Il contributo della genetica alla soluzione dei problemi ambientali causati dall'intensificazione colturale

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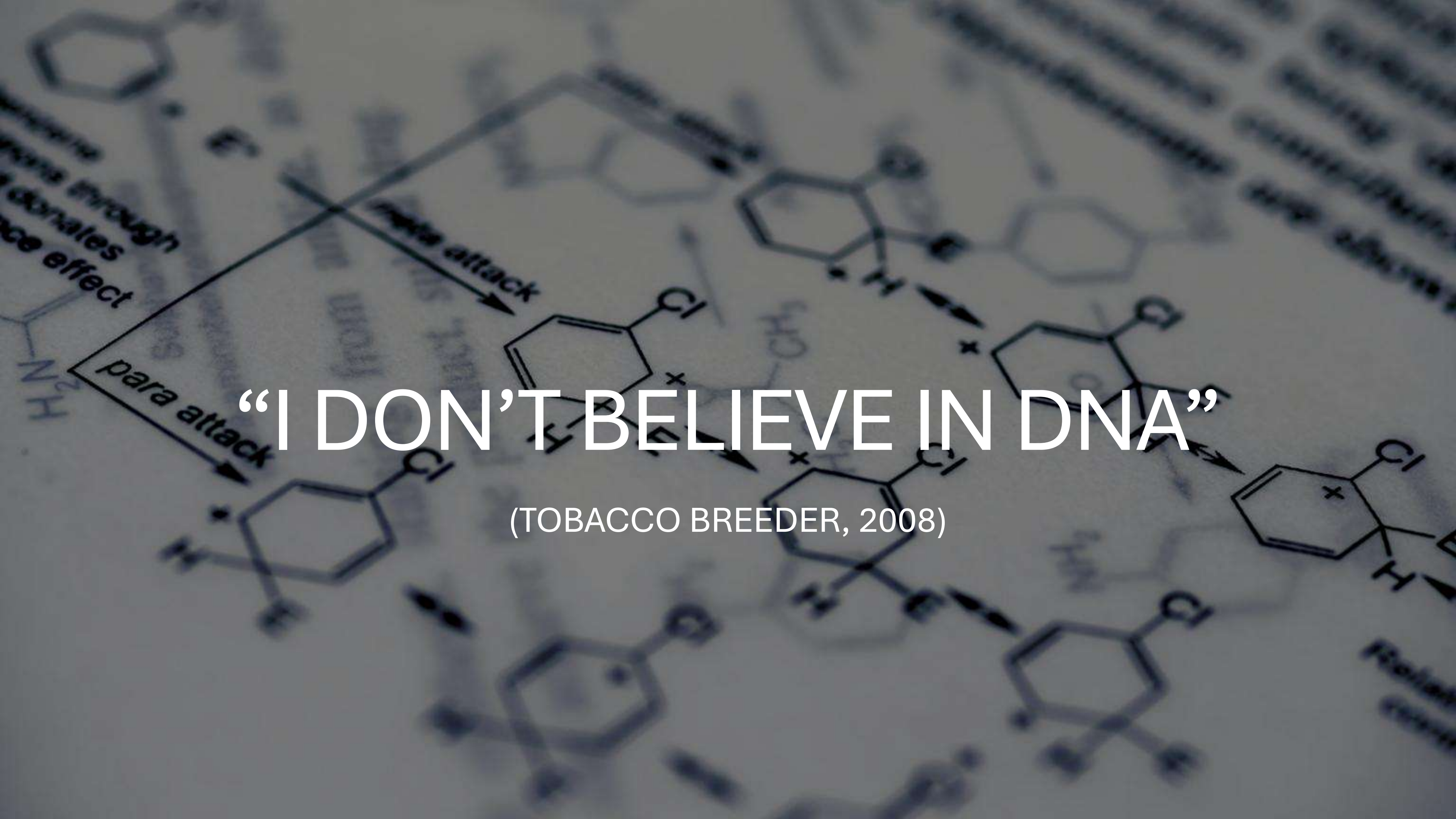
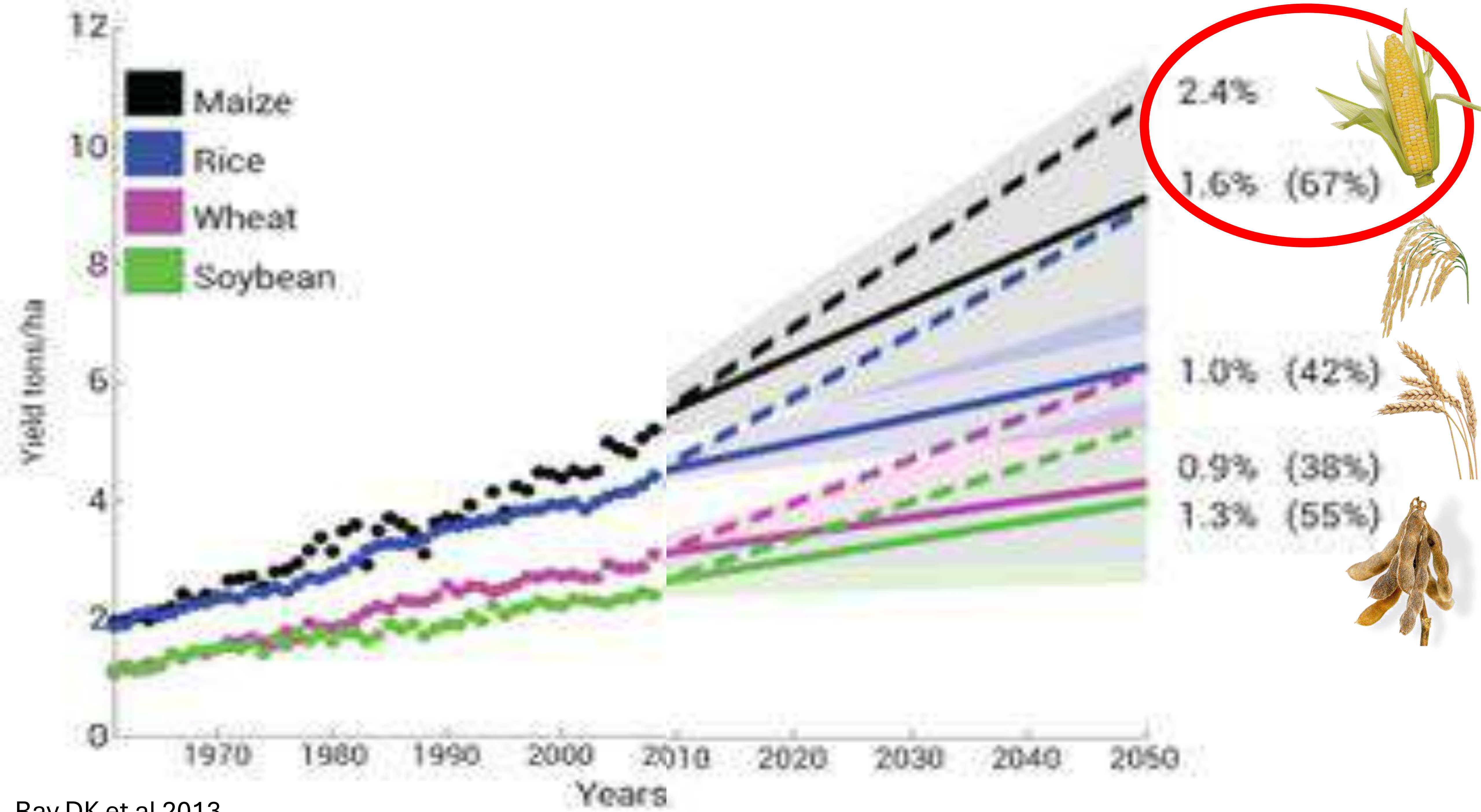
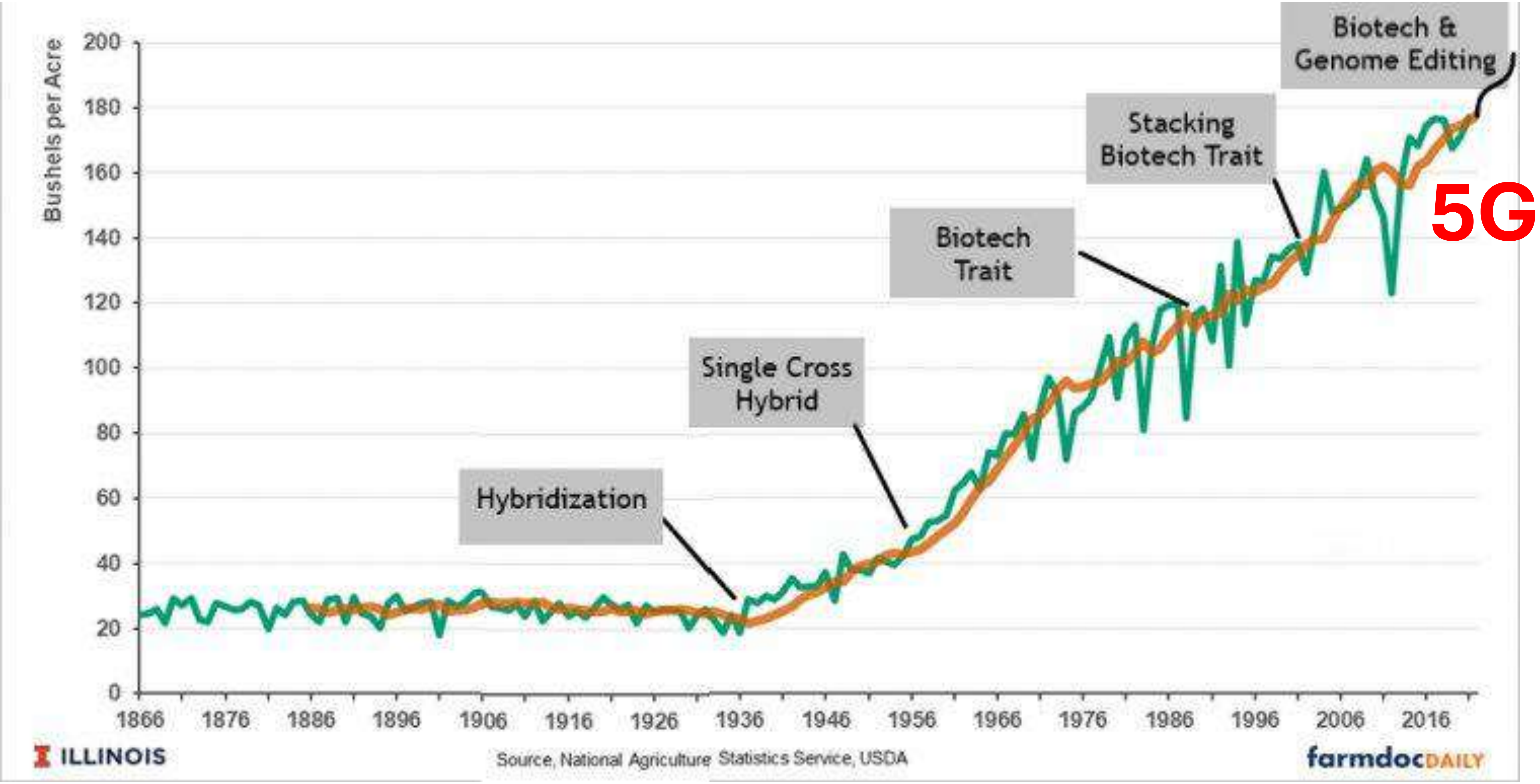


“I DON’T BELIEVE IN DNA”

(TOBACCO BREEDER, 2008)



Ray DK et al 2013


Bushels per Acre
200
180
160
140
120
100
80
60
40
20
0
1866
1876
1886
1896
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
2006
2016
Hybridization
Single Cross Hybrid
Biotech Trait
Stacking Biotech Trait
Biotech & Genome Editing
5G
ILLINOIS
Source, National Agriculture Statistics Service, USDA
farmdocDAILY

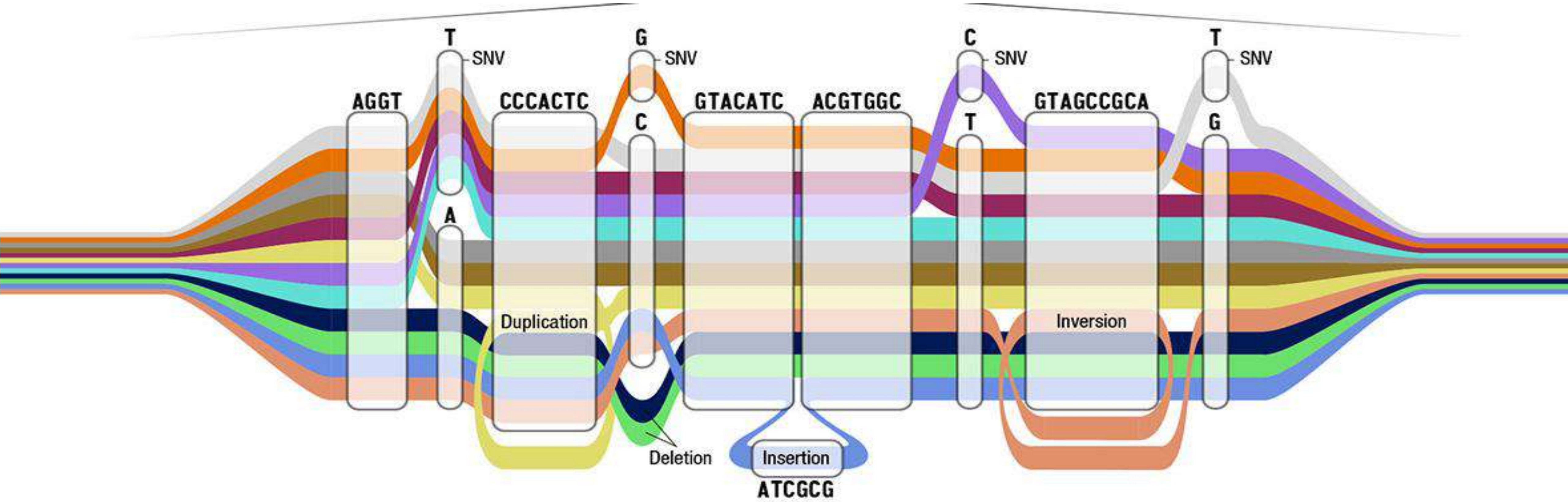
5G: the molecular genetics tools in the new breeding

