Coupling nature and nurture: supercharging predictions for agricultural crops

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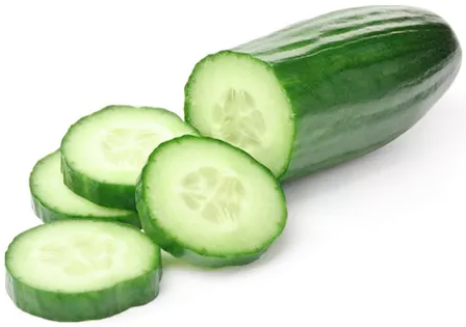
AAAS Meeting 2019
Session: Sustainably Feeding 10B people
Feb. 16, 2019

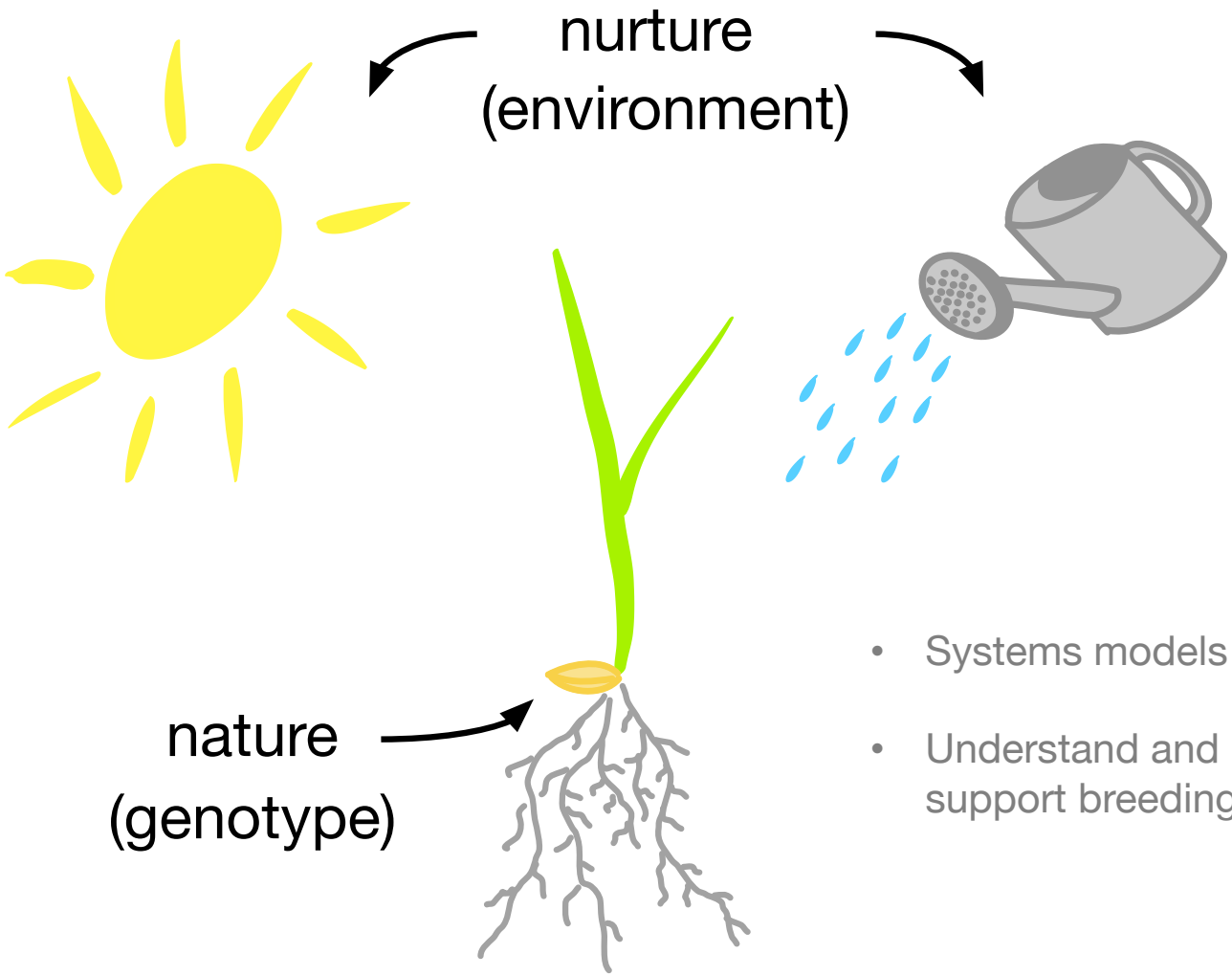


Year	Burpless Hybrid	Tendergreen
2016	sweet	sweet
2017	very bitter	sweet
2018	mildly bitter	sweet
2019	???	???

Cucumber image: Nutriliving.com

genotype by environment interaction

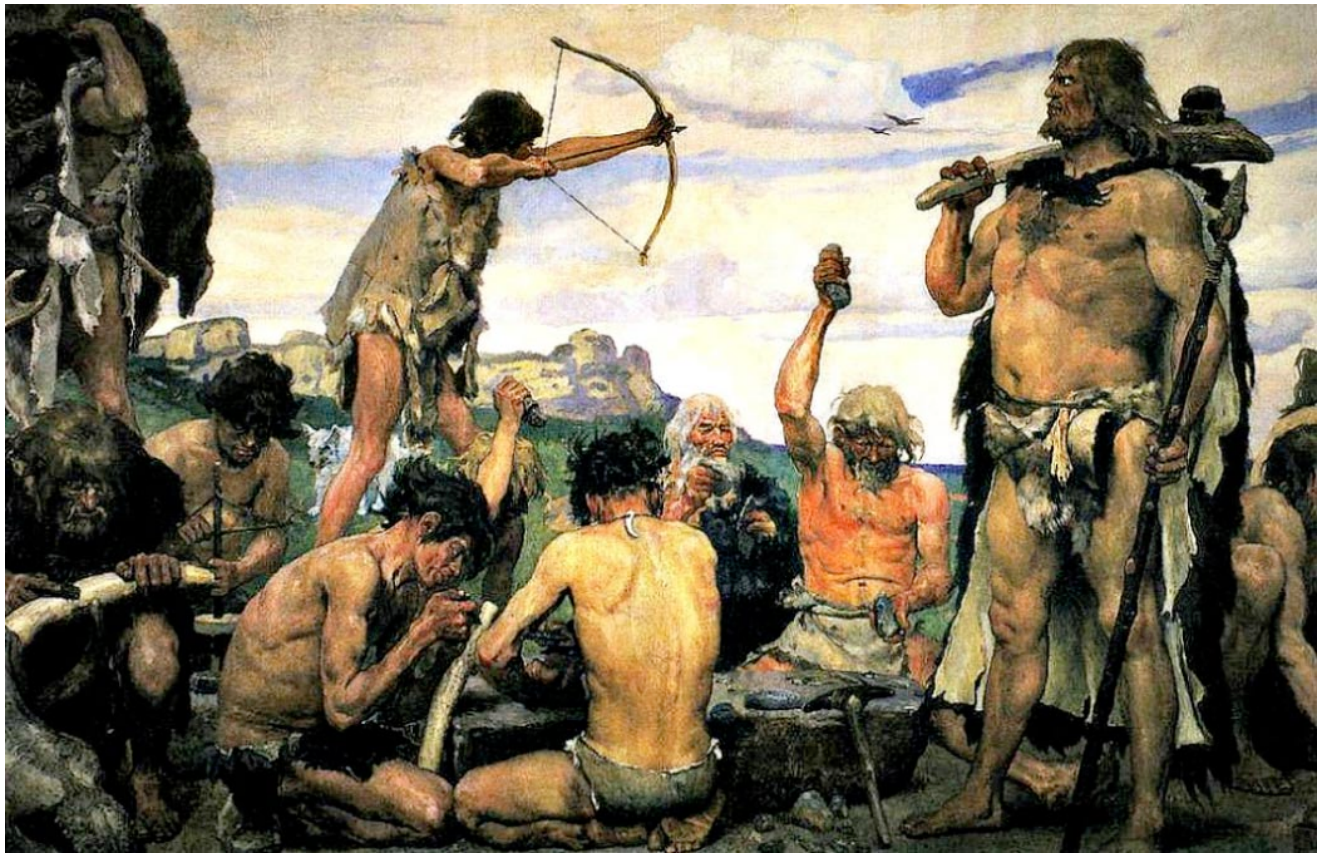
“G by E”



