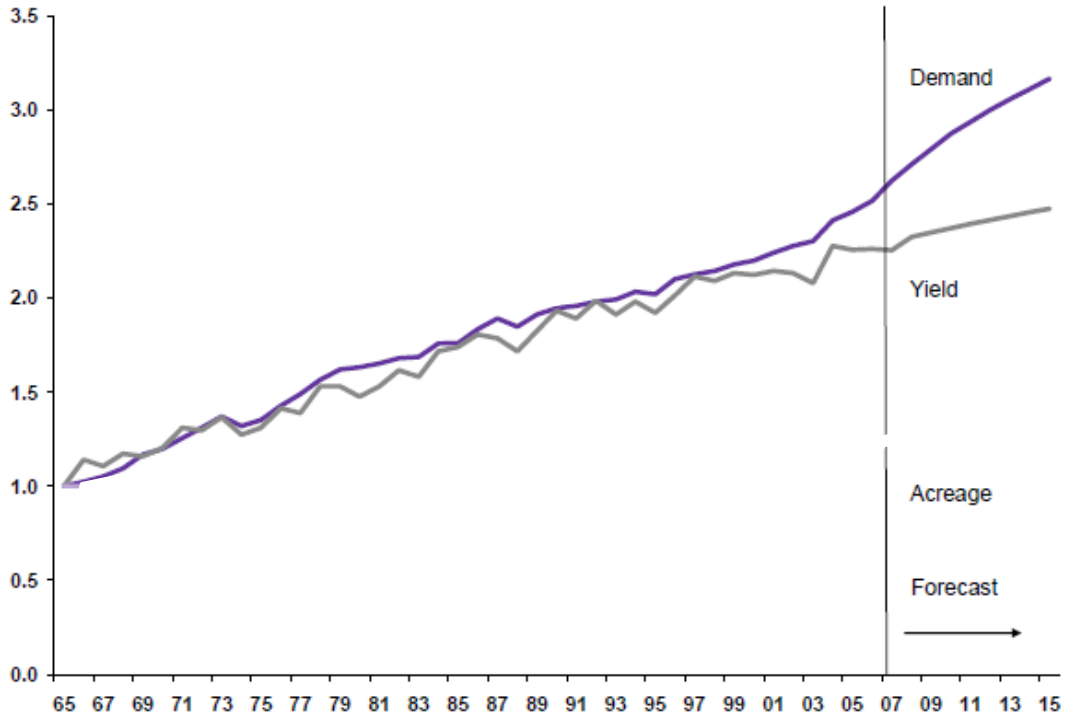
the problem

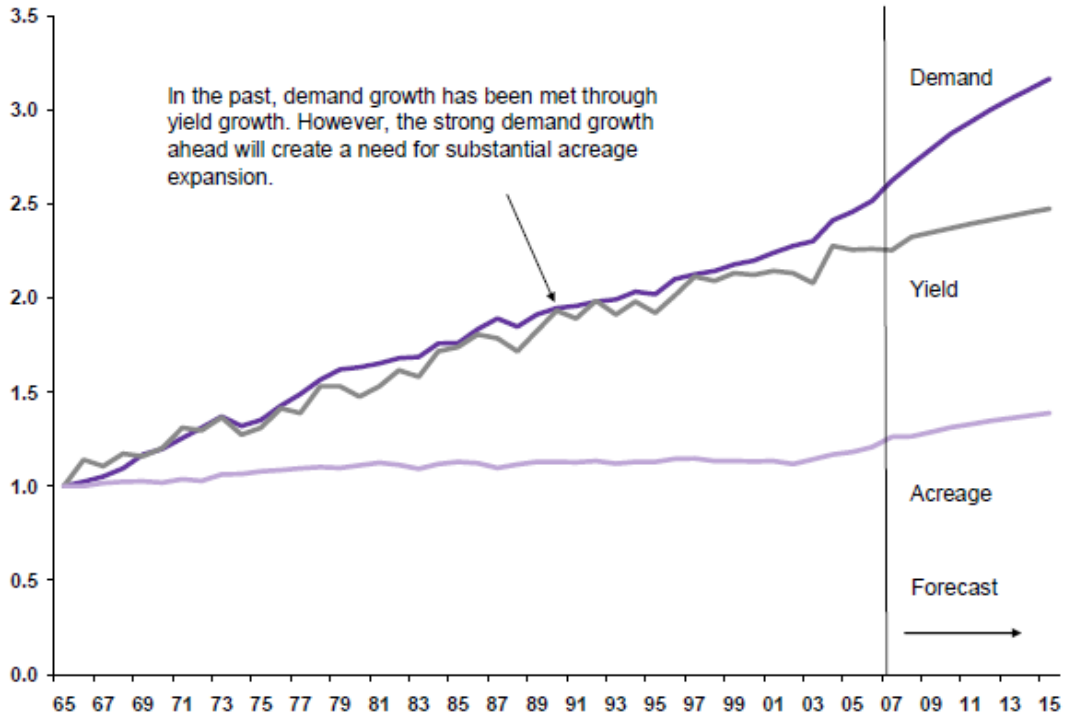
percent growth



Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

the goldman sachs perspective.....

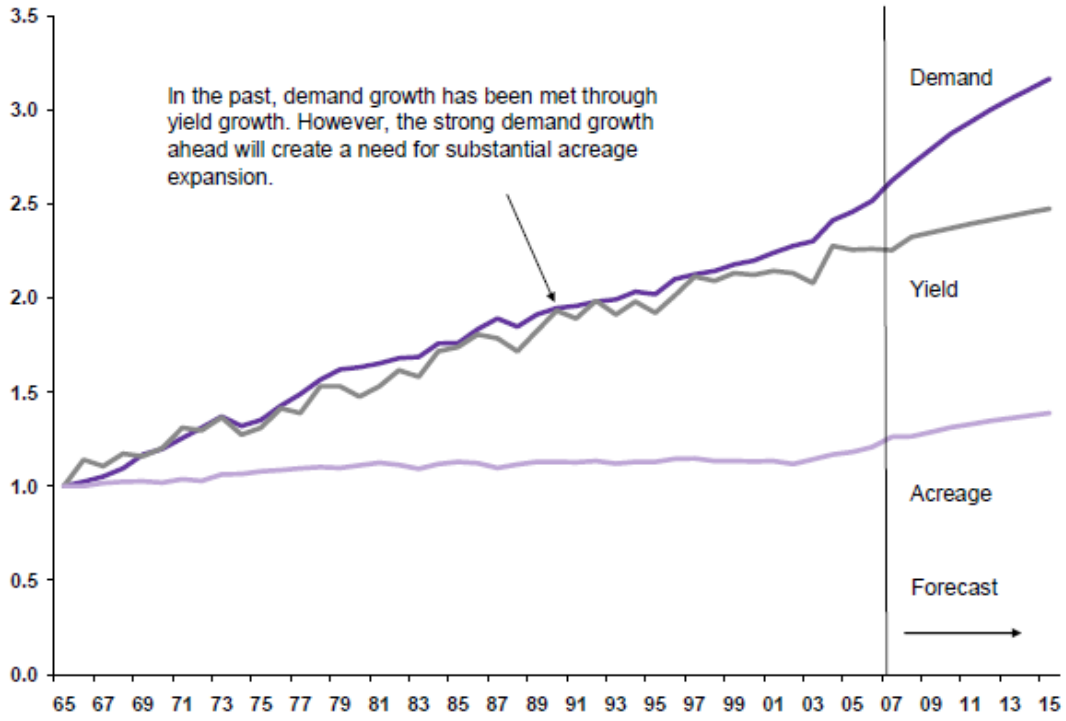
Exhibit 9: Tweaking of agriculture yields is no longer meeting demand growth, acreage must now be expanded
Percent growth



Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

.....does not add up

Exhibit 9: Tweaking of agriculture yields is no longer meeting demand growth, acreage must now be expanded
Percent growth



Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

sufficiency

- **demand**
  - **population size**
  - **diet (overconsumption = consumer waste**
- **production**
- **post-production**
  - **processing**
  - **storage**
  - **consumer waste**

sustainability – a definition

(Pretty 2008)