- Genome assembly
- Genomic breeding
- Genome Editing
- Germplasm characterization
- Gene Function

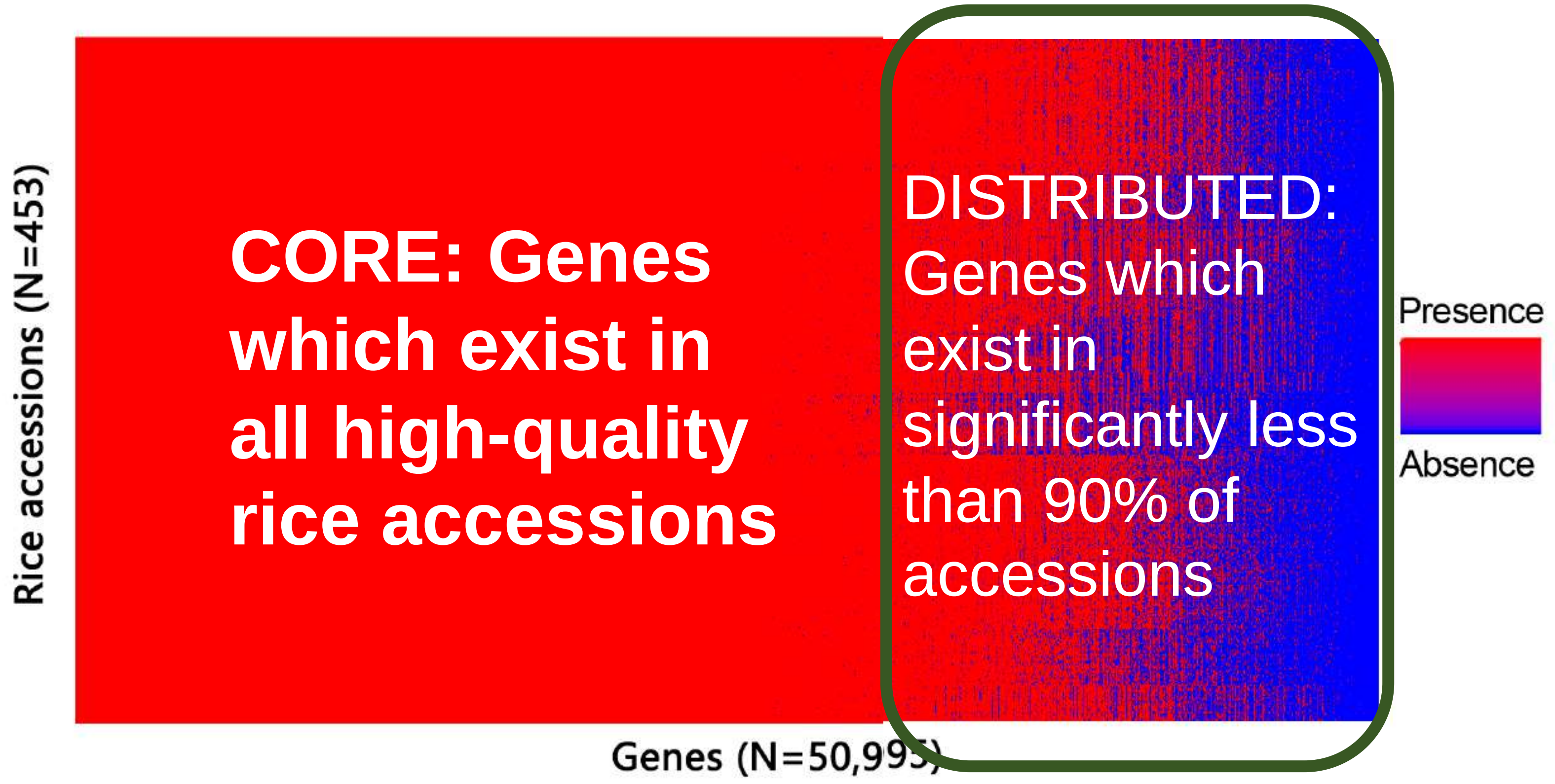
Varshney et al., 2020

Genome assembly

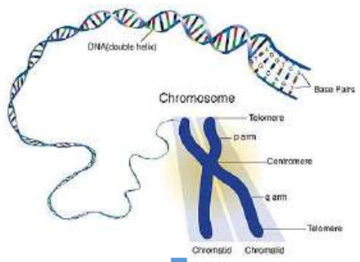
La pangenomica

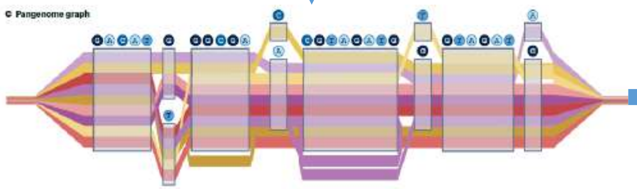


Strength of resenquencing



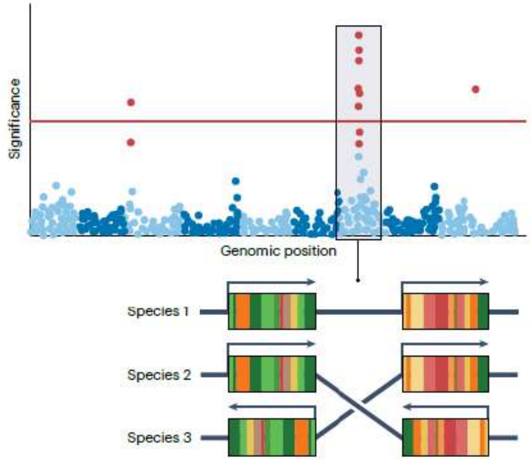
Benefit to plant breeding from pangenomics





IMPROVED GENE PREDICTION / ANNOTATION

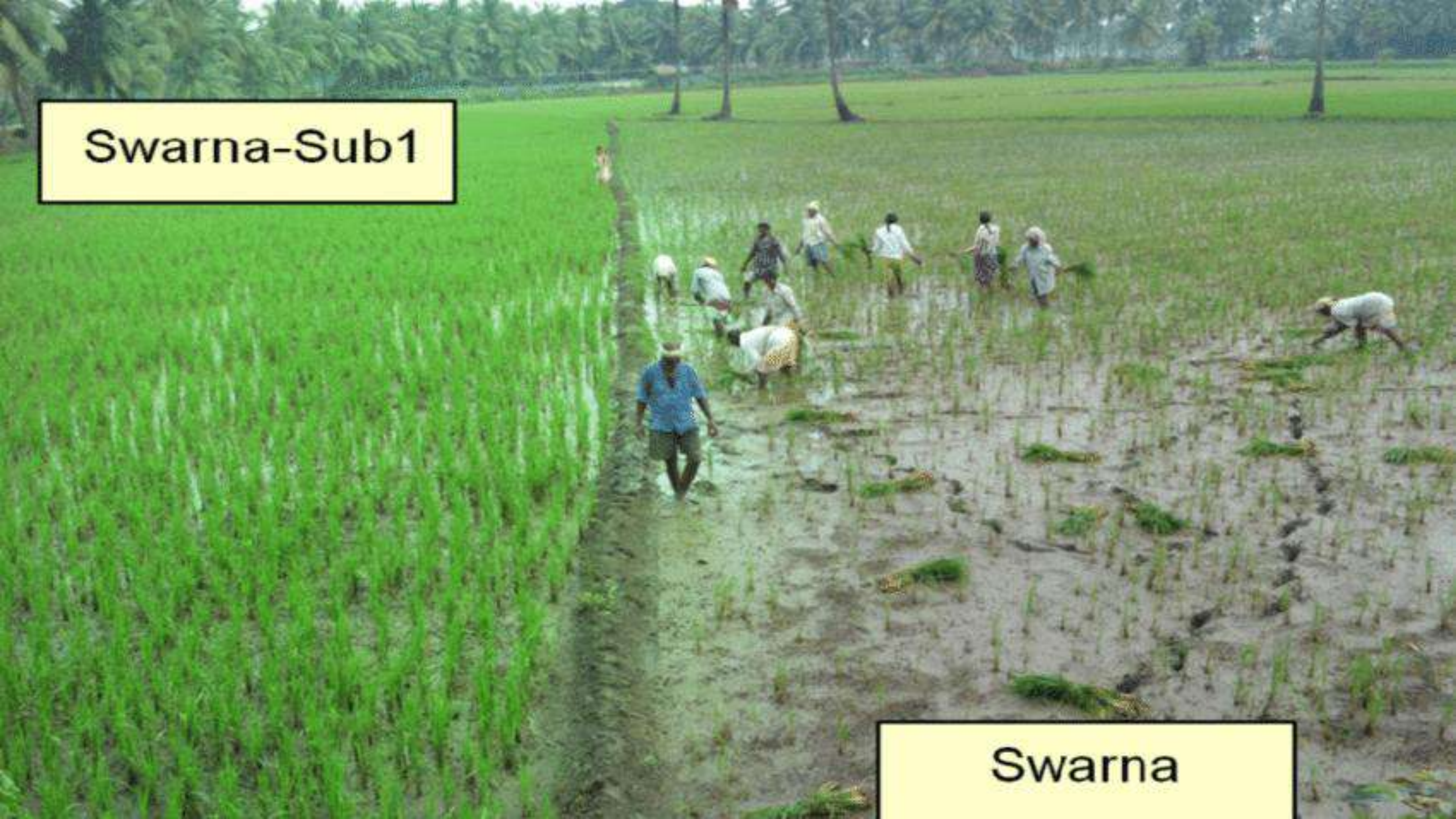
MACHINE LEARNING



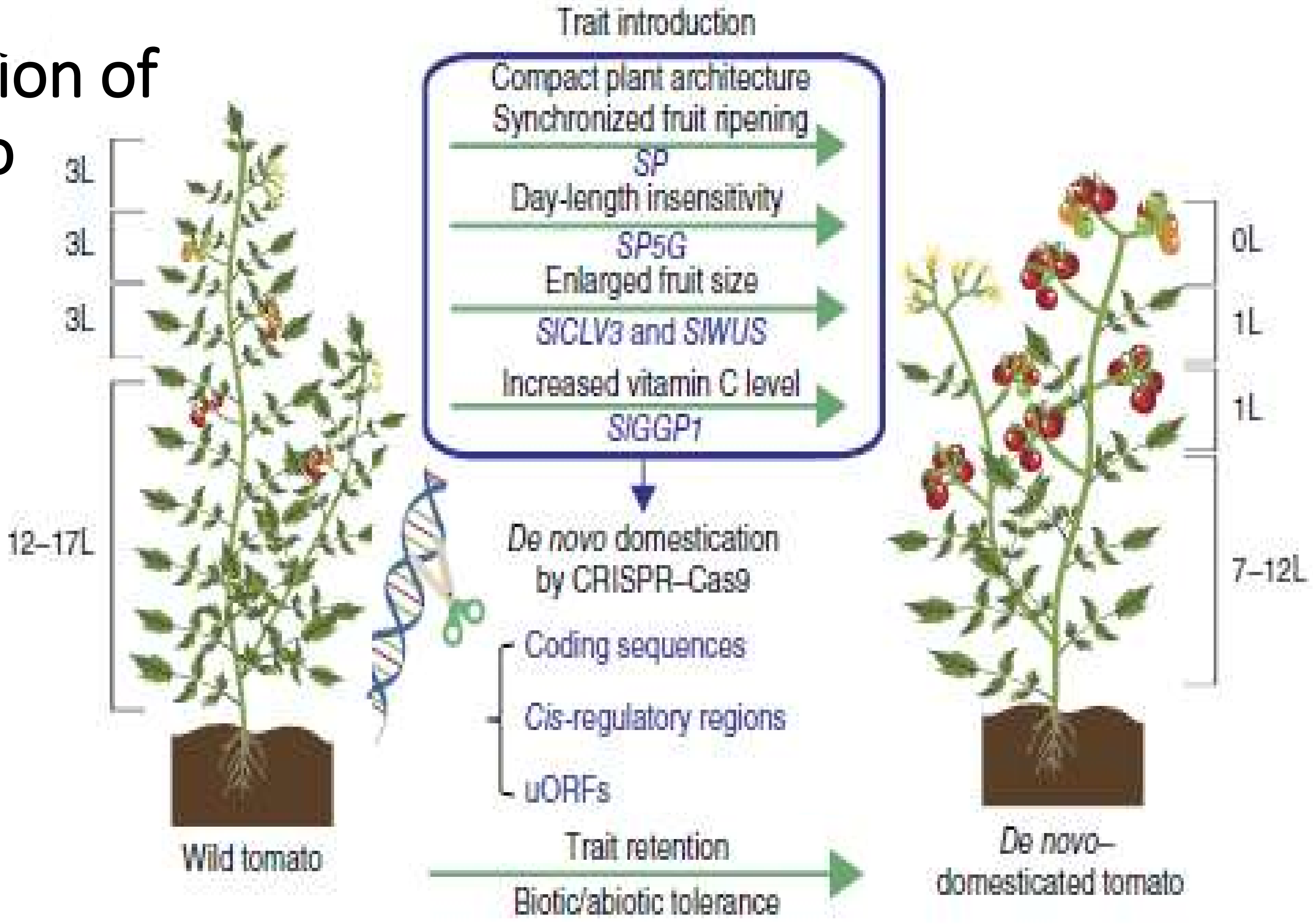
Link structural variation to quantitative traits