- Systems models
- Understand and predict → support breeding

Breeding is accelerated evolution

Stone Age hunter-gatherers



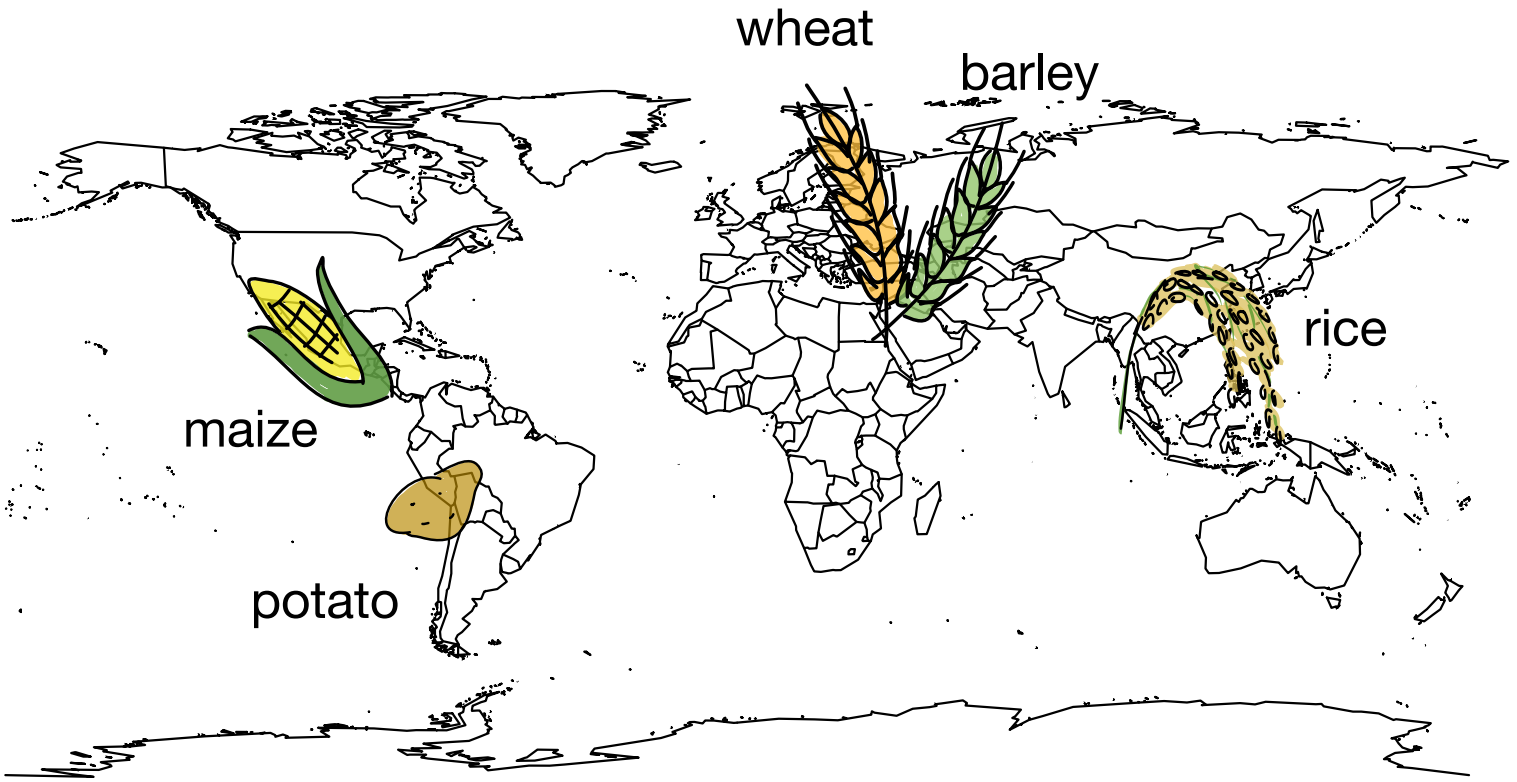
Source: Detail from The Stone Age' (1882-1885); painting by Viktor M. Vasnetsov.