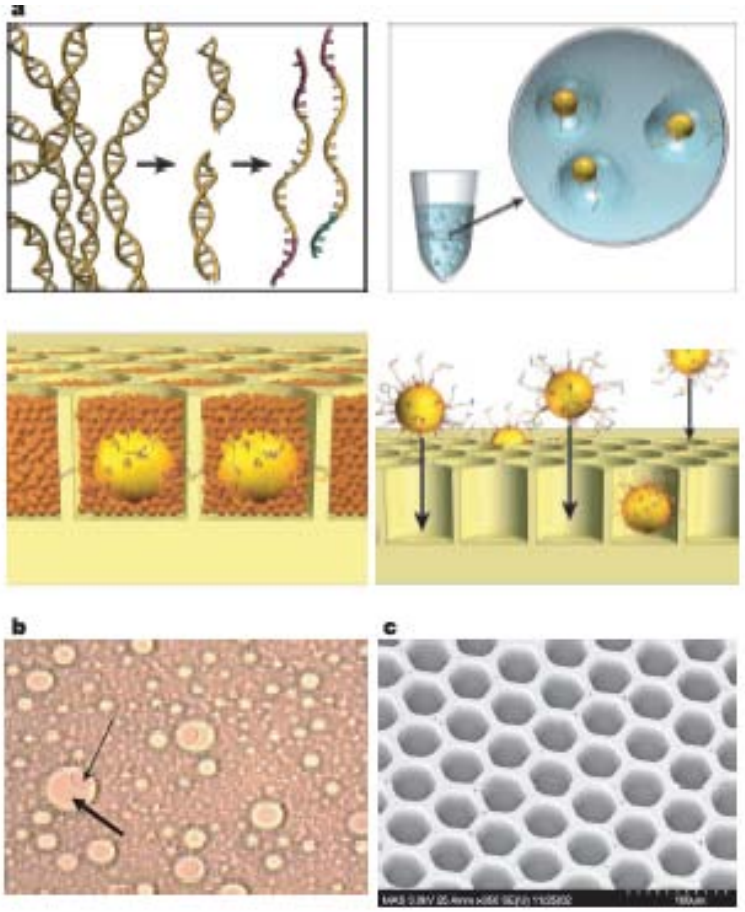
- **Persistence:** the capacity to continue to deliver desired outputs over long periods of time (human generations), thus conferring predictability;
- **Resilience:** the capacity to absorb, utilise or even benefit from perturbations (shocks and stresses), and so persist without qualitative changes in structure;
- **Autarchy:** the capacity to deliver desired outputs from inputs and resources (factors of production) acquired from within key system boundaries;
- **Benevolence:** the capacity to produce desired outputs (food, fibre, fuel, oil) while sustaining the functioning of ecosystem services and not causing depletion of natural capital (eg. minerals, biodiversity, soil, clean water).

approaches to sustainable and sufficient production

- markets
- infrastructure
- agroecology
- integrated crop management
- agronomy
- engineering
- genetics