1. Identify genes lost during domestication
2. Domesticate new varieties

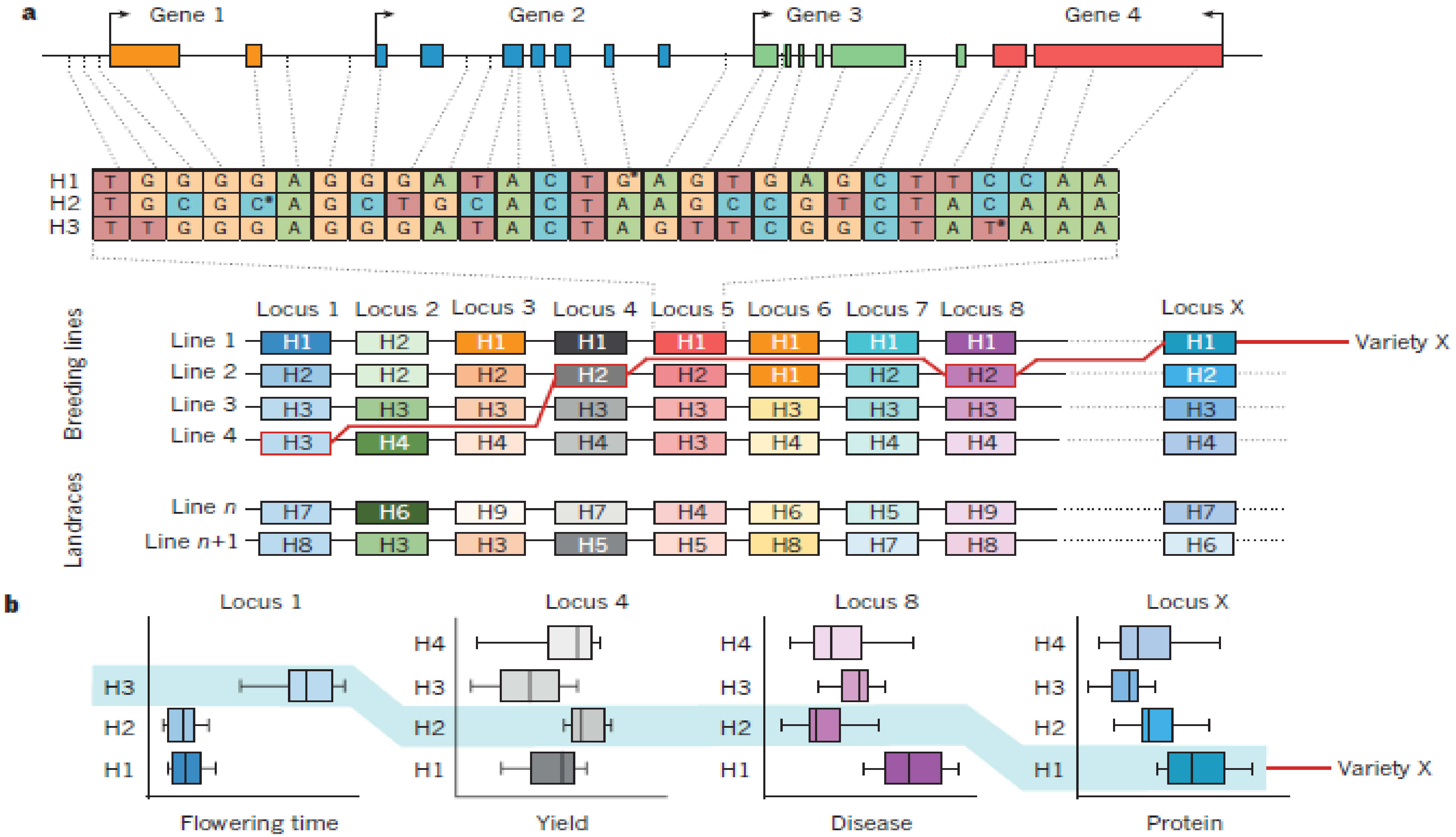
https://pmc.ncbi.nlm.nih.gov/articles/PMC8910360/


Swarna-Sub1
Swarna

Domestication of wild tomato



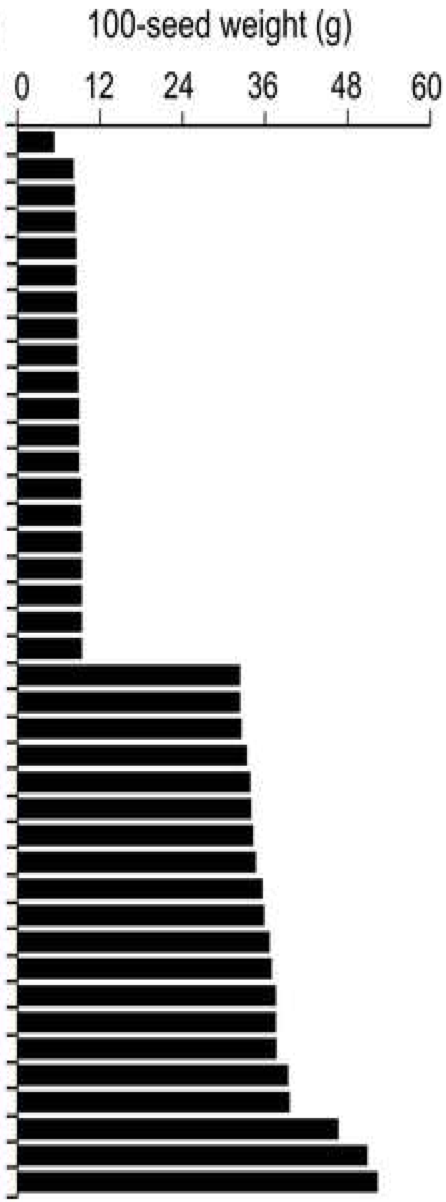
Genomic breeding



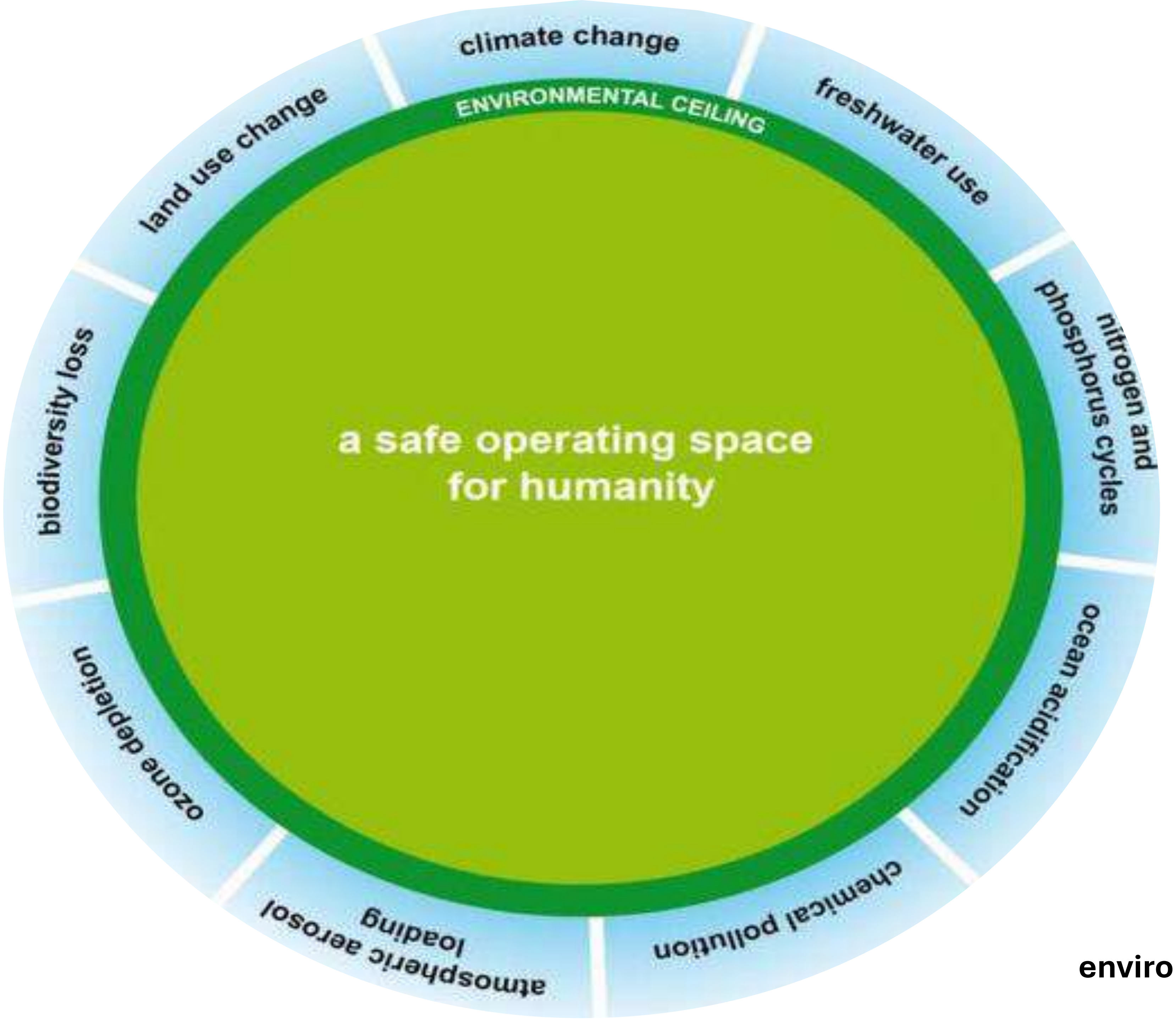
a
Gene 1
Gene 2
Gene 3
Gene 4
H1
H2
H3
Locus 1
Locus 2
Locus 3
Locus 4
Locus 5
Locus 6
Locus 7
Locus 8
Locus X
Breeding lines
Line 1
Line 2
Line 3
Line 4
Landraces
Line n
Line n+1
Variety X
b
Locus 1
Locus 4
Locus 8
Locus X
H4
H3
H2
H1
Flowering time
Yield
Disease
Protein
Variety X

Genomic breeding

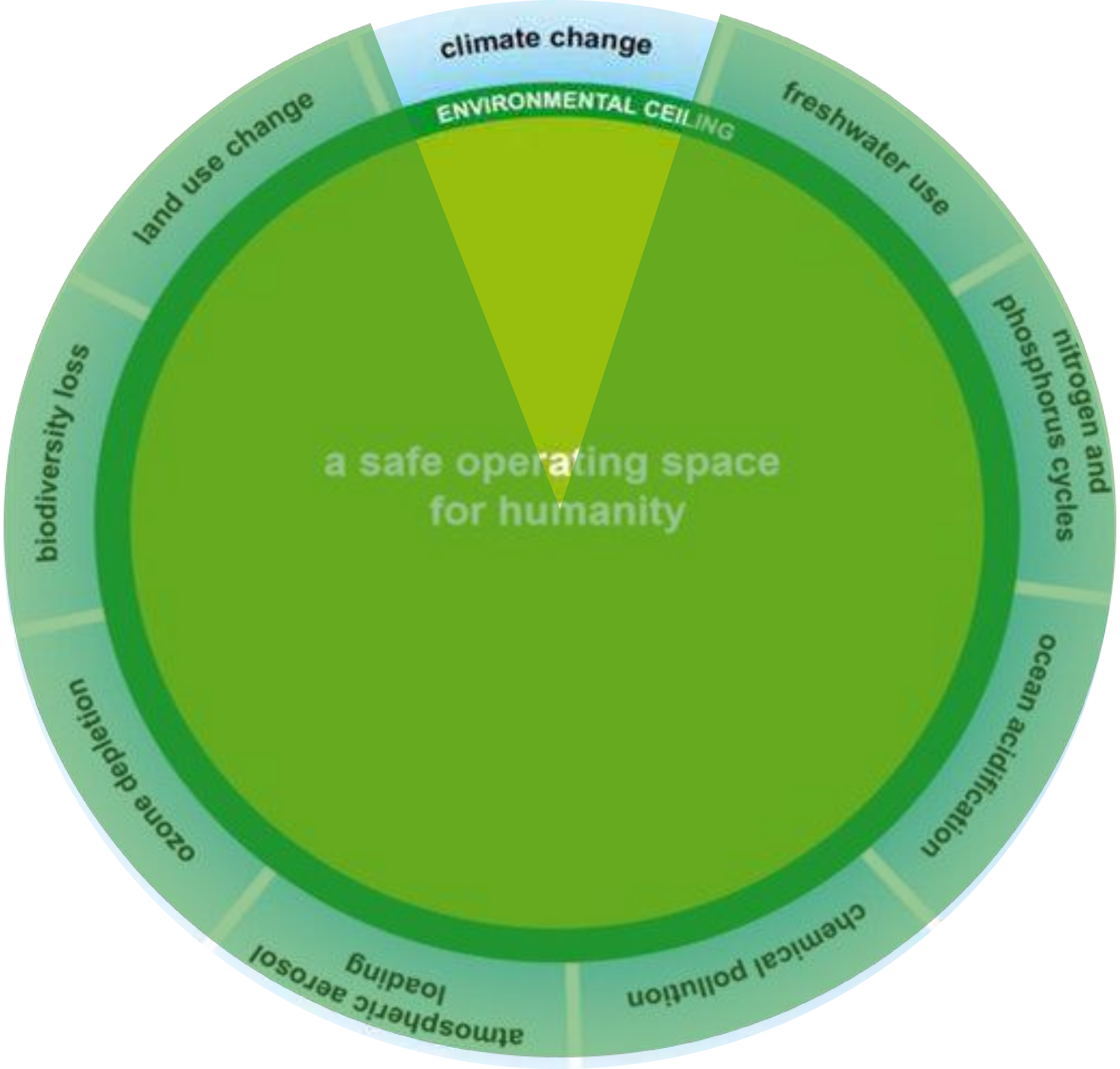
Accession no.	Biological status	Origin	Region	Sequence variation in "QTL-hotspot" region		
				Ca_04546	*Ca_04557*	*Ca_04558*
				Exon 3	Intron 2	Exon 6
				T/A	T/C	A/C
				Asn/Tyr		Ile/Ser
				2888*	598*	2922*
ICC 5002	Breeding material	India	South & East Asia	T	T	A
ICC 9974	Landrace	India	South & East Asia	T	T	A
ICC 6464	Landrace	Iran	West Asia	T	T	A
ICC 14340	Breeding material	India	South & East Asia	T	C	A
ICC 2342	Landrace	Iran	West Asia	T	C	A
ICC 9994	Landrace	India	South & East Asia	T	T	A
ICC 14083	Landrace	Ethiopia	Africa	T	C	A
ICC 16171	Landrace	Myanmar	South & East Asia	T	T	A
ICC 12288	Landrace	Nepal	South & East Asia	T	T	A
ICC 16215	Landrace	Myanmar	South & East Asia	T	T	A
ICC 1790	Landrace	India	South & East Asia	T	T	A
ICC 12299	Landrace	Nepal	South & East Asia	T	T	A
ICC 4065	Landrace	Iran	West Asia	T	C	A
ICC 9978	Landrace	India	South & East Asia	T	T	A
ICC 10673	Landrace	Turkey	Russian Federation	T	C	A
ICC 3617	Landrace	Iran	West Asia	T	C	A
ICC 4310	Landrace	Iran	West Asia	T	C	A
ICC 4623	Landrace	India	South & East Asia	T	T	A
ICC 7485	Landrace	India	South & East Asia	T	T	A
ICC 9970	Landrace	India	South & East Asia	T	T	A
ICC 1836	Landrace	India	South & East Asia	A	C	C
ICC 6122	Landrace	India	South & East Asia	T	C	C
C 5003LN	Breeding material	ICRISAT	South & East Asia	A	C	C
12379	Landrace	Iran	South & East Asia	A	C	C
12197	Breeding material	India	South & East Asia	T	C	C
15762	Landrace	Syrian Arab Republic	Mediterranean	T	C	A
3200	Landrace	Iran	West Asia	T	C	C
932	Landrace	India	South & East Asia	T	C	C
[illegible]	Advanced cultivar	ICRISAT	South & East Asia	A	C	C
53	Landrace	India	South & East Asia	T	C	N
9	Landrace	Nepal	South & East Asia	T	C	C
[illegible]	Landrace	India	South & East Asia	T	C	C
ICC 8474	Landrace	Spain	Mediterranean	T	C	C
ICC 12951	Breeding material	India	South & East Asia	A	C	C
ICC 4958	Advanced cultivar	India	South & East Asia	T	C	C
ICC 8348	Landrace	India	South & East Asia	T	C	C
ICCC 37	Breeding material	ICRISAT	South & East Asia	T	T	A
ICC 15574	Breeding material	India	West Asia	A	C	C
ICC 7672	Landrace	Morocco	Mediterranean	A	C	C
ICC 15554	Landrace	Morocco	South & East Asia	A	C	C
		Variation-index	Lowest bulk	1.00	0.65	1.00
			Highest bulk	0.60	0.05	0.11
		ΔVariation-index		-0.40	-0.60	-0.89