Threshing wheat, ~1400 BCE, Egypt

The Neolithic Revolution began ~10,000 years ago

Source: The Yorck Project Gesellschaft für Bildarchivierung GmbH

Crop Domestication



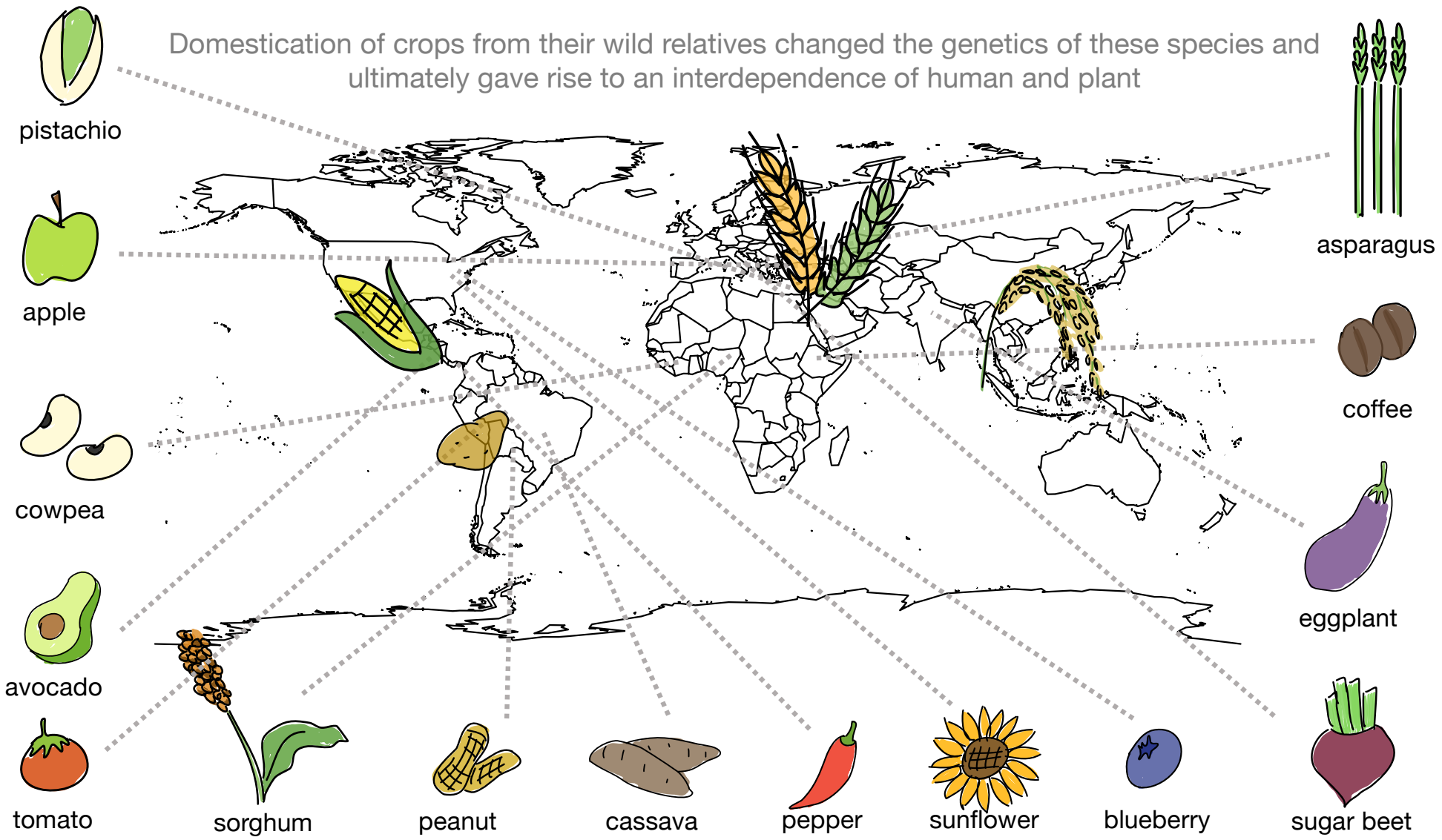
Early human domesticators preserved and propagated plants that had favorable traits
→ initially unintentional → led to genetic changes

Eventually, domesticated crops looked, tasted, and behaved quite differently from their wild ancestors

Source: HHMI

- Plant architecture
- Ear structure
- Seed structure
- Seed coloration

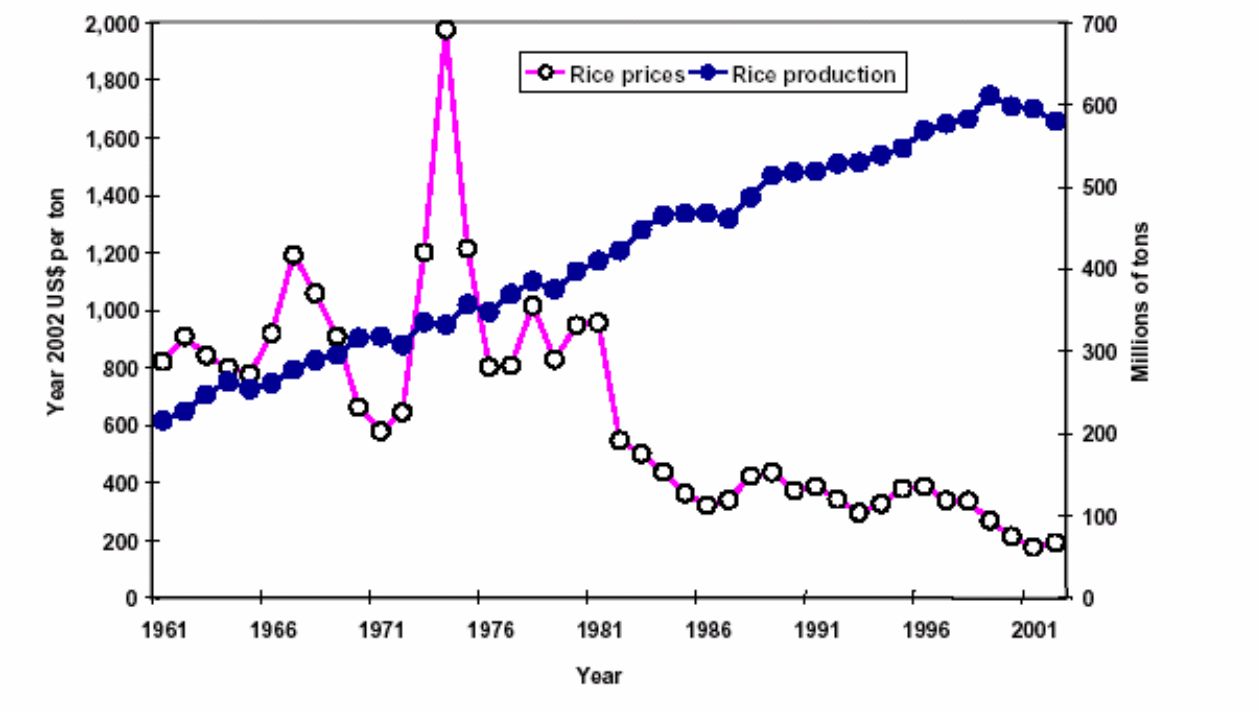
Source: maize.uga.edu


Domestication of crops from their wild relatives changed the genetics of these species and ultimately gave rise to an interdependence of human and plant
pistachio
apple
cowpea
avocado
tomato
sorghum
peanut
cassava
pepper
sunflower
blueberry
sugar beet
eggplant
coffee
asparagus

