

The National Association of Plant Breeders in partnership with the
Plant Breeding Coordinating Committee and The Plant Breeding
Genomics Community of Practice presents

How to breed new plant varieties: imagining and engineering crops



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Get the Dirt on Potato Breeding



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Part I

Characteristics of potatoes

Solanum tuberosum L.

- Cultivated:
 - $2n = 4x = 48$ (autotetraploid)
 - self compatible
- Diploids also exist:
 - $2n = 2x = 24$
 - self incompatible
- Varieties are clones
 - vegetatively propagated



potato: *Solanum tuberosum*

- Domesticated in Andes around Lake Titicaca, border of modern-day Bolivia and Peru
- High elevation – 3800m
- Thus potatoes originated as a cool weather crop



http://commons.wikimedia.org/wiki/File%3ALake_Titicaca_map.png

By es:Usuario:Haylli, based on map from <http://www.aquarius.geomar.de> (<http://www.aquarius.geomar.de/omc/>) [GFDL (<http://www.gnu.org/copyleft/fdl.html>), CC-BY-SA-3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>), CC-BY-2.5 (<http://creativecommons.org/licenses/by/2.5/>) or CC-BY-2.5 (<http://creativecommons.org/licenses/by/2.5/>)], via Wikimedia Commons

Changes under Domestication

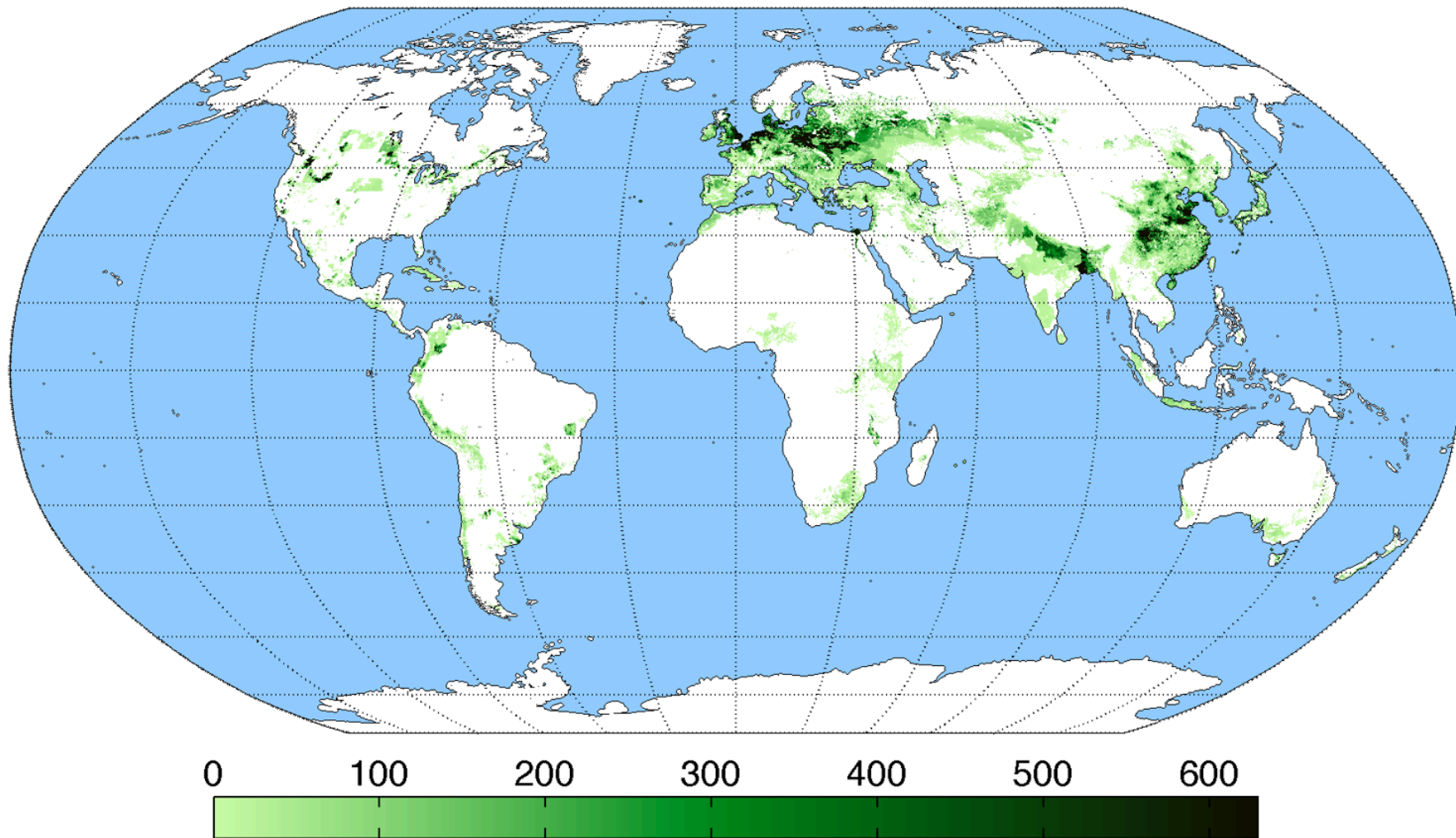
- reduced glycoalkaloid content
 - wild potatoes have high levels
- after introduction to Europe: ability to tuberize under long days
 - to get a crop by Fall



Potato Production in U.S.