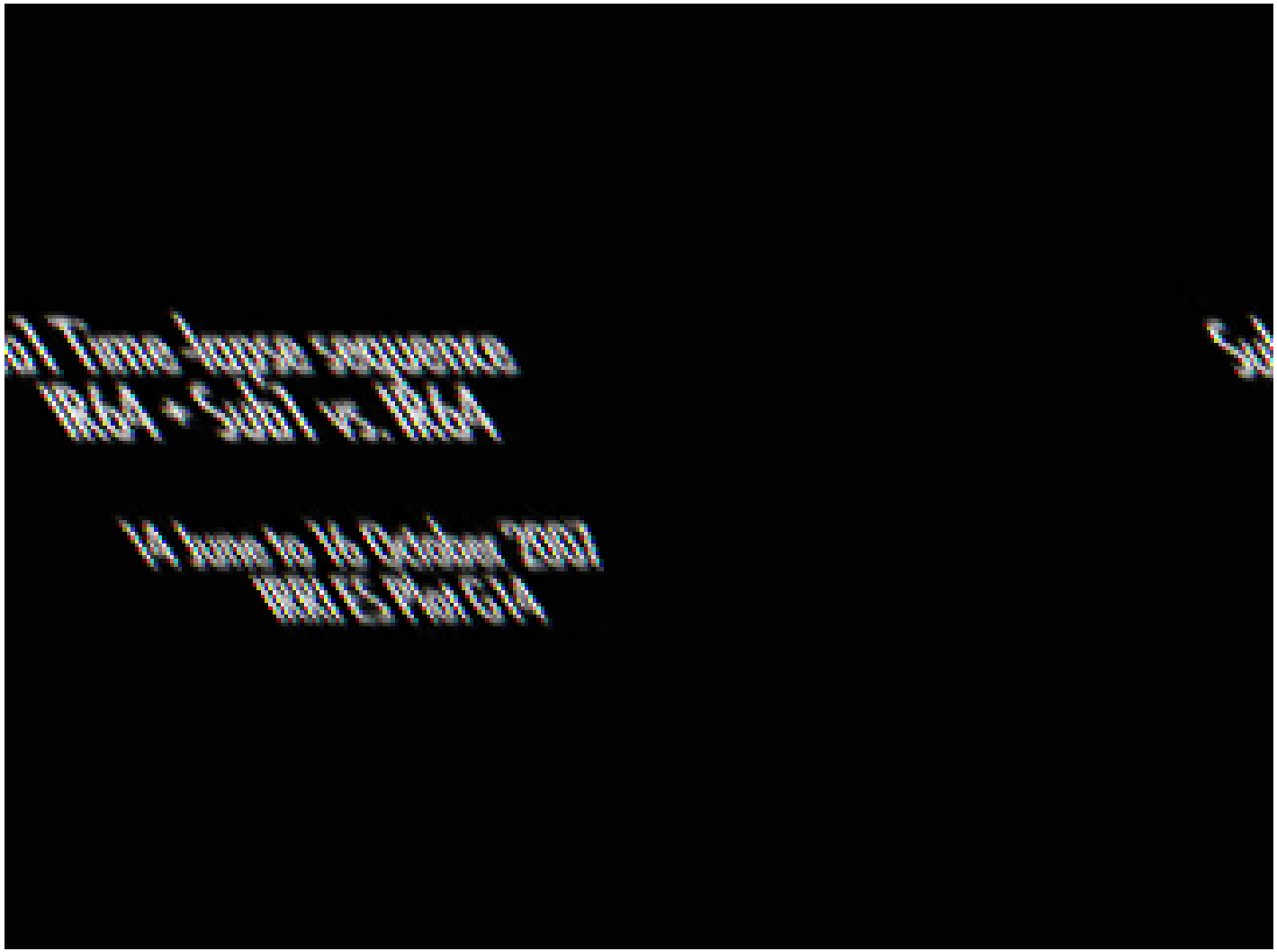
next generation DNA sequencing

- De novo sequencing of crop and crop pathogen genomes
- Sequencing of varieties and related species
- Expression profiling
- Characterisation of non coding RNAs and epigenetic modifications

