Coupling nature and nurture:
supercharging predictions for agricultural crops

Diane Wang
University at Buffalo

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

My garden in Ithaca, NY

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
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.

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

Source: HHMI

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.
Green Revolution
1960s, 1970s

Source: Mohindra Rising tractor company

Source: FAOSTAT
1967: Indian farmer Nekkanti Subbarao – “Mr. IR8”
A match made between “G” and “E”

Source: Khush 2001, Nature Reviews

Source: RiceToday v. 5 pg. 36
A match made between “G” and “E”
Submergence constrains rice production in flood-prone regions

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

FR13A (tolerant) × Swarna (non-tolerant)

Marker-assisted selection

Sub1

Swarna-Sub1

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

Source: Ismail et al. 2013
Flood-affected rice fields (10d submergence) (UP, India). Photo taken 27 days after water receded

Source: Singh et al. 2013
By 2012, 4 million farmers across India, Bangladesh and Nepal adopted Sub1 varieties

Farmer Nekkanti Subbarao

with IR8 in 1967

with Swarna-Sub1 in 2009

Source: IRRI

Source: IRRI RiceToday
10,000 BCE

Neolithic Rev.

Unconscious selection

1960s-70s

Green Rev.

Visual selection

2000s-10s

Sub1 Revolution

Marker-assisted selection

You are here
Trends in rice (paddy) area, production, and yield in India 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?
photosynthesis

growth &

development

plant hydraulics

transpiration

stomatal conductance

soil water transport

irrigation regime

soil health management

Nature (genotype)

Nurture (environment)

fertilizer schedule

pest management

solar radiation

wind speed

temperature

vapor pressure deficit

precipitation

environment

Nature (genotype)

Nurture (environment)
Nigerian rice farmers at harvest

Source: Jeremy Weate/Flickr

Indian rice farmer using a pest management mobile app

Source: ICRISAT