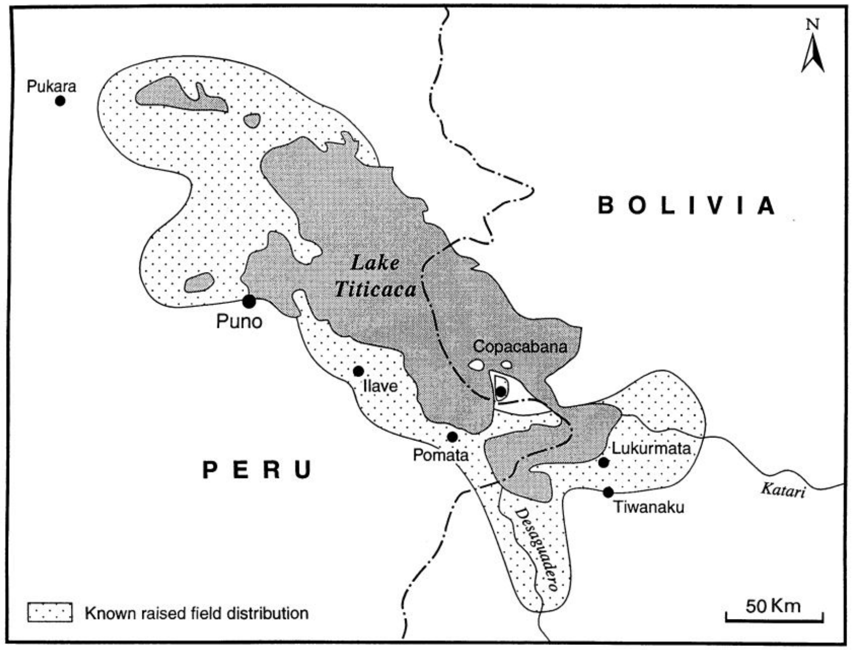