Green Revolution

1960s, 1970s

Source: Mohindra Rising tractor company

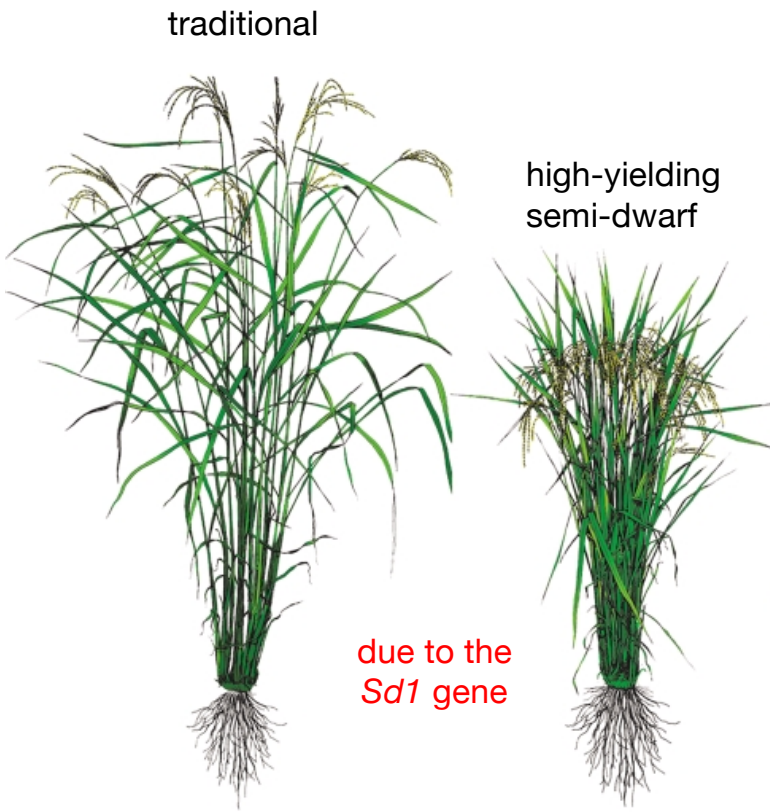


Source: FAOSTAT

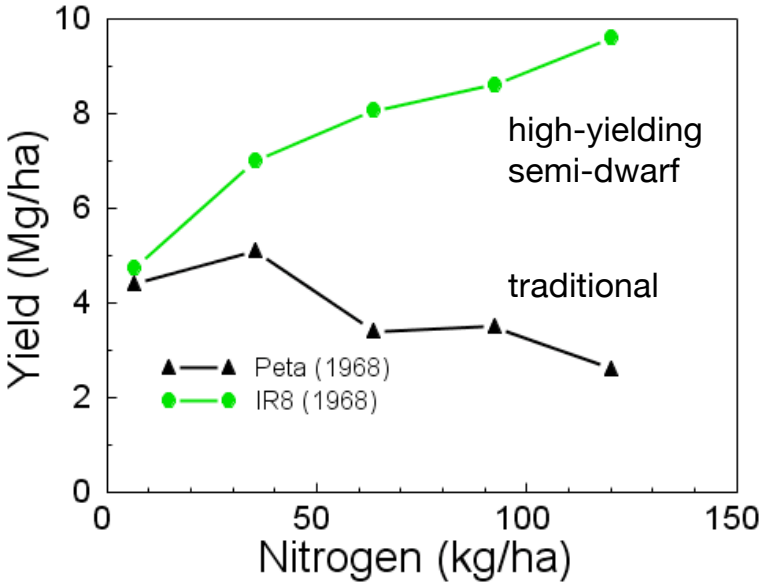
1967: Indian farmer Nekkanti Subbarao – “Mr. IR8”

Source: IRRI

A match made between “G” and “E”



Source: Khush 2001, Nature Reviews



Source: RiceToday v. 5 pg. 36

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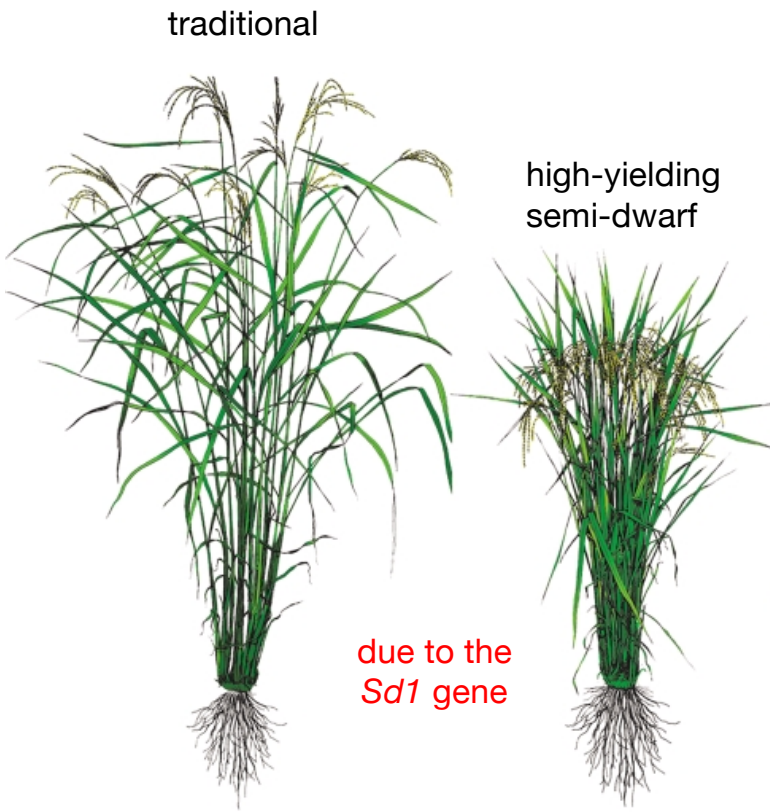