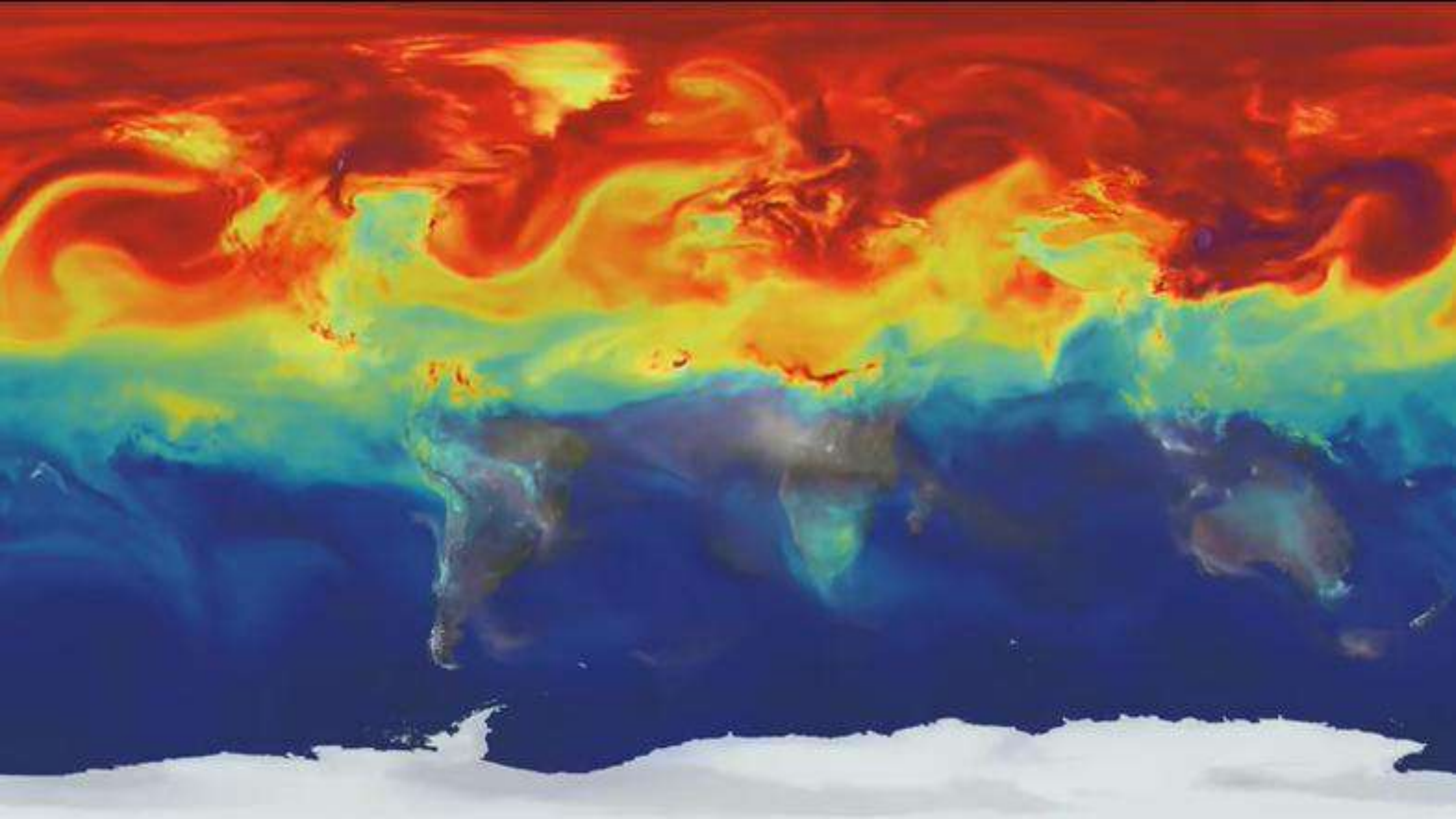


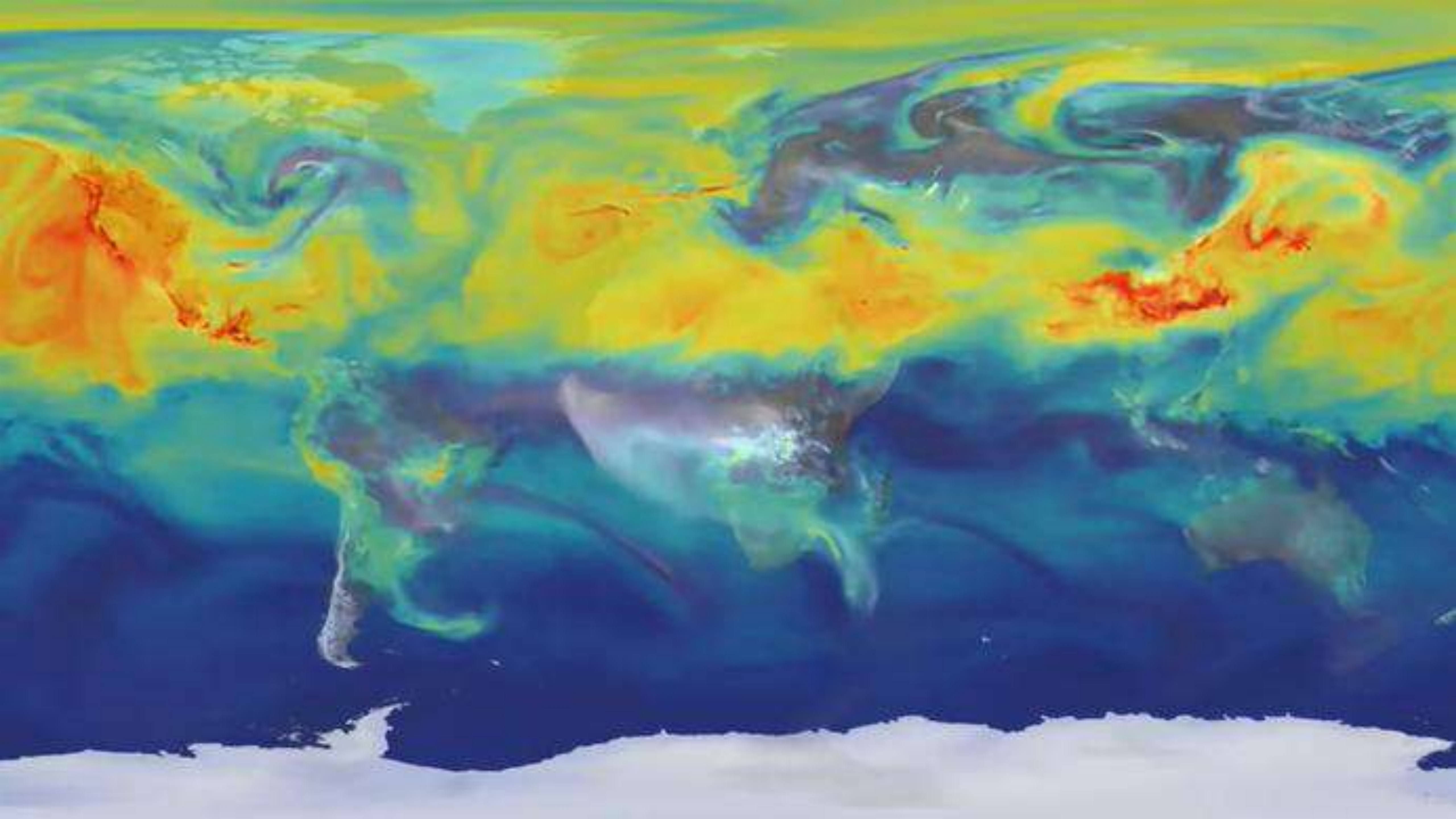
The planet boundaries & biotech

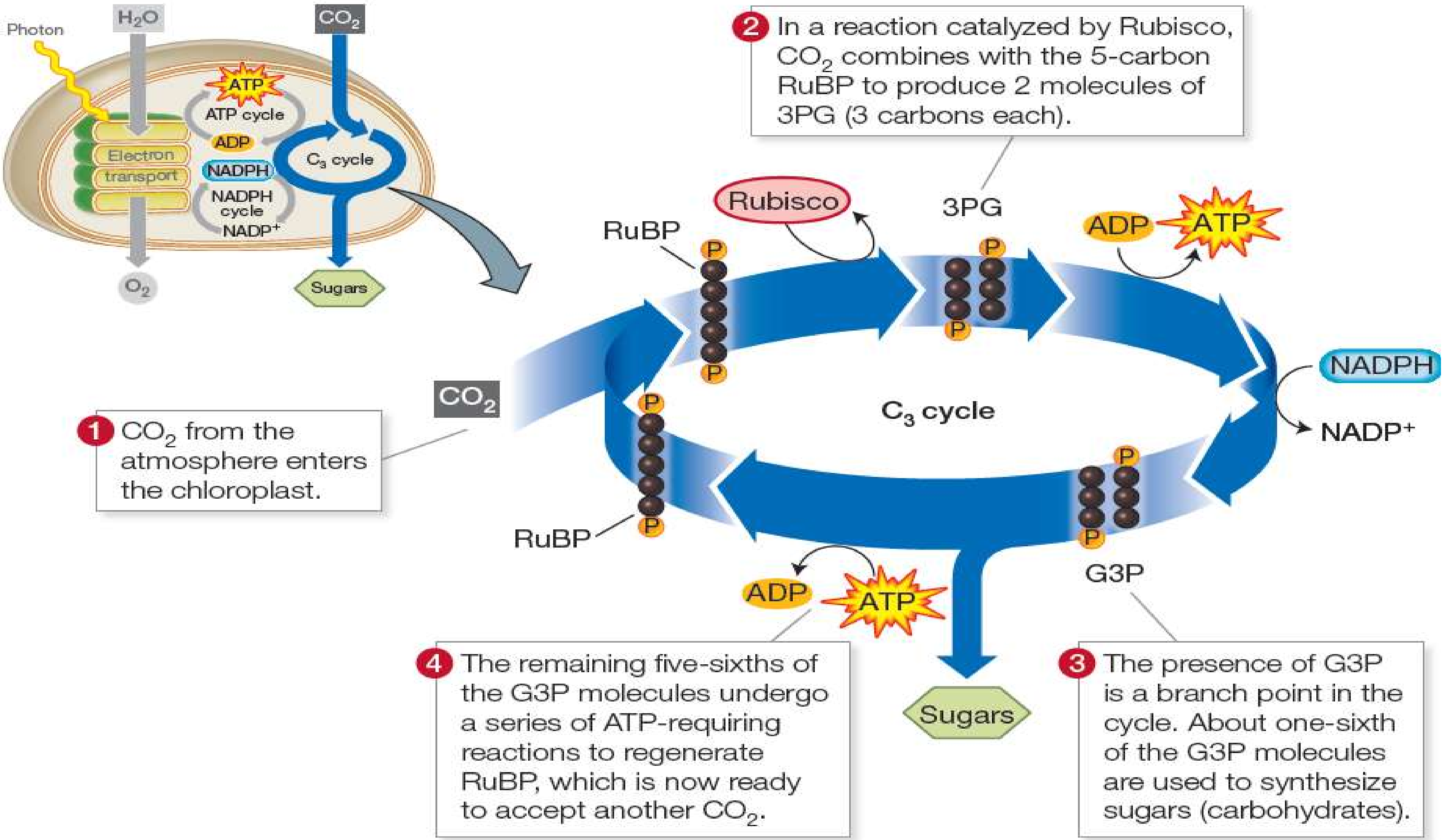


environmental processes


climate change
ENVIRONMENTAL CEILING
freshwater use
nitrogen and phosphorus cycles
ocean acidification
chemical pollution
atmospheric aerosol loading
ozone depletion
biodiversity loss
land use change
a safe operating space for humanity