- Widely distributed, with heaviest concentration in Pacific Northwest (Idaho, Washington, Oregon)
- About 1.1 million acres planted in 2012, average yield ~40,000 pounds per acre

(USPB 2013 Statistical Yearbook)



Average regional potato output (kg/ha)

<http://upload.wikimedia.org/wikipedia/commons/5/55/PotatoYield.png>

Types of potatoes

- Three market classes:
 - French Fry
 - Chip
 - Fresh



Three red potatoes are arranged in a triangular pattern against a black background. The top potato is slightly behind the other two. The bottom-left potato shows several dark, sunken eyes. The bottom-right potato has a vertical scar on its side. The text 'Part II' is centered over the top potato.

Part II

What traits are important in potato?

some important traits

- processing quality
 - high starch
 - fry color
 - shallow eyes
 - round (chips), long (fries)
- tablestock quality
 - overall appearance
 - do not turn gray or fall apart after boiling
- disease resistance
 - late blight
 - viruses (PVY, PLRV)
 - cyst nematodes
 - common scab
 - and many, many more
- general
 - yield
 - few physical defects
 - low glycoalkaloids
 - acceptable maturity

Why high starch content?

- the higher the starch, the less oil is absorbed during frying
- starch content typically measured indirectly by measuring tuber density



Fry Color

- potatoes stored in the cold accumulate glucose and fructose
- these sugars turn brown when fried (Maillard reaction)



shallow eyes



round versus long



Tuber appearance

- composite of skin smoothness, eye depth, color, shape



After cooking darkening, sloughing



late blight

- many known R genes, but none have proven durable



potato viruses



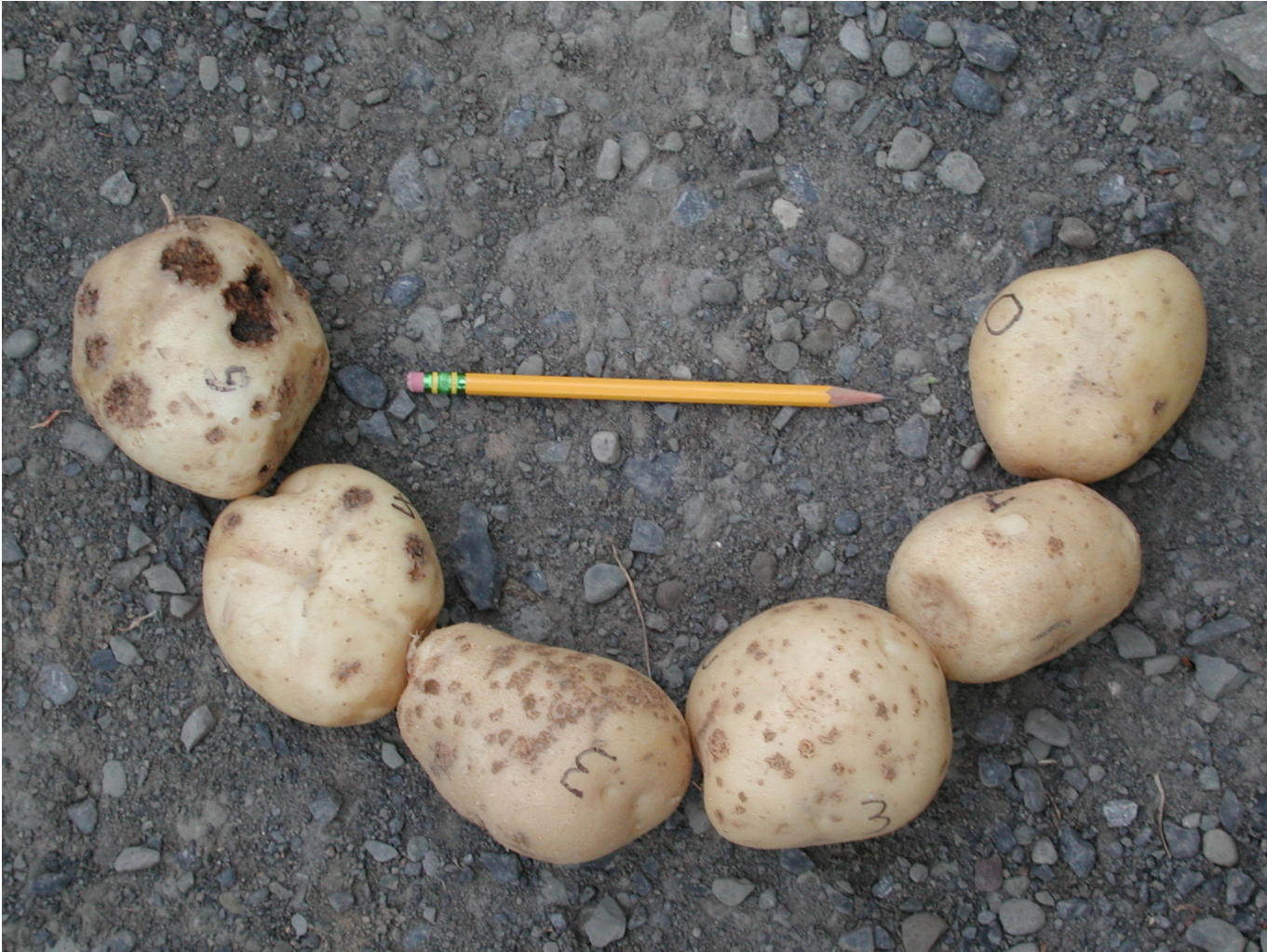
A single dominant gene (Ry) is useful against PVY