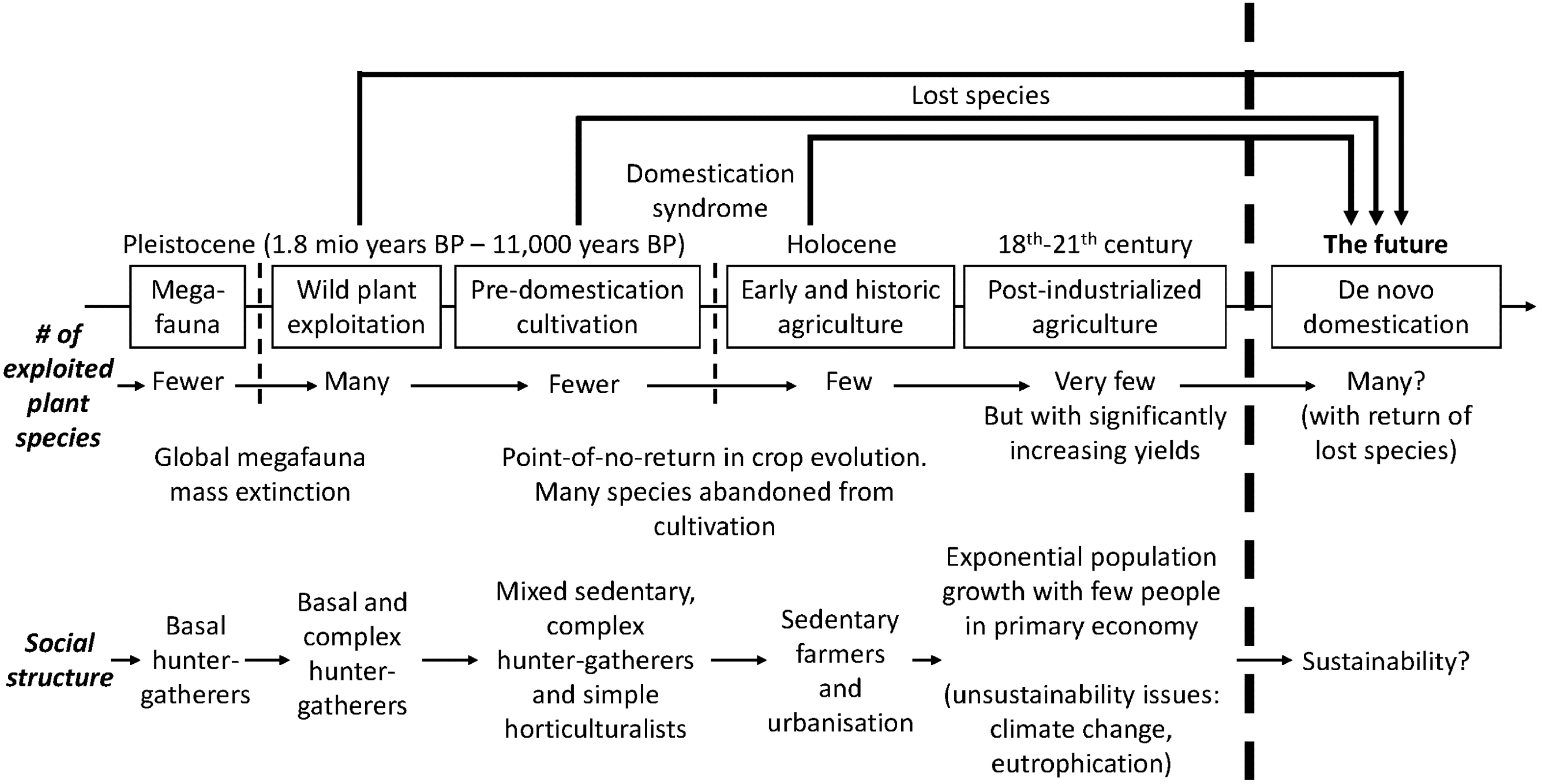