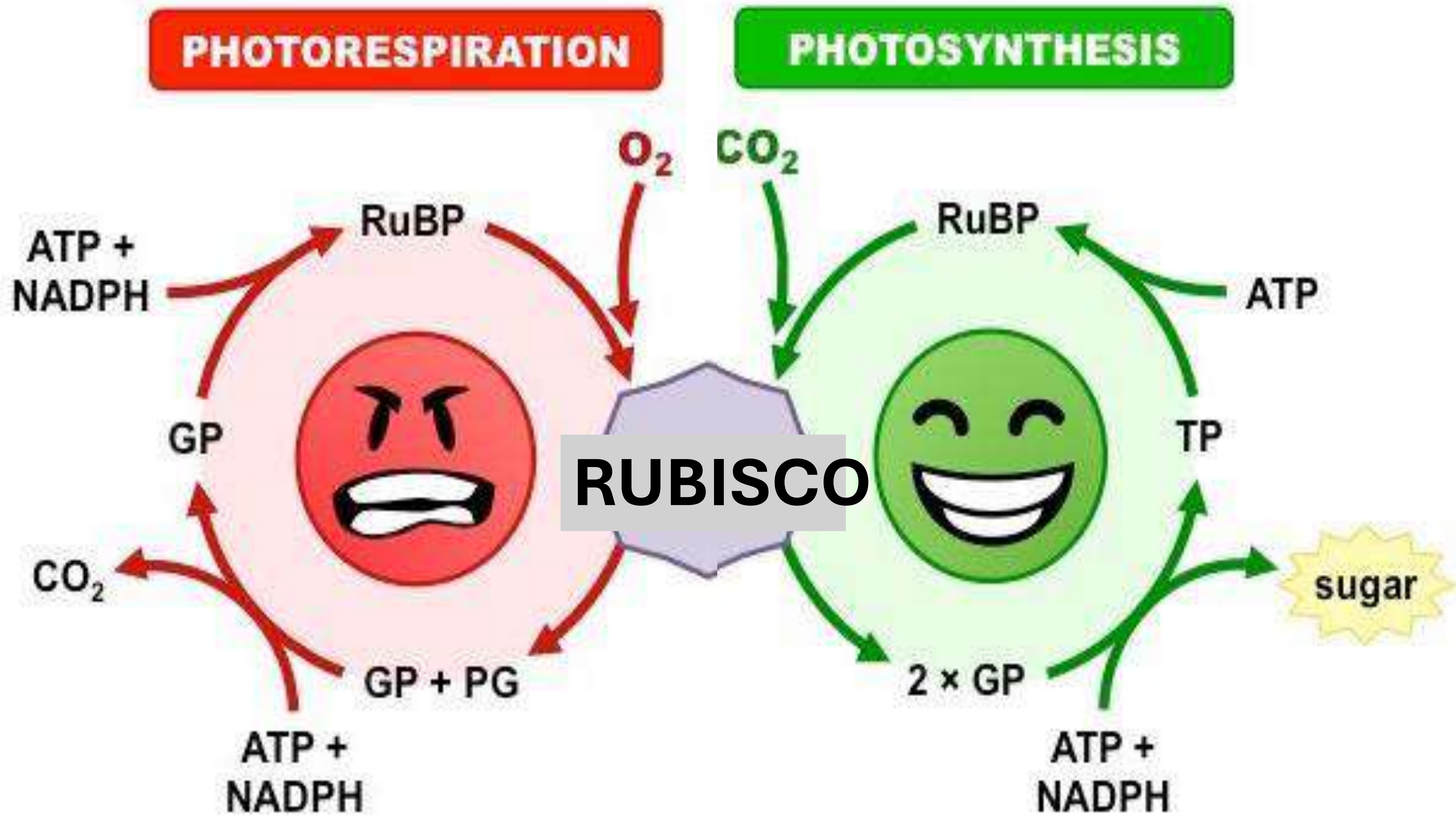
Photon
H_2O
CO_2
ATP
ATP cycle
ADP
Electron transport
NADPH
NADPH cycle
$NADP^+$
C_3 cycle
O_2
Sugars
2 In a reaction catalyzed by Rubisco, CO_2 combines with the 5-carbon RuBP to produce 2 molecules of 3PG (3 carbons each).
Rubisco
RuBP
3PG
P
ADP
ATP
NADPH
$NADP^+$
C_3 cycle
CO_2
1 CO_2 from the atmosphere enters the chloroplast.
RuBP
G3P
ADP
ATP
Sugars
4 The remaining five-sixths of the G3P molecules undergo a series of ATP-requiring reactions to regenerate RuBP, which is now ready to accept another CO_2.
3 The presence of G3P is a branch point in the cycle. About one-sixth of the G3P molecules are used to synthesize sugars (carbohydrates).

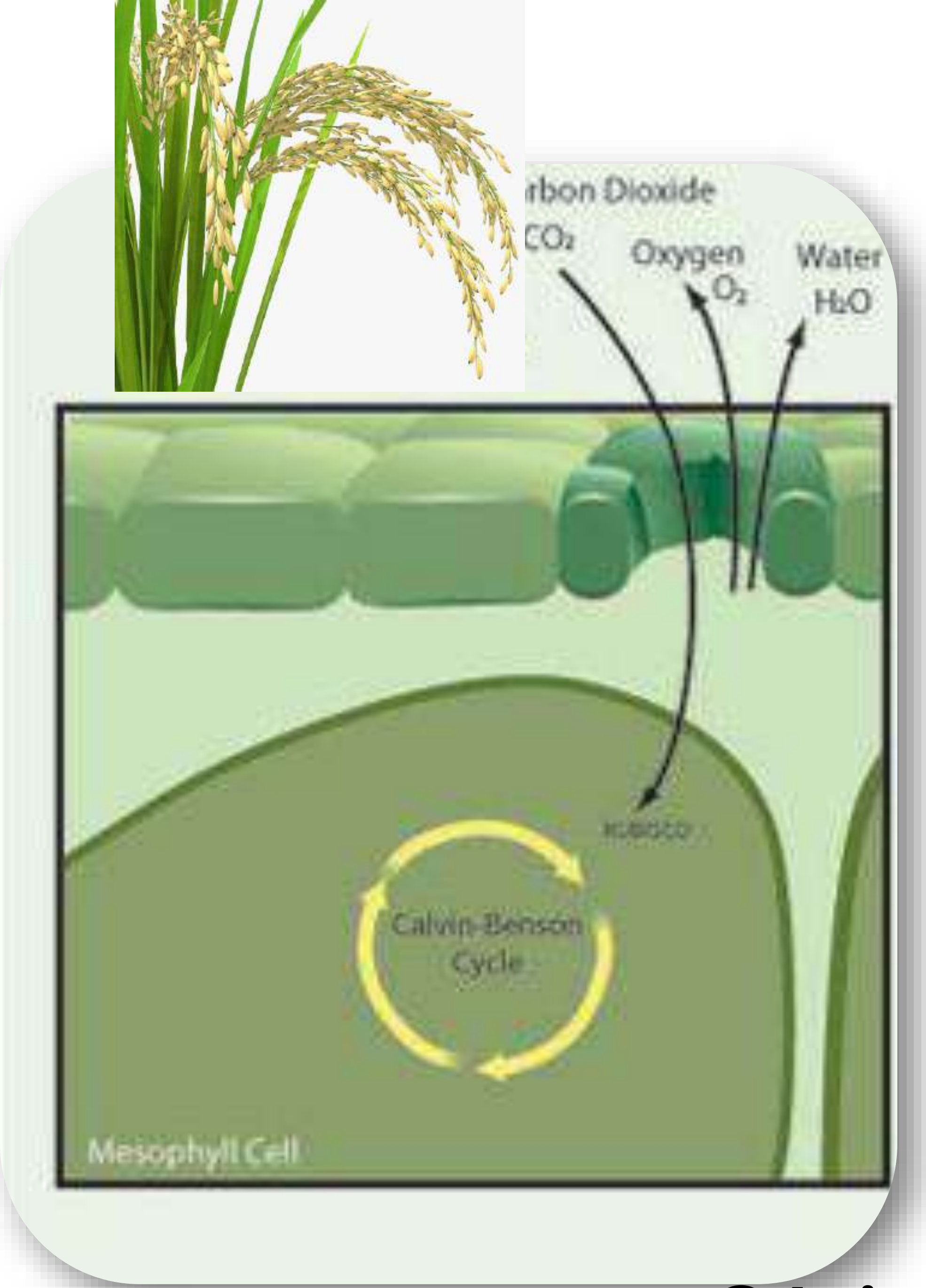
What is the maximum yield we may expect for a crop?

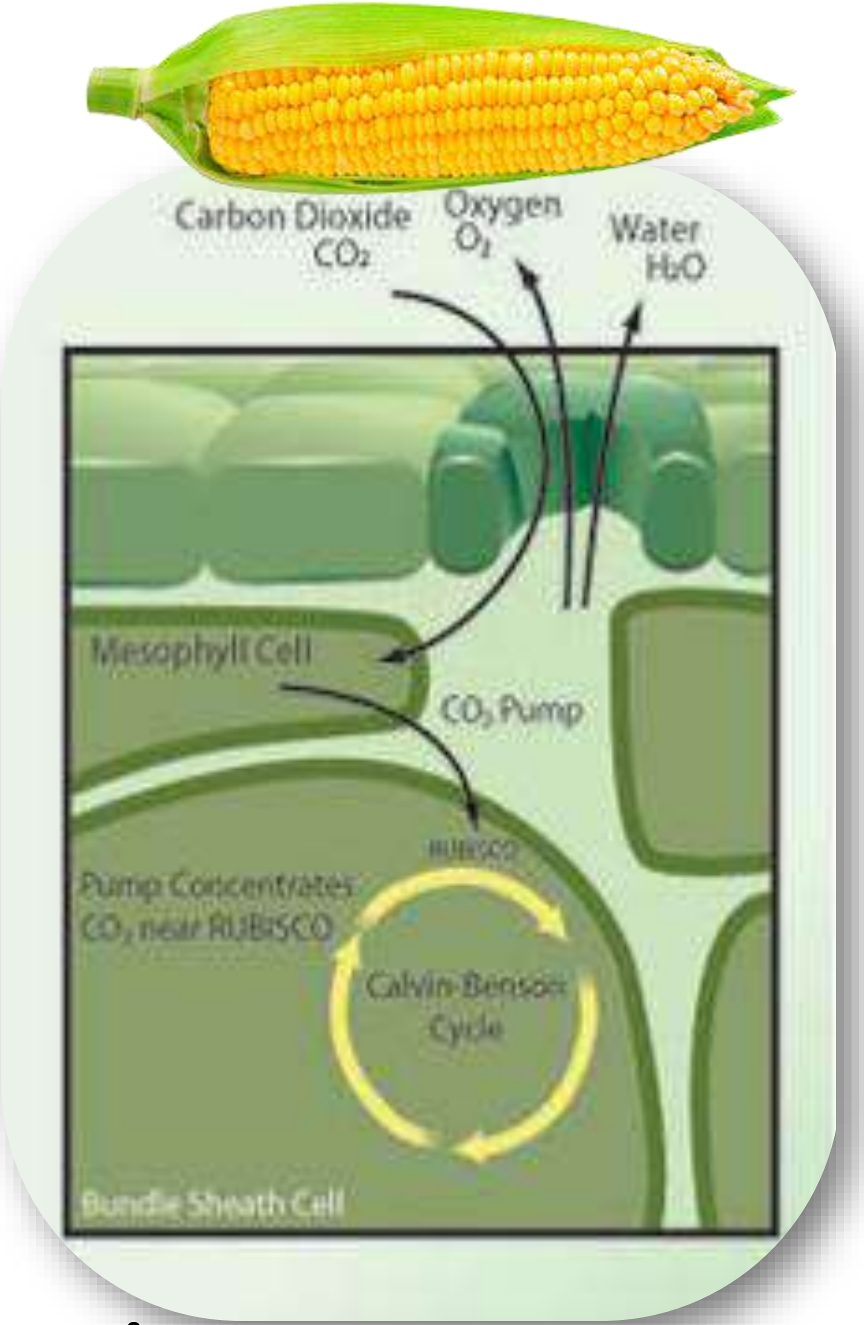
$$W_h = S \, \varepsilon_i \, \varepsilon_c \, \eta$$

YIELD POTENTIAL = TOTAL SOLAR ENERGY × INTERCEPTION EFFICIENCY × CONVERSION EFFICIENCY × PARTITIONING EFFICIENCY

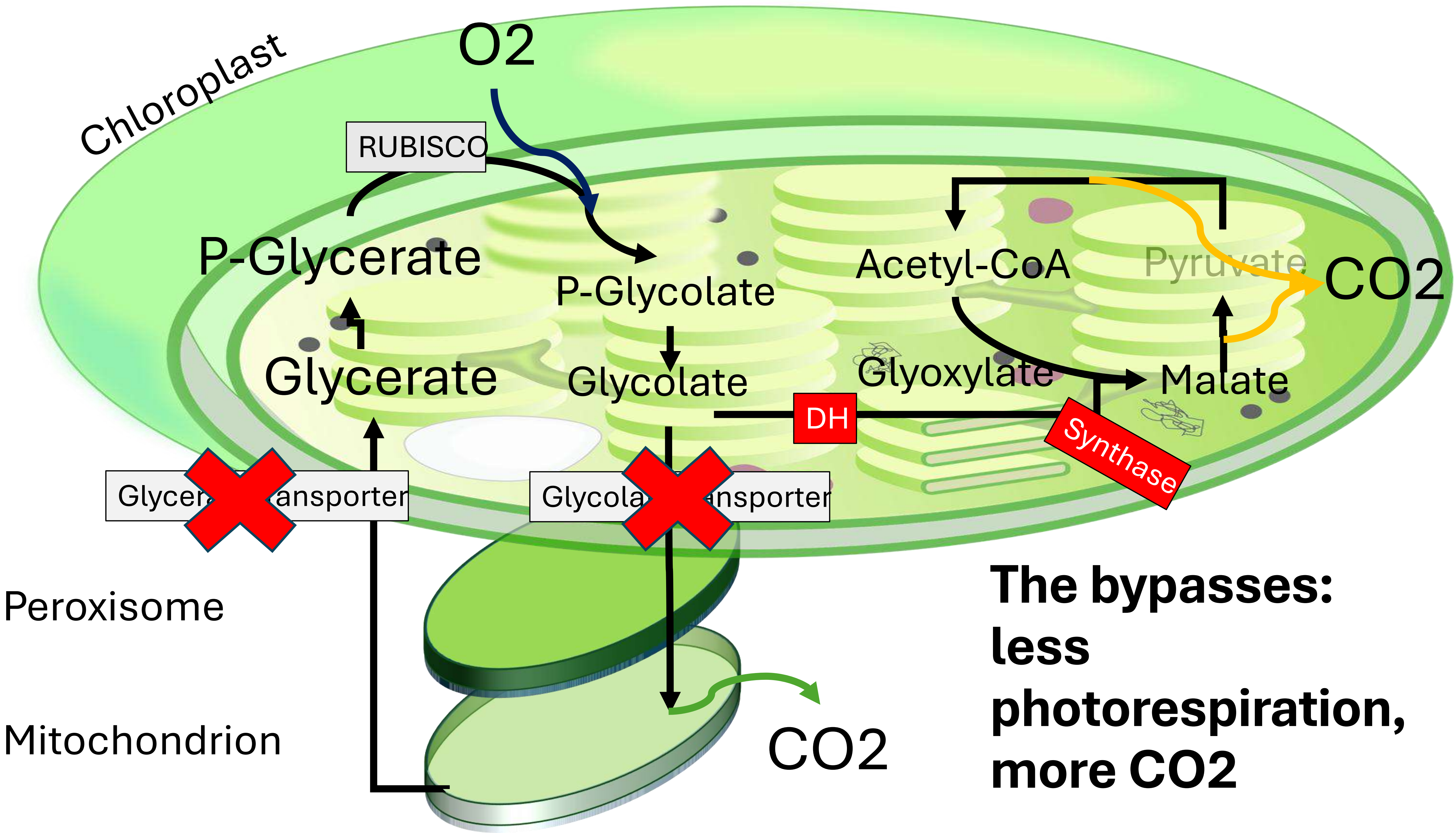
CONVERSION
EFFICIENCY


PHOTORESPIRATION
PHOTOSYNTHESIS
O_2
CO_2
RuBP
ATP +
NADPH
GP
CO_2
GP + PG
ATP +
NADPH
RUBISCO
RuBP
ATP
TP
sugar
2 × GP
ATP +
NADPH