cyst nematodes



golden nematode, a quarantine pest, can survive in soil 30+ years

common scab



few chemical control options

yield

hasn't improved much
after 100+ years of
breeding

for new cultivars, aim
for yield comparable
to existing cultivars



physical defects



hollow heart / brown center



growth cracks

acceptable maturity

tubers cling to late
maturing vines;
harvest is difficult



Part III



Potato Breeding

Potato Breeding

- In theory, simple and straightforward
 - cross two parents with complementary traits
 - spend a dozen years sifting through the F1, which are **clonally propagated**, to determine if any merit release as a new cultivar

Why is potato breeding so...slow?

- it takes 4-5 years to produce enough tubers for yield trial / large scale testing



true potato seed (TPS)



cutting seed tubers (knives in lime)

Why is potato breeding so...slow?

- then, need to evaluate for several years to make sure clone performs well consistently



Why is potato breeding so...slow?

- then, need to remove any viruses/other diseases - and begin multiplication again



Typical progression through Cornell program

year approximately

0	50-200 crosses
1	25,000 seedlings
2	20,000 4-hill plots
3	2000 20-hill plots
4	200 100-hill plots
5	50 400-hill plots
6	20 800-hill plots
7	5 2000-hill plots
8+	several 2000 hill plots
11+	release new variety

← We save 7-10% after first year in field. All these are chipped during winter

} all these are tested for resistance to golden nematode each year





seedling tubers (four per clone)

Tray 12

in early generations,
selections are made based
on (brief) visual assessment
of yield and appearance

in later years, as plot sizes
increase, and more
potatoes are available for
testing, additional criteria
are added



we plant 5 to 10 ha of potatoes each year
limit to program size is cold storage space, not land



primary challenge in potato breeding

- is NOT autotetraploid genetics
 - although they are complex
- rather, the high degree of heterozygosity
 - potato has a SNP every 20 bp or so
 - every time you make a cross – thousands of loci segregate
- applied potato breeding requires weighing the many strengths and many weaknesses of each clone to identify something “better”
 - art, not just science

‘Potato Show & Tell’ - annual Cornell event to solicit grower/industry feedback on promising clones



where autotetraploidy *is* an issue

- desirable recessive alleles of low frequency
 - obtaining homozygous recessives is not easy
 - e.g. $AAaa \times AAaa \rightarrow$ only $1/36$ of offspring are $aaaa$
 - even if you obtain an $aaaa$ individual, as soon as you use it as a parent, few offspring will be $aaaa$



Biotechnology and Potato Breeding

- molecular markers are not yet widely used
 - in part because so few have been developed
 - there are good markers for PVY and GN resistance
- potato is easy to transform
 - like a variety, but wish it had one more trait?
 - add a gene!
- if genome editing ever becomes efficient
 - change the genome to get desired allelic combinations!

Further Reading

- *Potato Genetics*. J.E. Bradshaw and G. R. Mackay, eds. CAB International. 1994. 552 pp
- *The Complete Book of Potatoes: What Every Grower and Gardener Needs to Know*. H. De Jong, J.B. Sieczka, W. De Jong. Timber Press. 2011. 258 pp.

Thanks for joining us today.

Join us for the rest of the webinar series:

http://www.extension.org/plant_breeding_genomics

[http://www.extension.org/pages/60426/
webinar-registration-and-archive](http://www.extension.org/pages/60426/webinar-registration-and-archive)

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