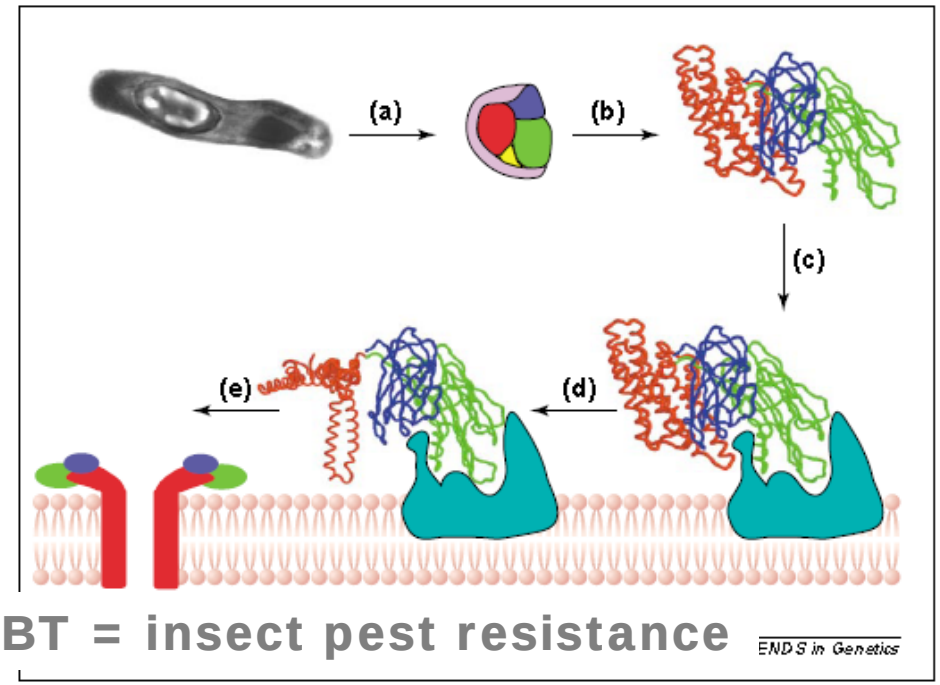


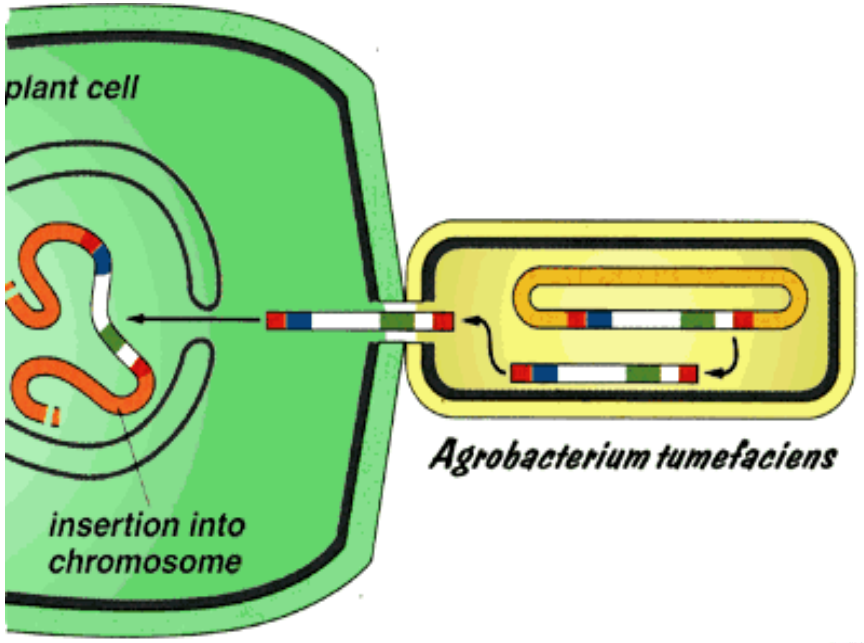
readily accessible genome sequence facilitates gene identification and marker-assisted plant breeding