C4 rice consortium



The bypasses: less photorespiration, more CO2

Project leader Paul South assesses the progress of engineered tobacco plants grown in real-world conditions © Claire Benjamin/RIPE Project

Engineering the ligule for increased biomass

A rice plant with broken breaks

https://www.nature.com/articles/s41587-021-00982-9

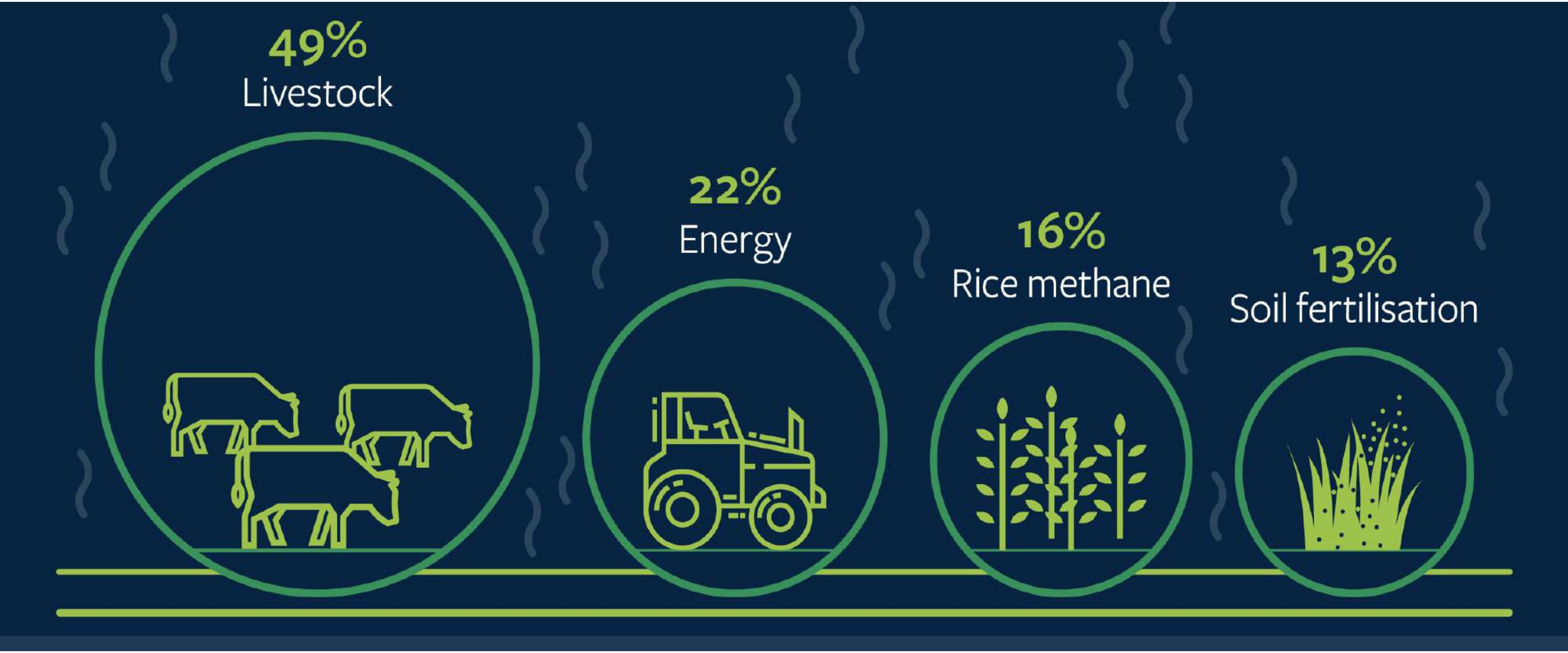
Radical solutions

- introduction of perennialism into annual crops
- de novo domestication of wild, perennial species.

Thinopyrum intermedium

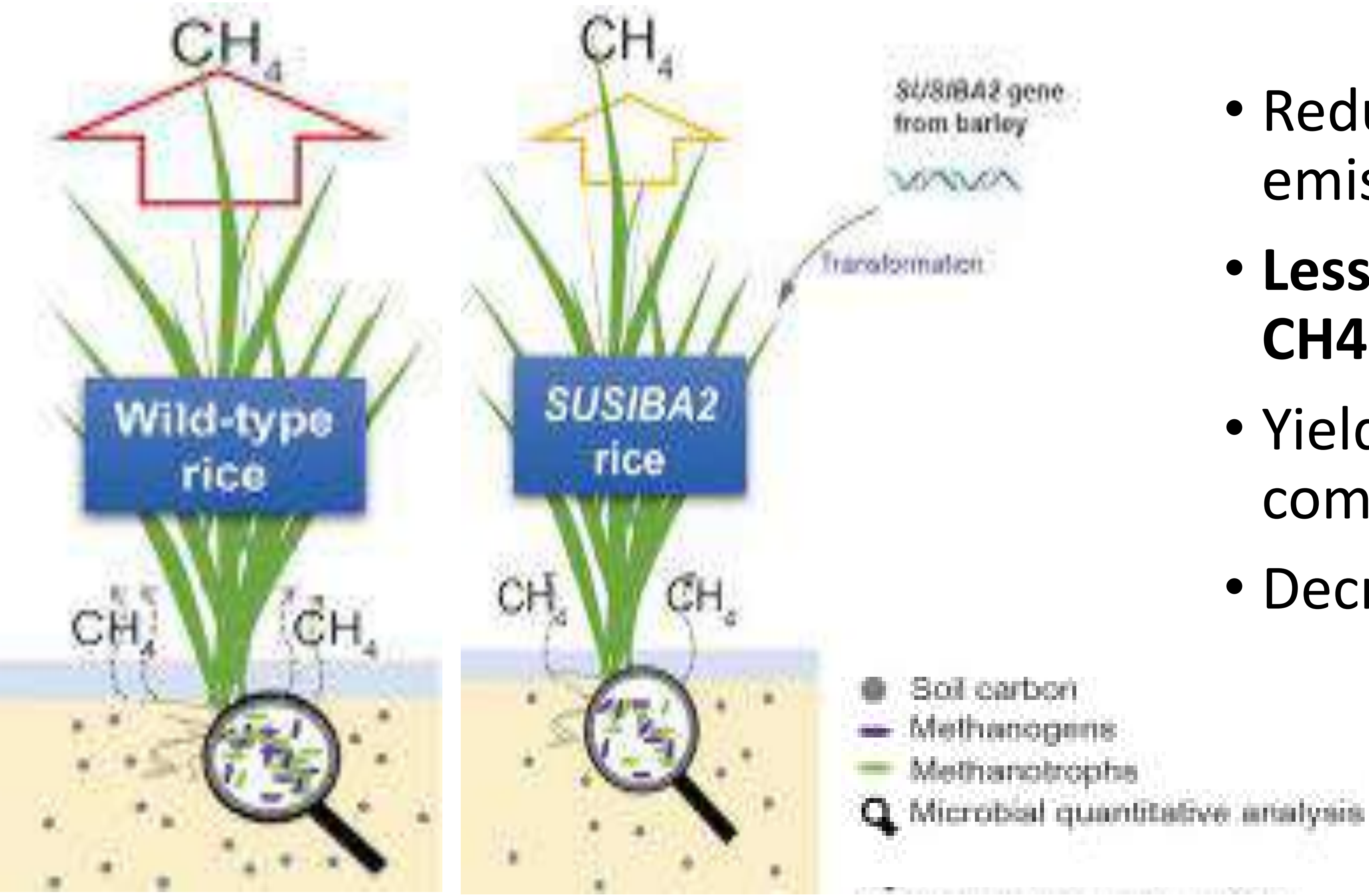

Perennial Rice 23 (PR23; 6.8 t/ha)