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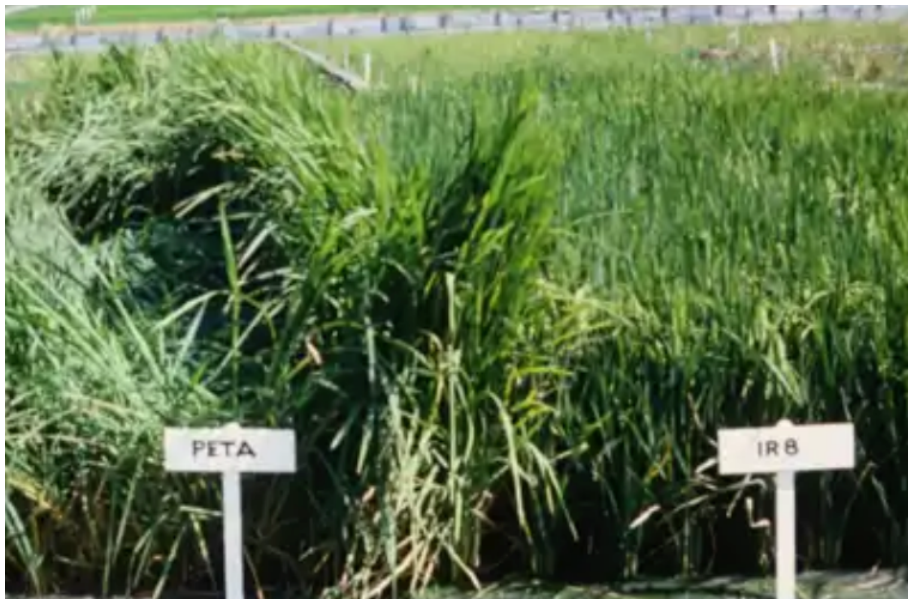
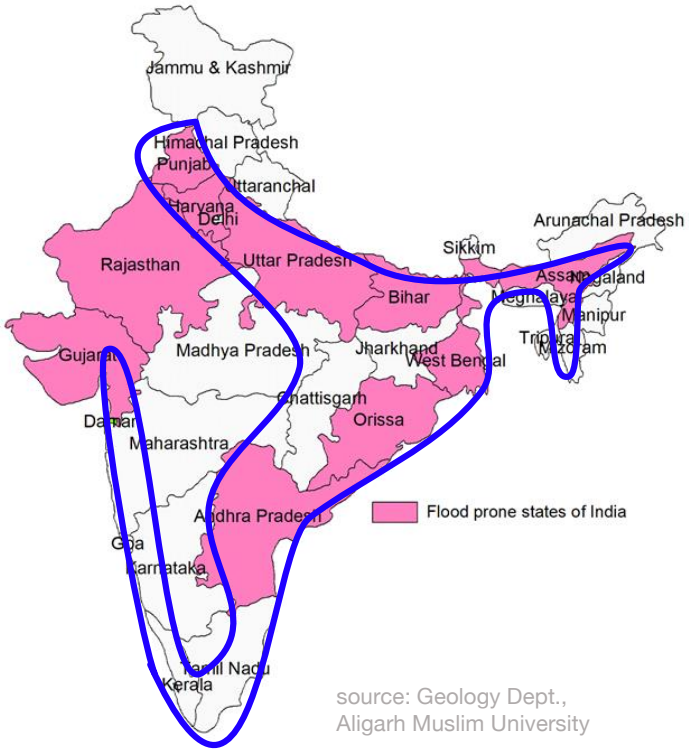


Source: De Datta PMCP presentation, 2018

Submergence constrains rice production in flood-prone regions

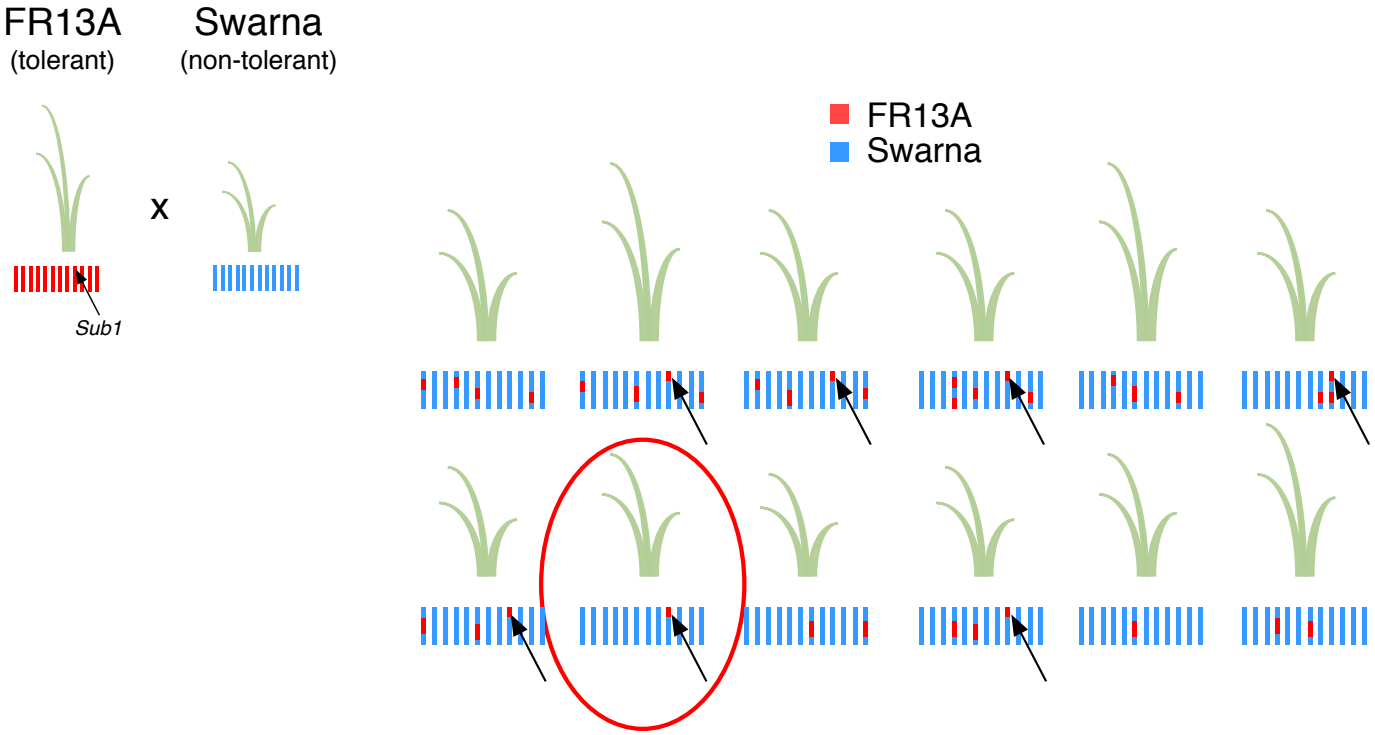


source: Geology Dept.,
Aligarh Muslim University

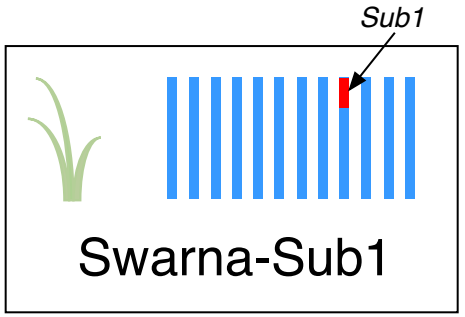
Farmer re-transplanting rice field due to floods