- *Sub1*

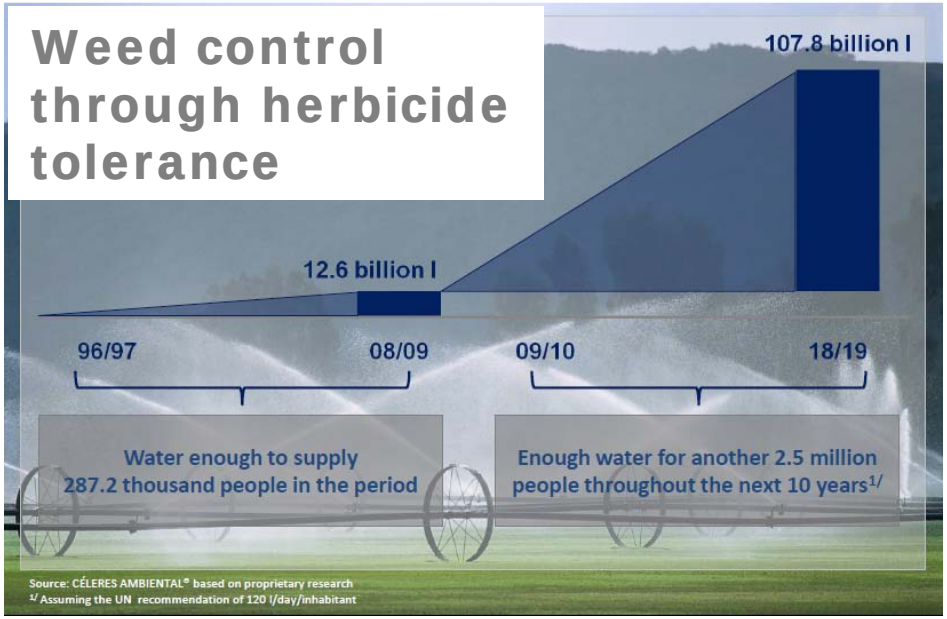


1st generation GM

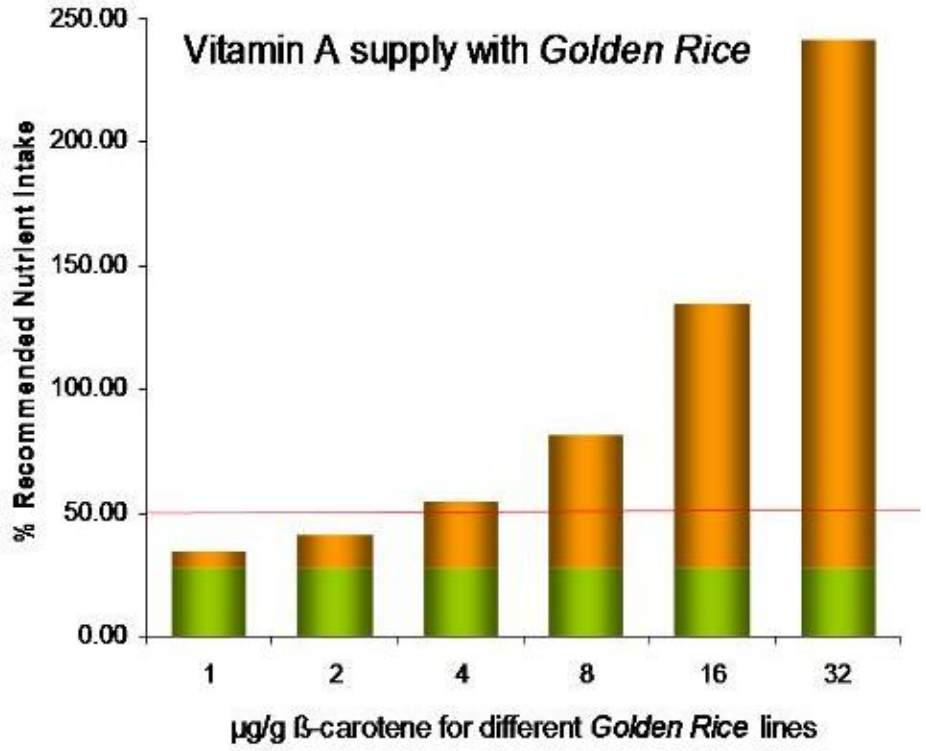




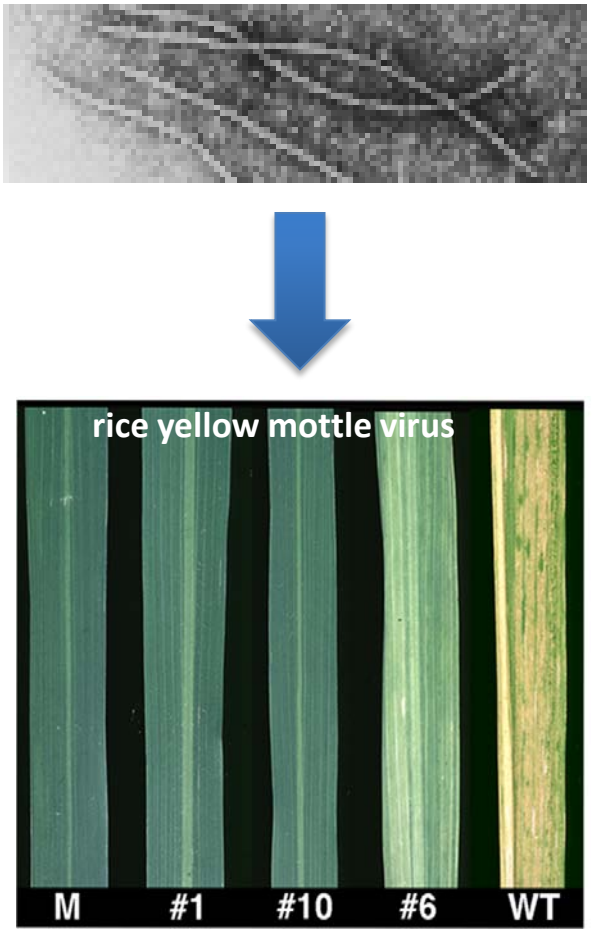
Biotech adoption in Brazil allowed a substantial reduction of water deployed on chemical spraying



1st generation GM has not been fully exploited



Golden rice



Parasite-derived resistance

2nd generation GM

- isolated genes can be used in genetic manipulation – transfer of plant genes between plants - cisgenesis

Gene RB cloned from Solanum bulbocastanum confers broad spectrum resistance to potato late blight
Junqi Song*†, James M. Bradeen†‡, S. Kristine Naess‡, John A. Raasch§, Susan M. Wielgus*‡, Geraldine T. Haberlach‡,
Jia Liu¶, Hanhui Kuang, Sandra Austin-Phillips§, C. Robin Buell¶, John P. Helgeson‡, and Jiming Jiang*,****

www.pnas.orgcgidoi10.1073pnas.1533501100

nextgen DNA sequence allows genes to be mapped easily so that GM can be used to achieve many of the targets of conventional breeding