Methane emissions

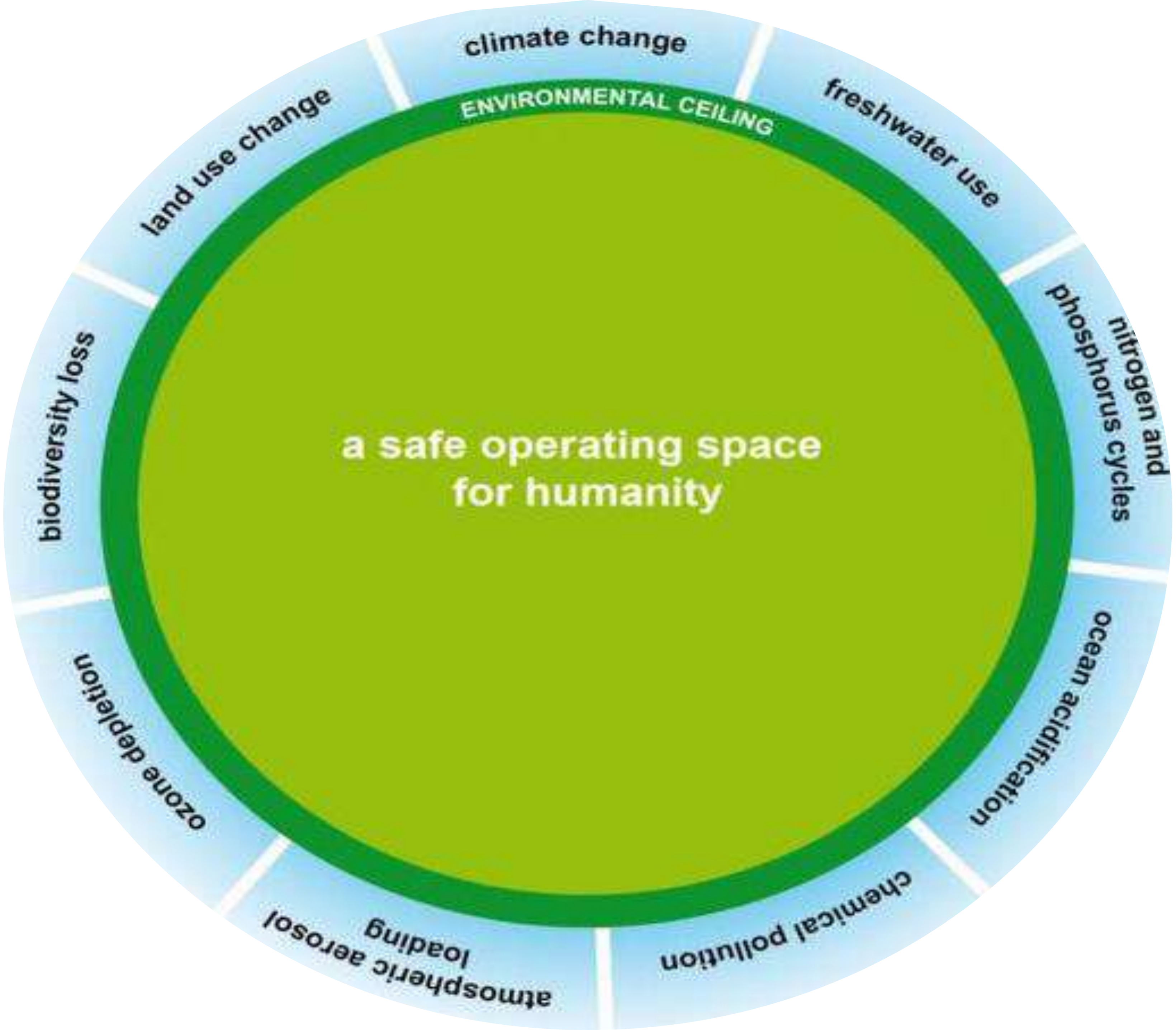


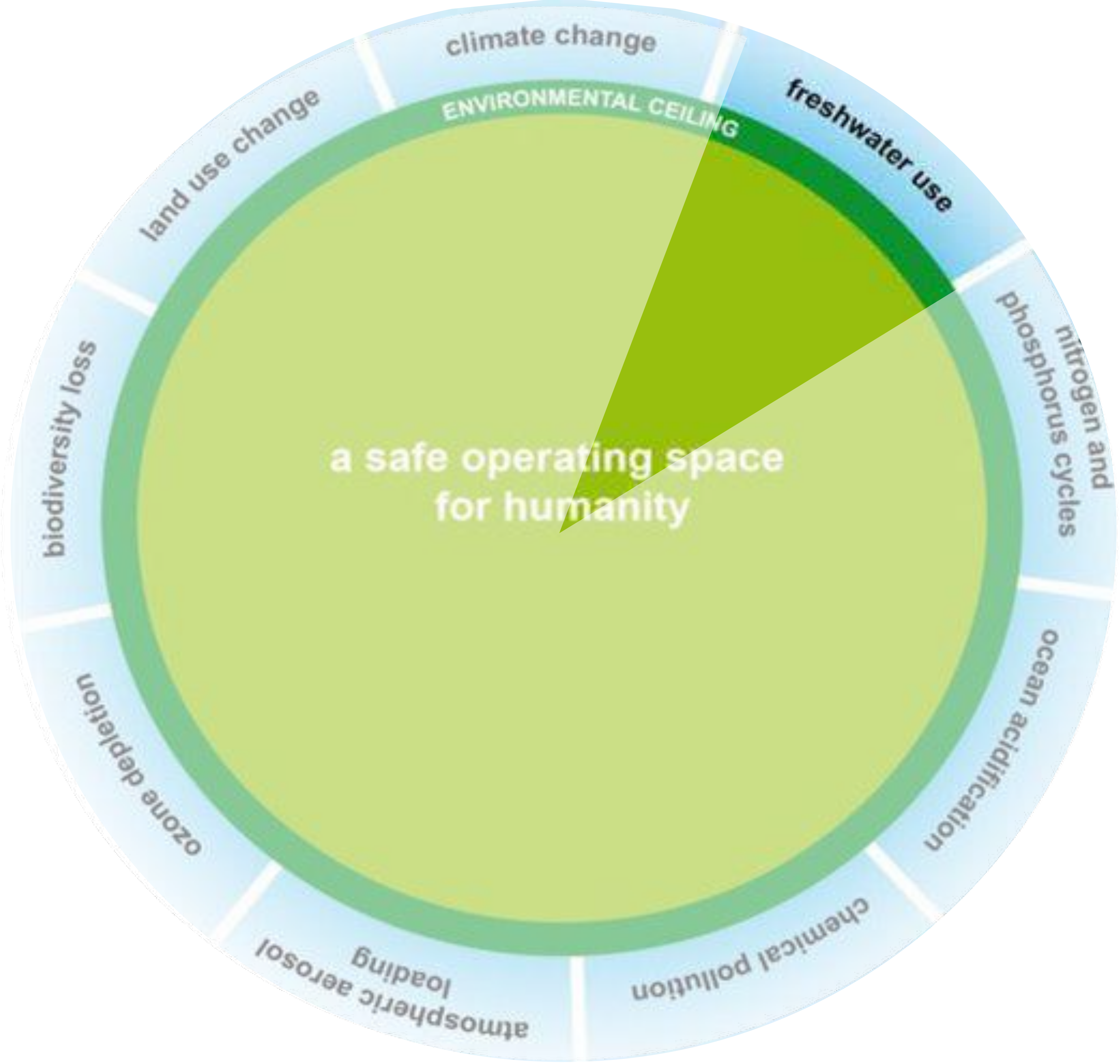
World resources report

SUSIBA rice



- Reduced total CH4 emissions
- **Less microbes involved in CH4 emissions**
- Yield traits are comparable or greater
- Decrease in soil organic C


climate change
freshwater use
nitrogen and phosphorus cycles
ocean acidification
chemical pollution
atmospheric aerosol loading
ozone depletion
biodiversity loss
land use change
ENVIRONMENTAL CEILING
a safe operating space for humanity


climate change
freshwater use
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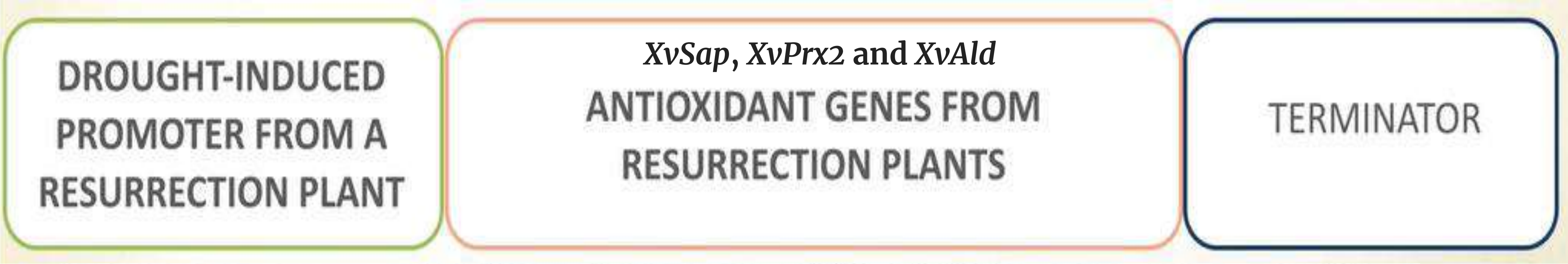
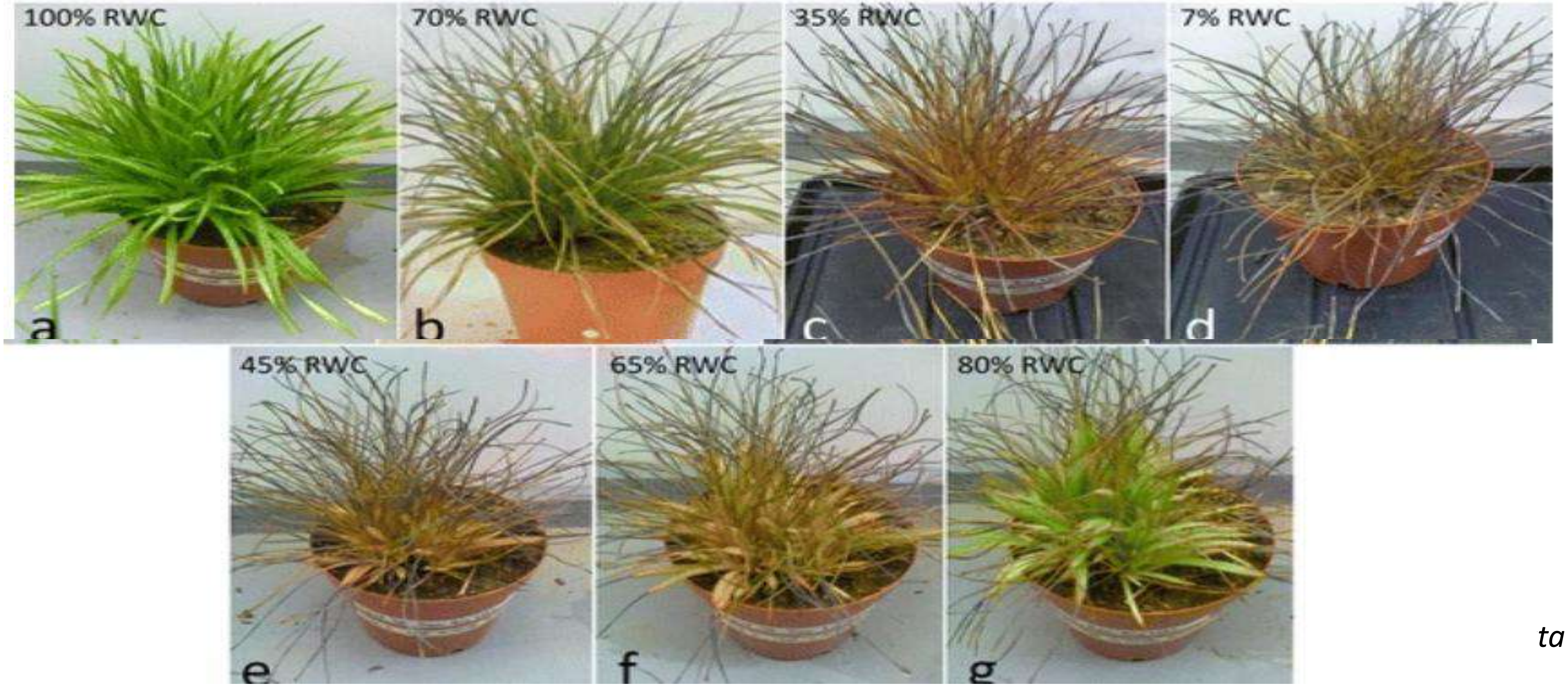
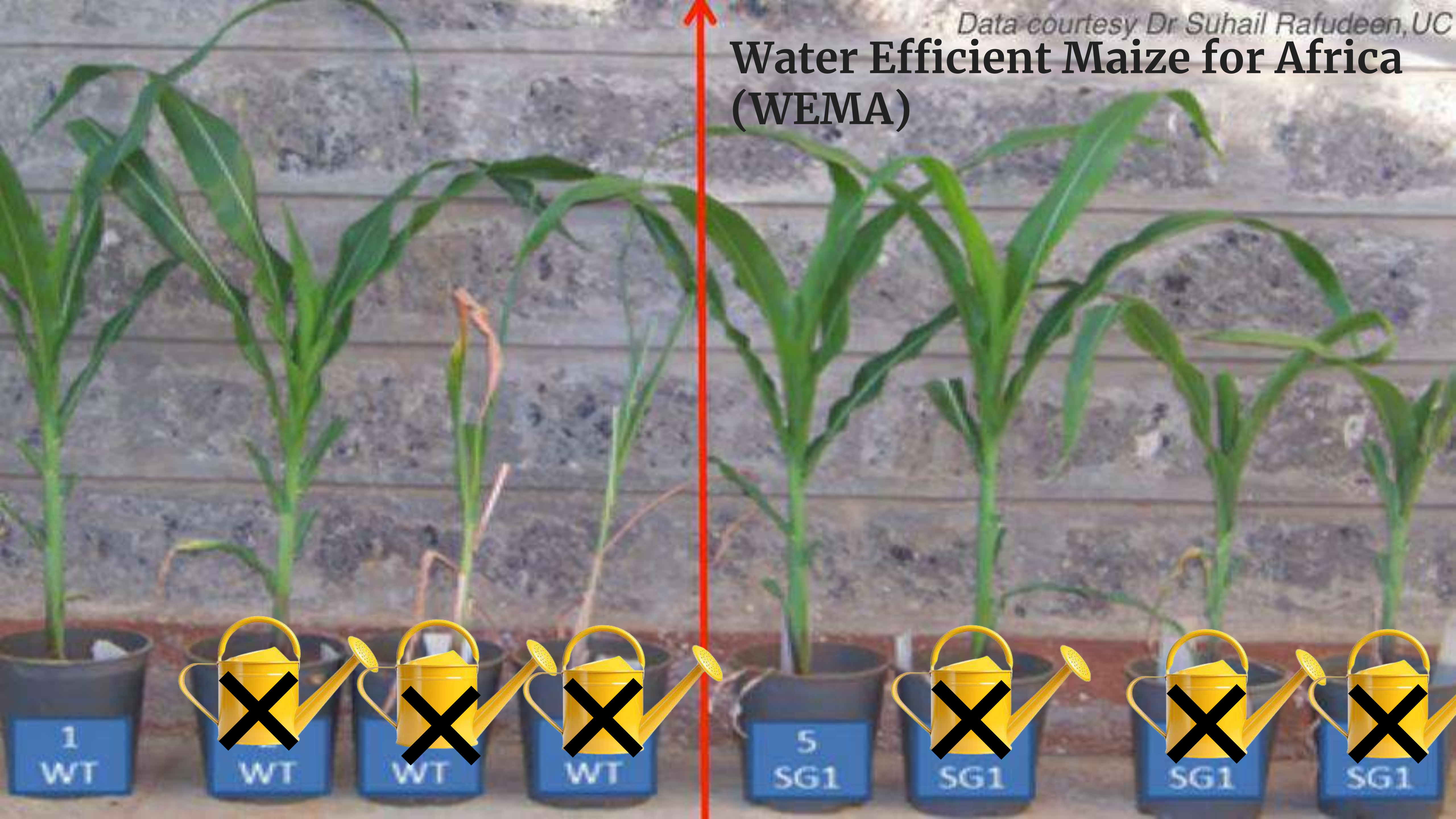
ocean acidification
chemical pollution
atmospheric aerosol loading
ozone depletion
biodiversity loss
land use change
ENVIRONMENTAL CEILING
a safe operating space for humanity


DROUGHT-INDUCED PROMOTER FROM A RESURRECTION PLANT
XvSap, *XvPrx2* and *XvAld*
ANTIOXIDANT GENES FROM RESURRECTION PLANTS
TERMINATOR


100% RWC
a
70% RWC
b
35% RWC
c
7% RWC
d
45% RWC
e
65% RWC
f
80% RWC
g

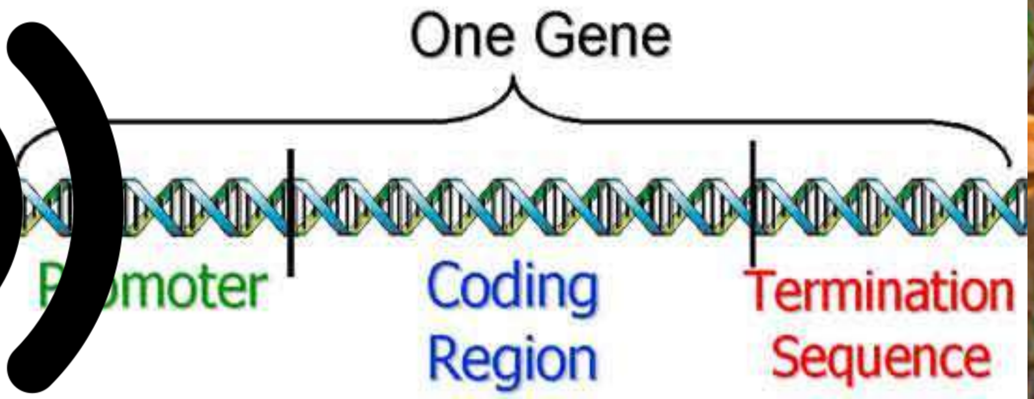
ta viscosa

Water Efficient Maize for Africa (WEMA)