Vergara and Mazaredo 1975; HilleRisLambers and Vergara 1982; Mohanty and Chaudhary 1986; Mackill et al. 1993; Mackill et al. 1996

Development of submergence-tolerant rice



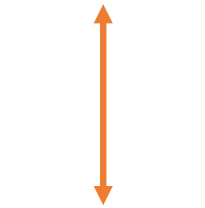
Marker-assisted selection



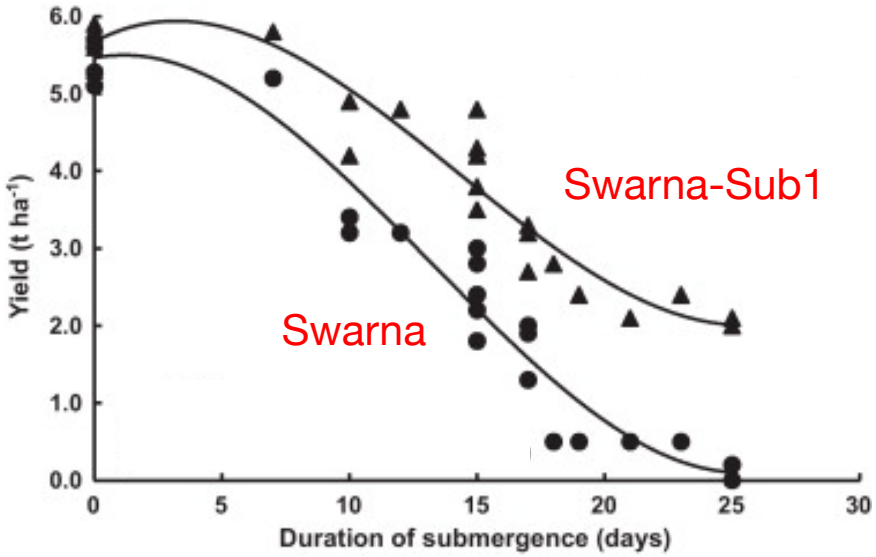
Xu and Mackill 1996; Xu et al. 2006; Septiningsih et al., 2009; Bailey-Serres et al. 2010

No yield cost under favorable conditions + yield benefit under submergence

More yield



Less yield



Shorter submergence

Longer submergence

Source: Ismail et al. 2013

Flood-affected rice fields (10d submergence) (UP, India). Photo taken 27 days after water receded

By 2012, 4 million farmers across India, Bangladesh and Nepal adopted Sub1 varieties