- drought and stress resistance
- improved post harvest storage
- modified plant architecture
  - dwarf for resistance to lodging and improved harvest index
  - more root hairs for increased nutrient uptake
- modified plant metabolism (for biofuel crops or to enhance nutritional content)
- complex multigene traits can also be transferred

GM can be used to achieve targets of conventional breeding

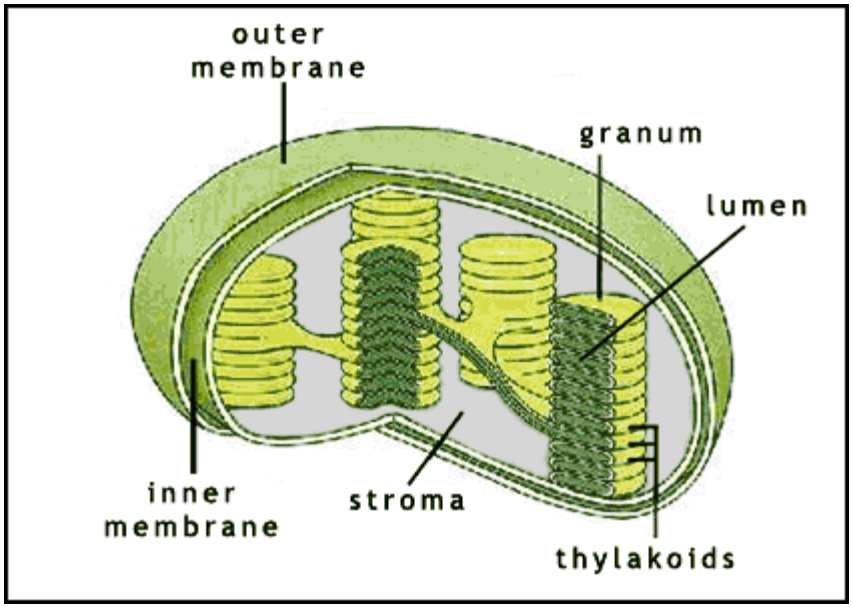
- retaining the characteristics of original variety
- to generate several new varieties at once

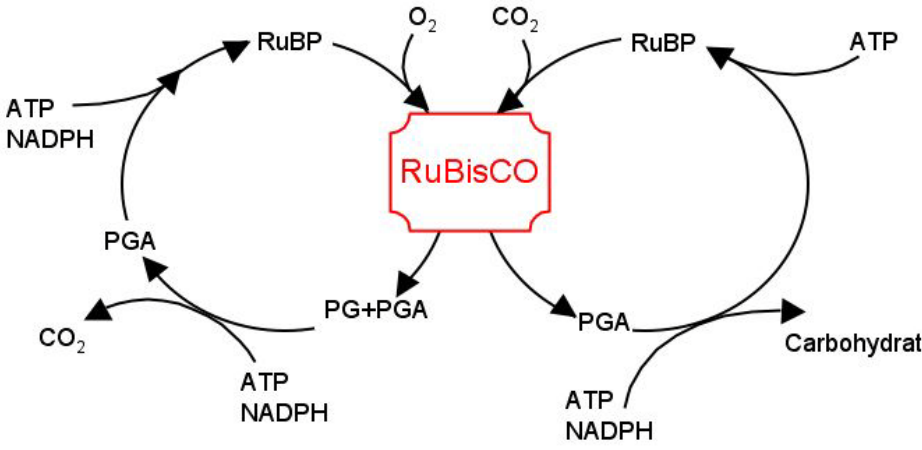
3rd generation GM

- radically altered or completely novel crops for food and fuel
- complex traits or sets of traits
- genes from plants and non plants – or both

long term grand challenges for plant science ?

- Increasing the efficiency of photosynthesis??