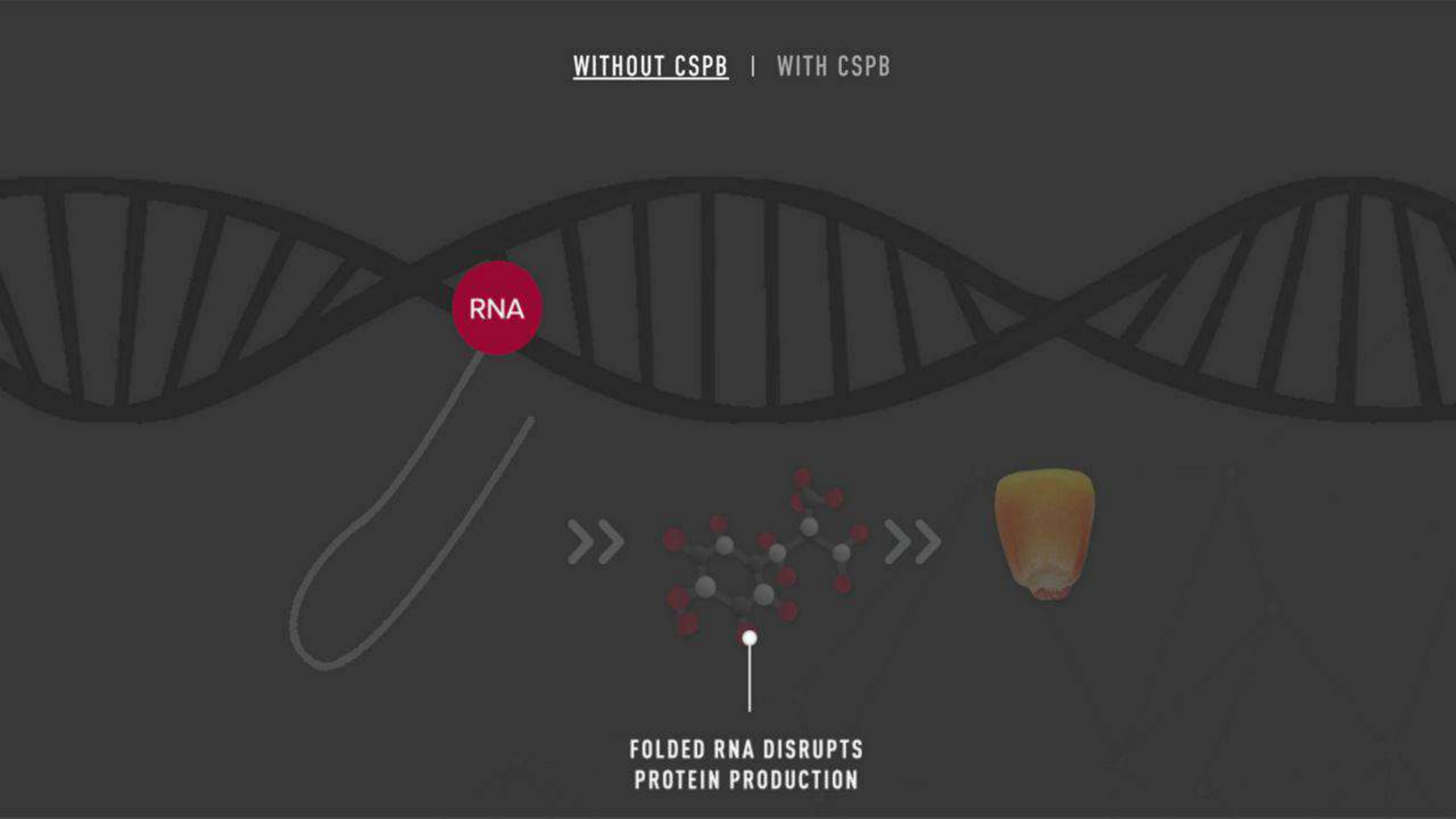


CRISPR and drought resistance

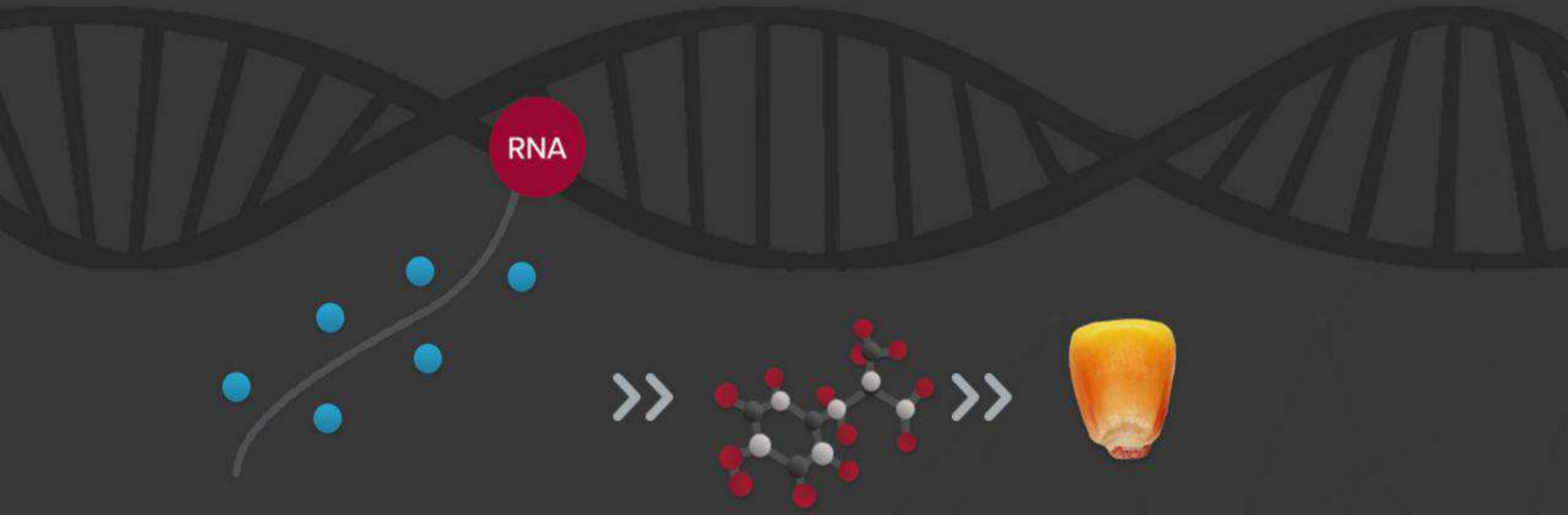
- **ARGOS8** negatively regulates ethylene response



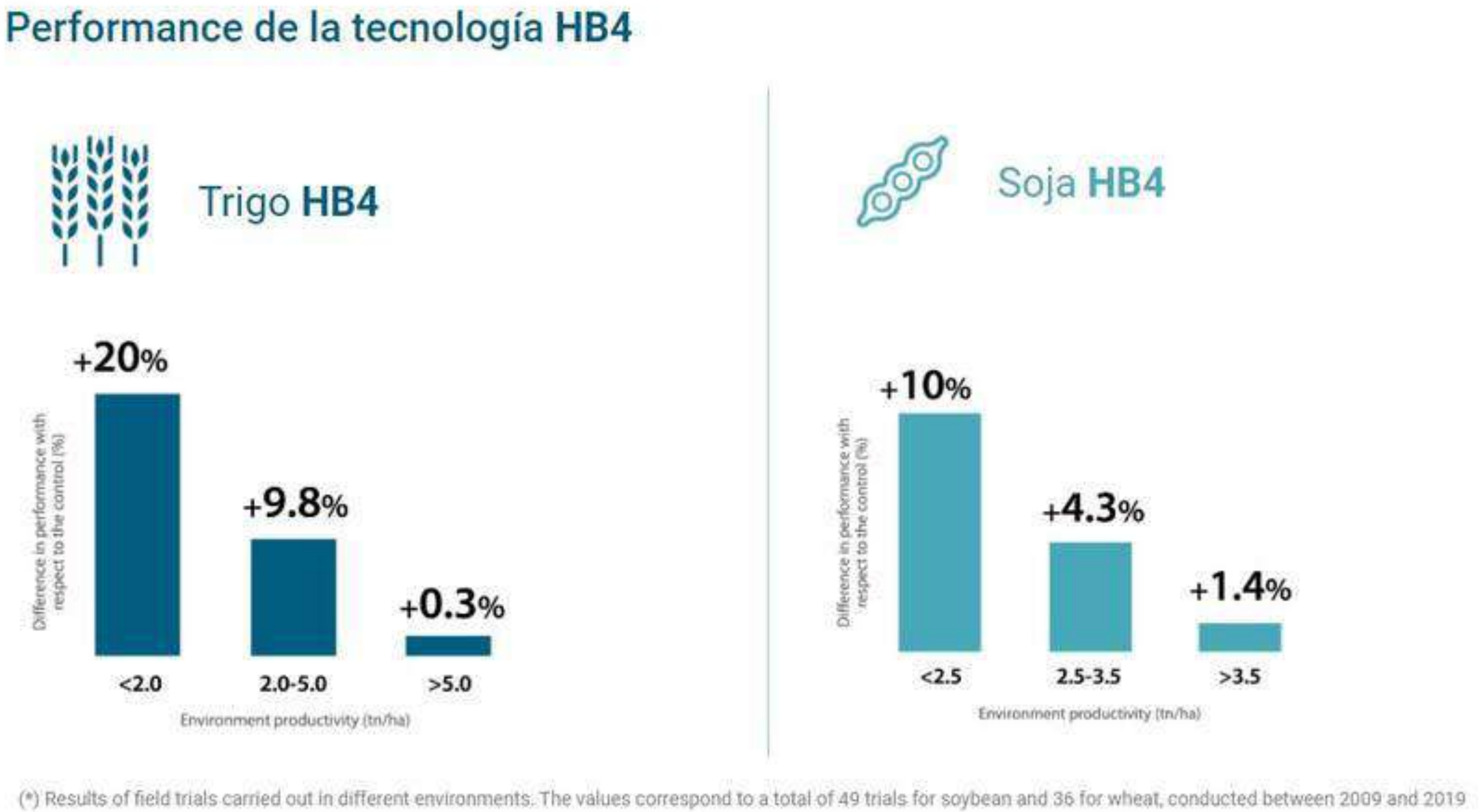
DROUGHTGARD


WITHOUT CSPB | WITH CSPB
RNA
FOLDED RNA DISRUPTS
PROTEIN PRODUCTION

WITHOUT CSPB | **WITH CSPB**

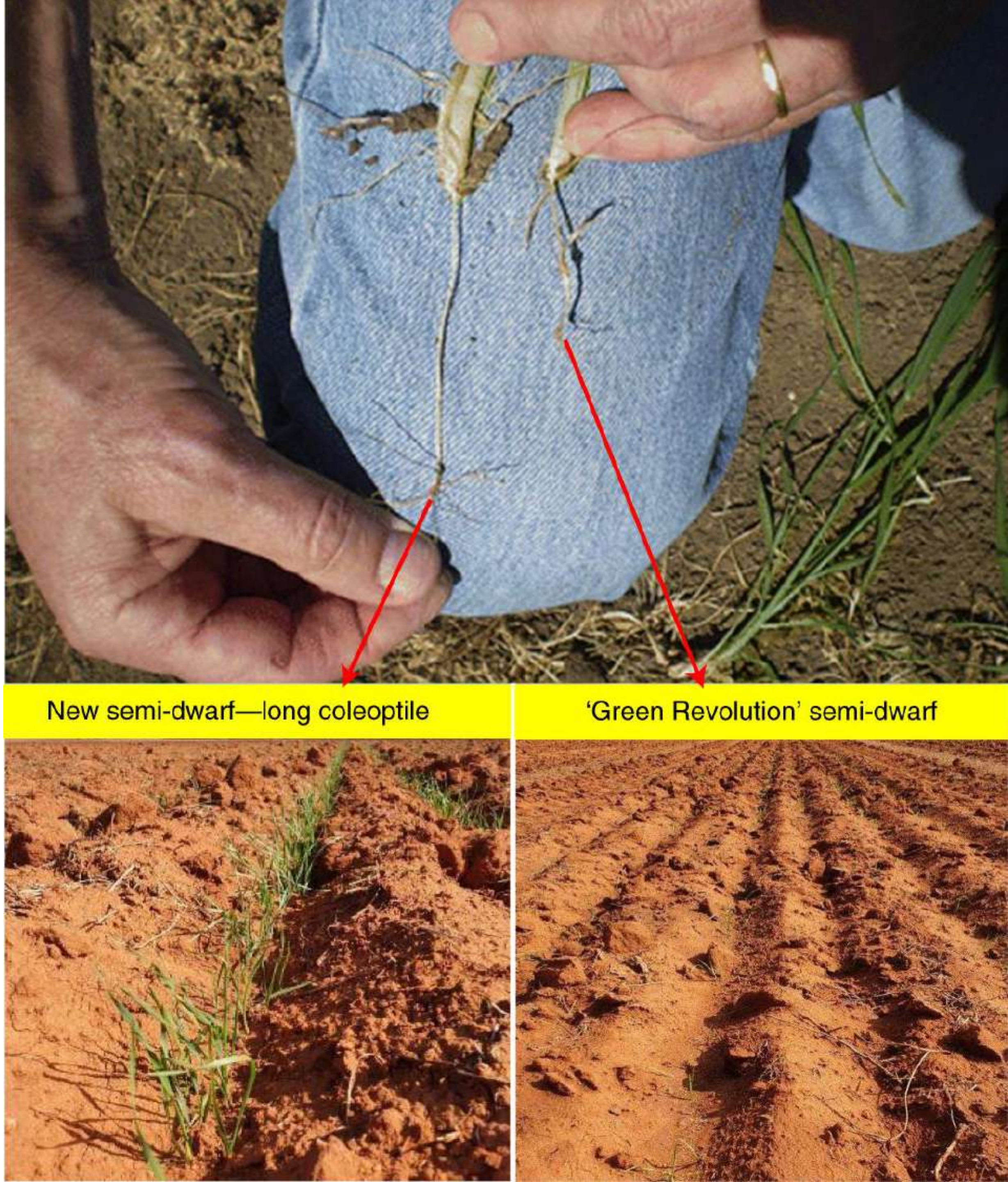


HB4



HaHB4 (**Helianthus annuus homeobox 4**)→wheat

Wheat breeding programs in Australia



Novel wheat varieties facilitate deep sowing to beat the heat of changing climates, 2022

Tolerance to salinity

"Sometimes I feel unease thinking of the quality of data that are driving breeding innovation in maize"

(Maize breeder, private company, 2024)

“It’s not a fantasy. This isn’t a thing that maybe in 25 years will be happening; it’s happening right now.”

J. Doudna on Editing applied to plants, 2024

Some references

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That's all Folks!