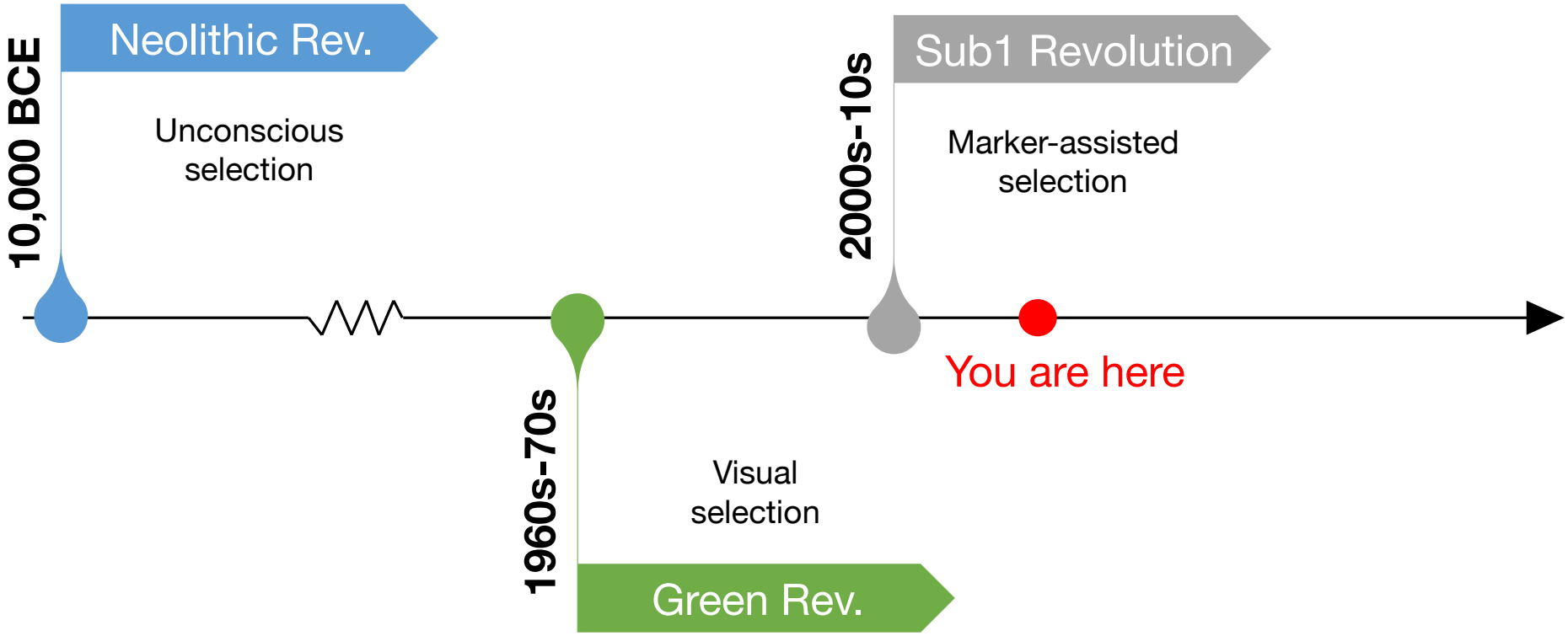
Farmer Nekkanti Subbarao

with IR8 in 1967

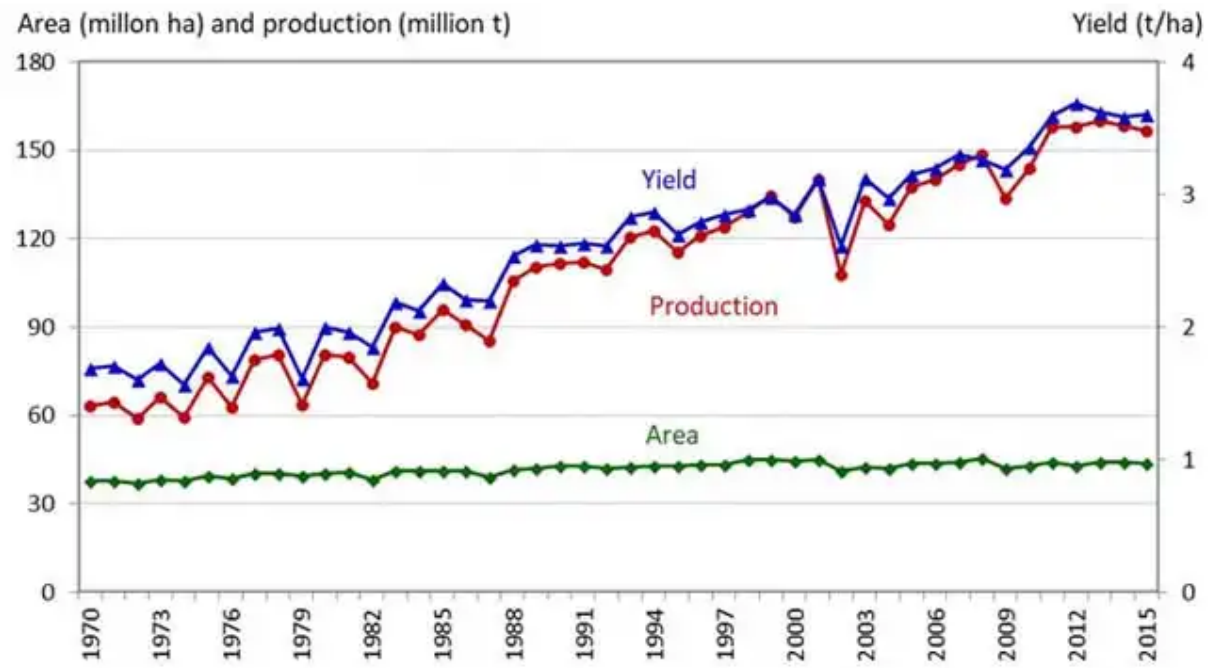
Source: IRRI

with Swarna-Sub1 in 2009

Source: IRRI RiceToday


10,000 BCE
Neolithic Rev.
Unconscious selection
1960s-70s
Visual selection
Green Rev.
2000s-10s
Sub1 Revolution
Marker-assisted selection
You are here