photosynthesis

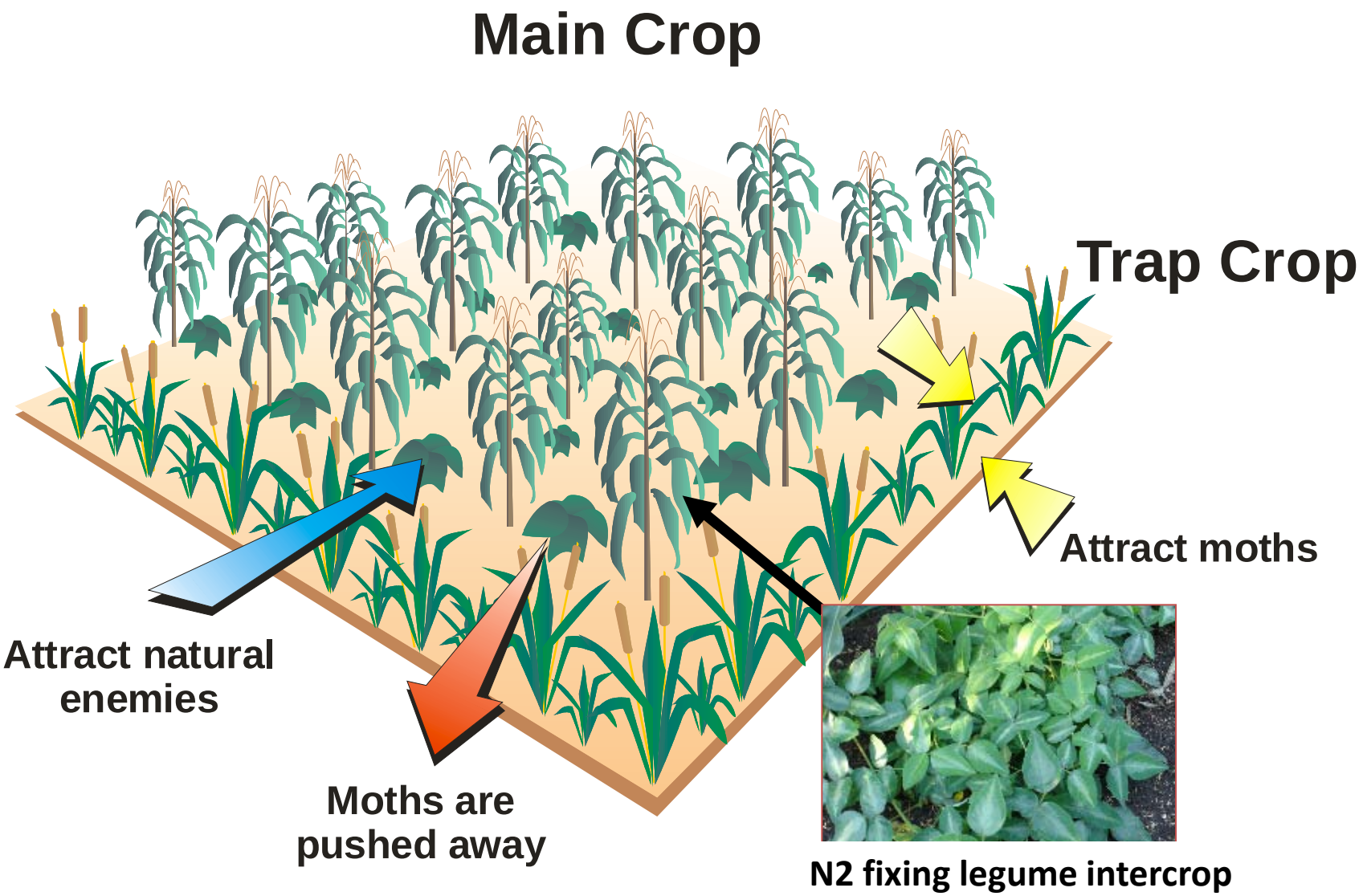
www.helpsavetheclimate.com/chloroplast1.gif

scientific grand challenges in crop production

- enhanced photosynthesis
- perennial crops so that soil erosion prevented, better retention and uptake of water and nutrients from the soil, no need to rebuild root system each year
- nitrogen fixation???
- vegetative seed production (ie seed produced without pollination)
- harnessing of hybrid vigour
- new species as crops

combining advances in genetics with agronomy

Push-pull or companion cropping



next generation companion cropping

- Use of GM and breeding to **adapt main and companion** crop to companion cropping
- Application of **companion cropping in developed country** agriculture to reduce inputs. Combine with 21st century maincrops with biotech enhanced traits and with improved engineering
- Requires **new IP and effective regulatory framework** for GM
- Raises important questions about **intensification and land sparing vs extensification**

summary – new genetics for sustainable agriculture

- next generation sequencing is revolutionary – gene identification and genome analysis are greatly enhanced
- enhanced genome analysis provides opportunities in marker assisted selection and variations on conventional breeding
- 1st generation GM has not been fully exploited
- 2nd generation GM achieves the targets of conventional breeding and follows from enhanced genome analysis and gene identification
- 3rd generation GM could provide radically new crops
- Genetics (GM and conventional breeding) should be linked to innovation in agronomy and crop management