Fig. 1. The Lake Titicaca region and distribution of former raised fields
Source: Kolata, *1996*



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COMING TO THE OLD WORLD

QUARTERLY JOURNAL OF ECONOMICS

THE POTATO'S CONTRIBUTION TO POPULATION AND URBANIZATION: EVIDENCE FROM A HISTORICAL EXPERIMENT*

NATHAN NUNN AND NANCY QIAN

We exploit regional variation in suitability for cultivating potatoes, together with time variation arising from their introduction to the Old World from the Americas, to estimate the impact of potatoes on Old World population and urbanization. Our results show that the introduction of the potato was responsible for a significant portion of the increase in population and urbanization observed during the eighteenth and nineteenth centuries. According to our most conservative estimates, the introduction of the potato accounts for approximately one-quarter of the growth in Old World population and urbanization between 1700 and 1900. Additional evidence from within-country comparisons of city populations and adult heights also confirms the cross-country findings. *JEL* Codes: J1, N1N5, O14.

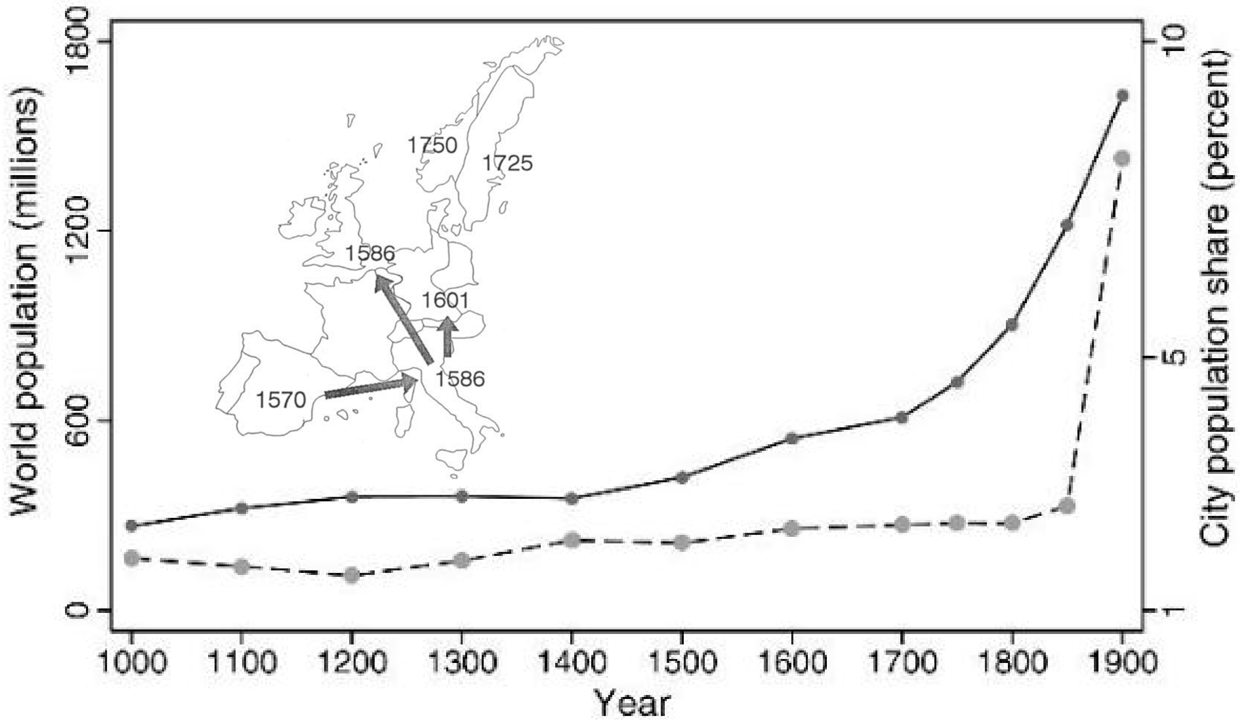
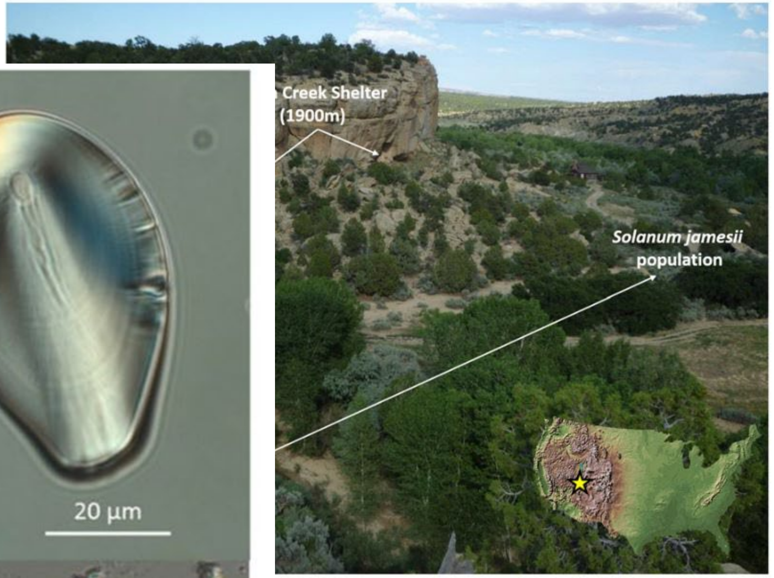