Trends in rice (paddy) area, production, and yield in India 1970-2015

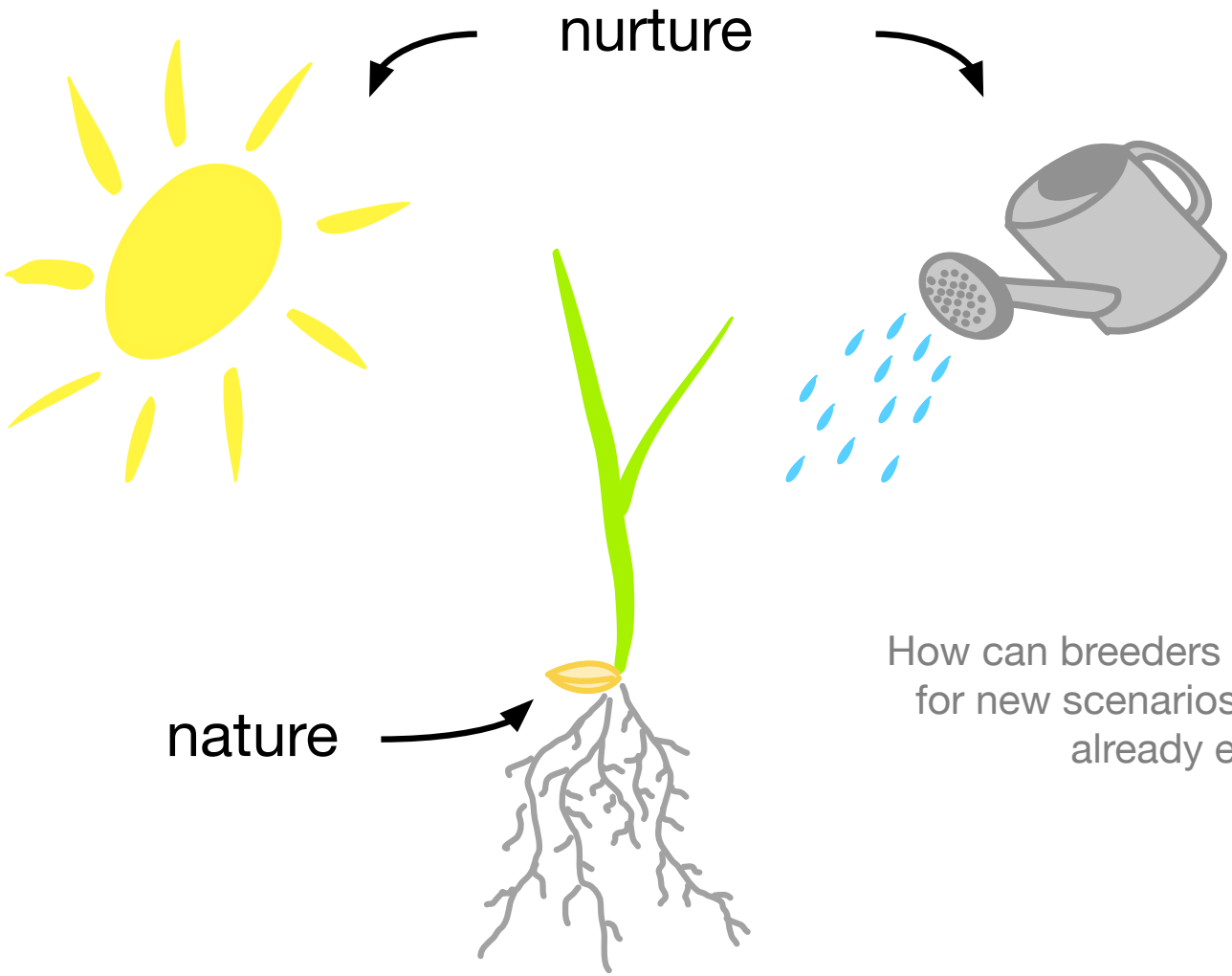


1970 2015

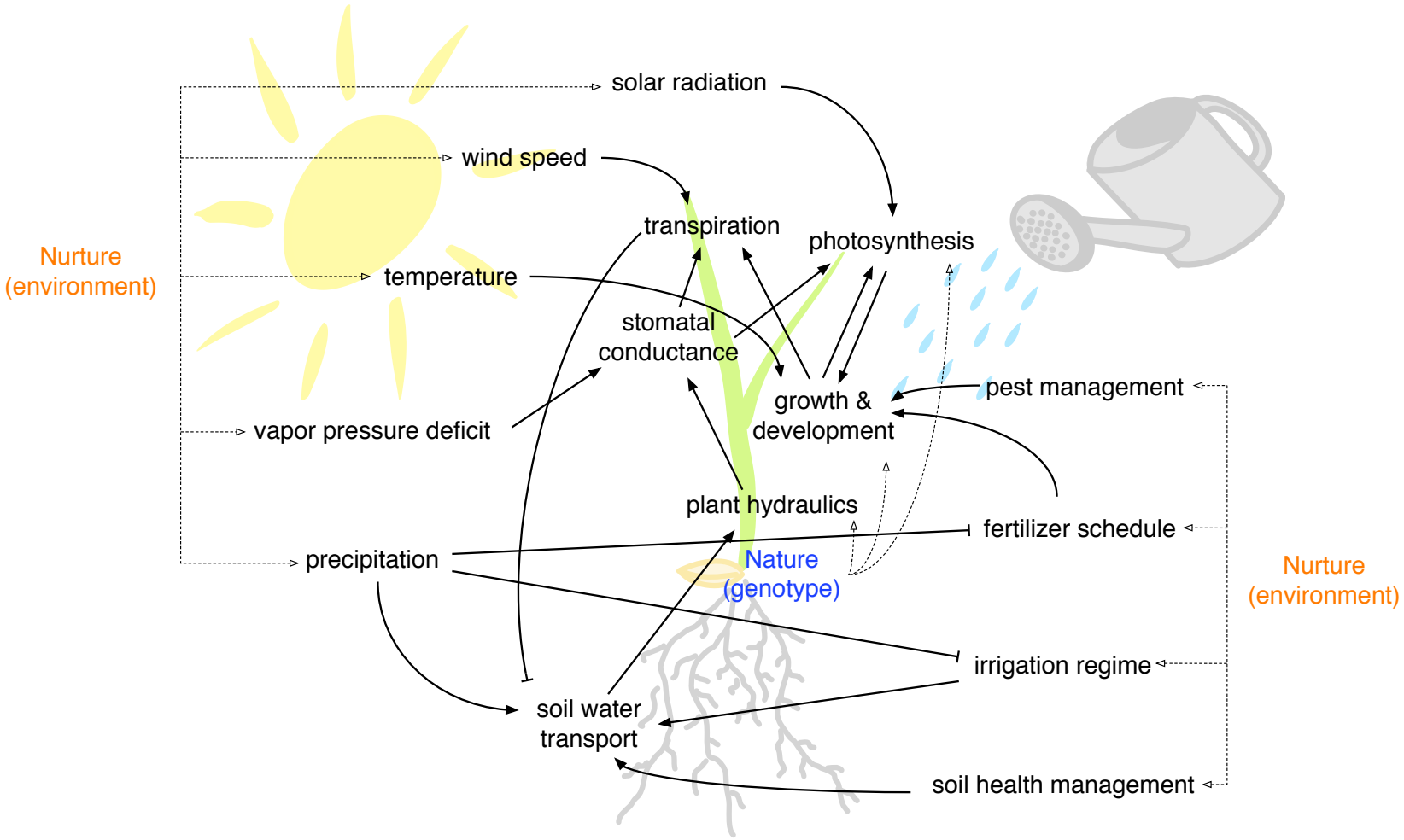
Source: Data from Ministry of Agriculture, GOI

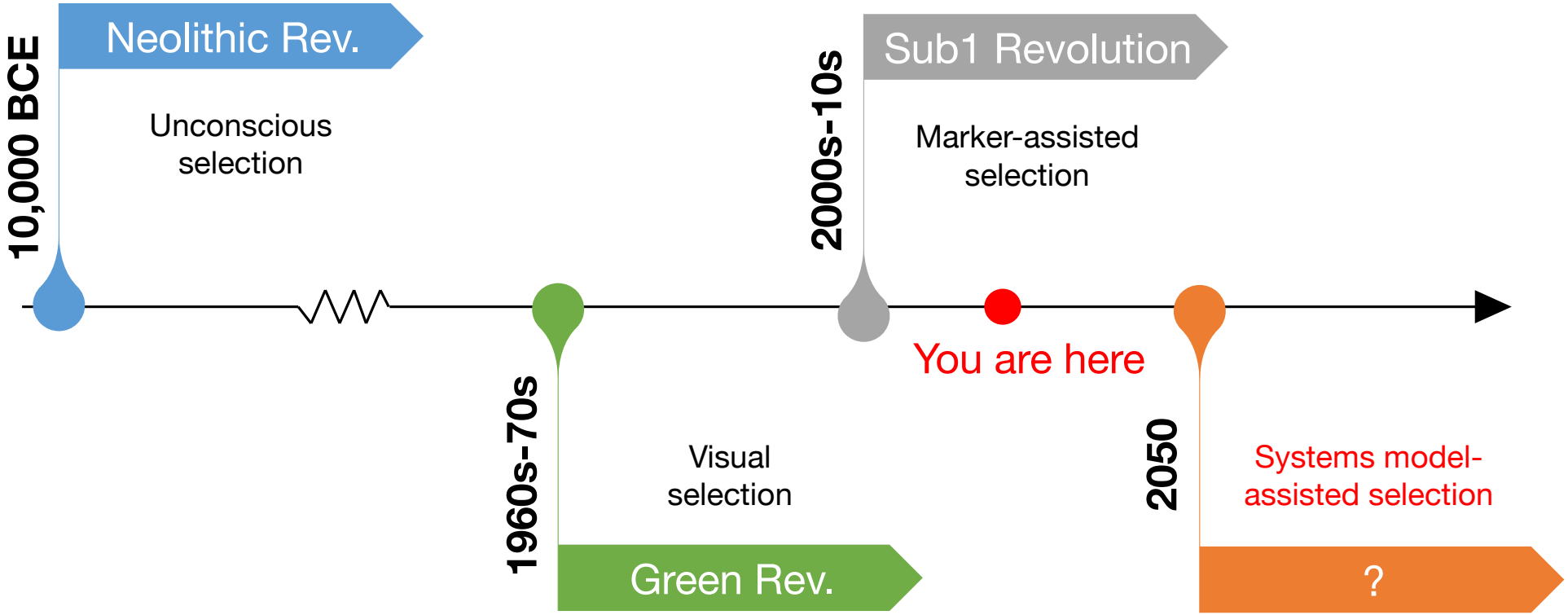
Climate change will increase the urgency with which breeders make selection

Climate change will increase the urgency
with which breeders make prediction



How can breeders make selection for new scenarios that may not already exist?


Nurture
(environment)
solar radiation
wind speed
temperature
vapor pressure deficit
precipitation
transpiration
photosynthesis
stomatal
conductance
growth &
development
plant hydraulics
Nature
(genotype)
pest management
fertilizer schedule
irrigation regime
soil water
transport
soil health management
Nurture
(environment)


10,000 BCE
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Marker-assisted selection
You are here
2050
Systems model-assisted selection
?

Nigerian rice farmers at harvest

Source: Jeremy Weate/Flickr

Indian rice farmer using a pest management mobile app

Source: ICRISAT