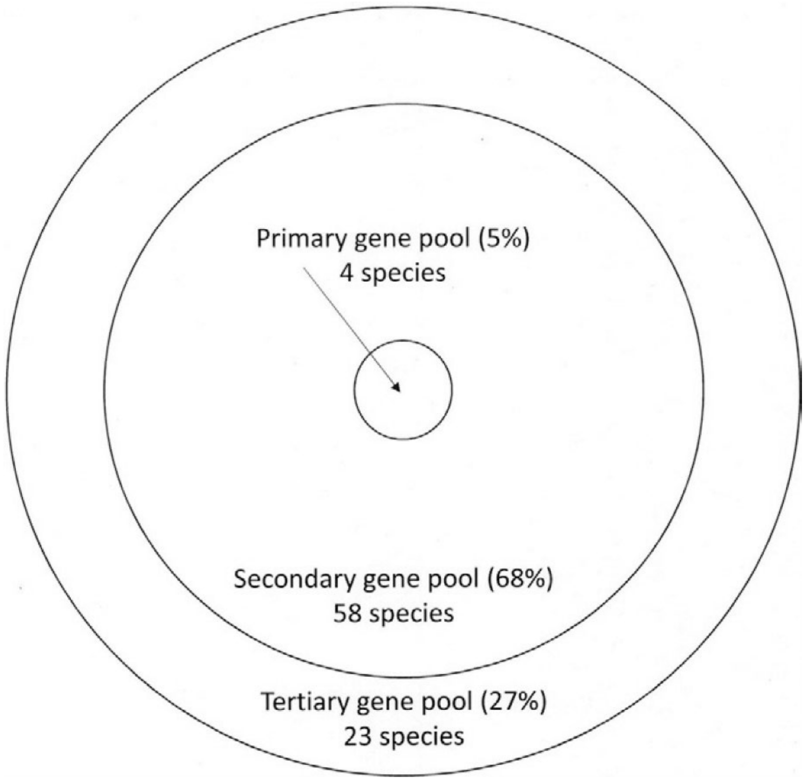
Fig. 3. Slab metate (2004.8.2346.1) from substratum 5
mano (2004.8.3474.1 and 2004.8.3474.2) from substratun
starch granules of *S. jamesii* and dated between 9,300 and
collections held at BYU Museum of Peoples and Cultures)

Fig. 4. Starch granules of *S. jamesii*. (*Upper*) Modern reference material from Escalante, Utah. (*Lower*) Archaeological granules from a ground stone tool (2004.8.3607.2) in substratum 5t (9,300 cal B.P.).



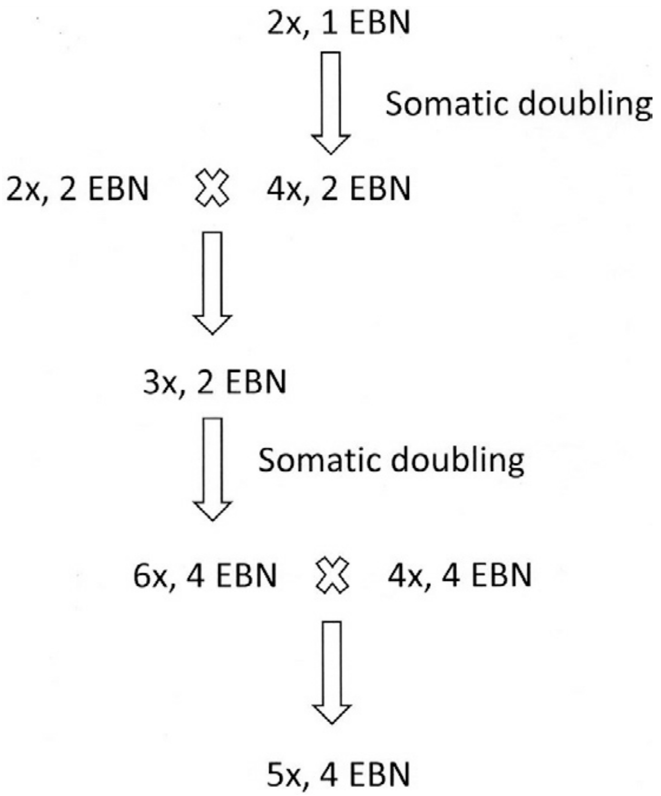
outhern Utah and nearby population of *S. jamesii* (*Inset*).

PNAS | **July 18, 2017** | vol. 114 | no. 29 | **7607**



Genepool composition of potato germplasm. The primary genepool is comprised of cultivated potato and is **4 endosperm balance number** (EBN). The secondary genepool contains **2EBN** and 4EBN species that can be crossed to cultivated potato. The tertiary genepool contains **1EBN** species that are sexually incompatible with cultivated potato.

Bethke *et al.* 2017, Crop Science, 57, 1241-1258



Ploidy manipulation scheme to introgress tertiary (1 endosperm balance number [**1EBN**]) germplasm into the cultivated germplasm pool using somatic doubling.