

Integrated Omics Approach for Crop Improvement

Yedomon Ange Bovys Zoclanclounon, PhD

 @angeomics  angez9914@gmail.com

July 13, 2023

Content



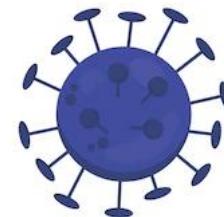
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1 | A little bit of context



A little bit of context



SEARCH

MICROSITES

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WHERE WE WORK

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International Livestock Research Institute

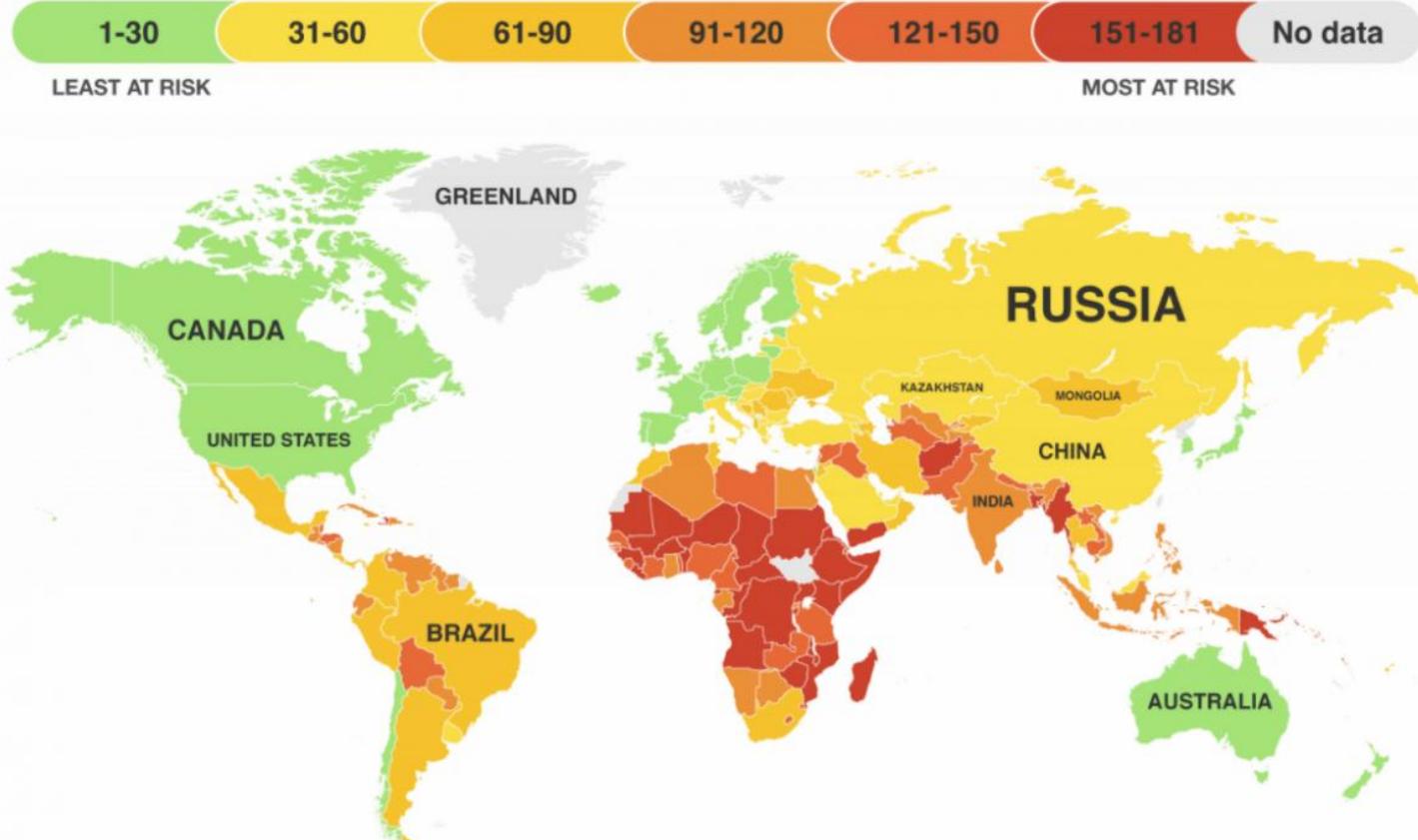
▶ NEWS & EVENTS > NEWS

Climate change in Africa: What will it mean for agriculture and food security?

Posted on 28 February, 2022 by Elliot Carleton

©ILRI 2022 | <https://tinyurl.com/mpvejuuf>

A little bit of context



A little bit of context



BOOK

West African agriculture and climate change: A comprehensive analysis

BY ABDULAI JALLOH, ED., GERALD C. NELSON, ED., TIMOTHY S. THOMAS, ED., ROBERT ZOUGMORÉ, ED. AND HAROLD ROY-MACAULEY, ED.

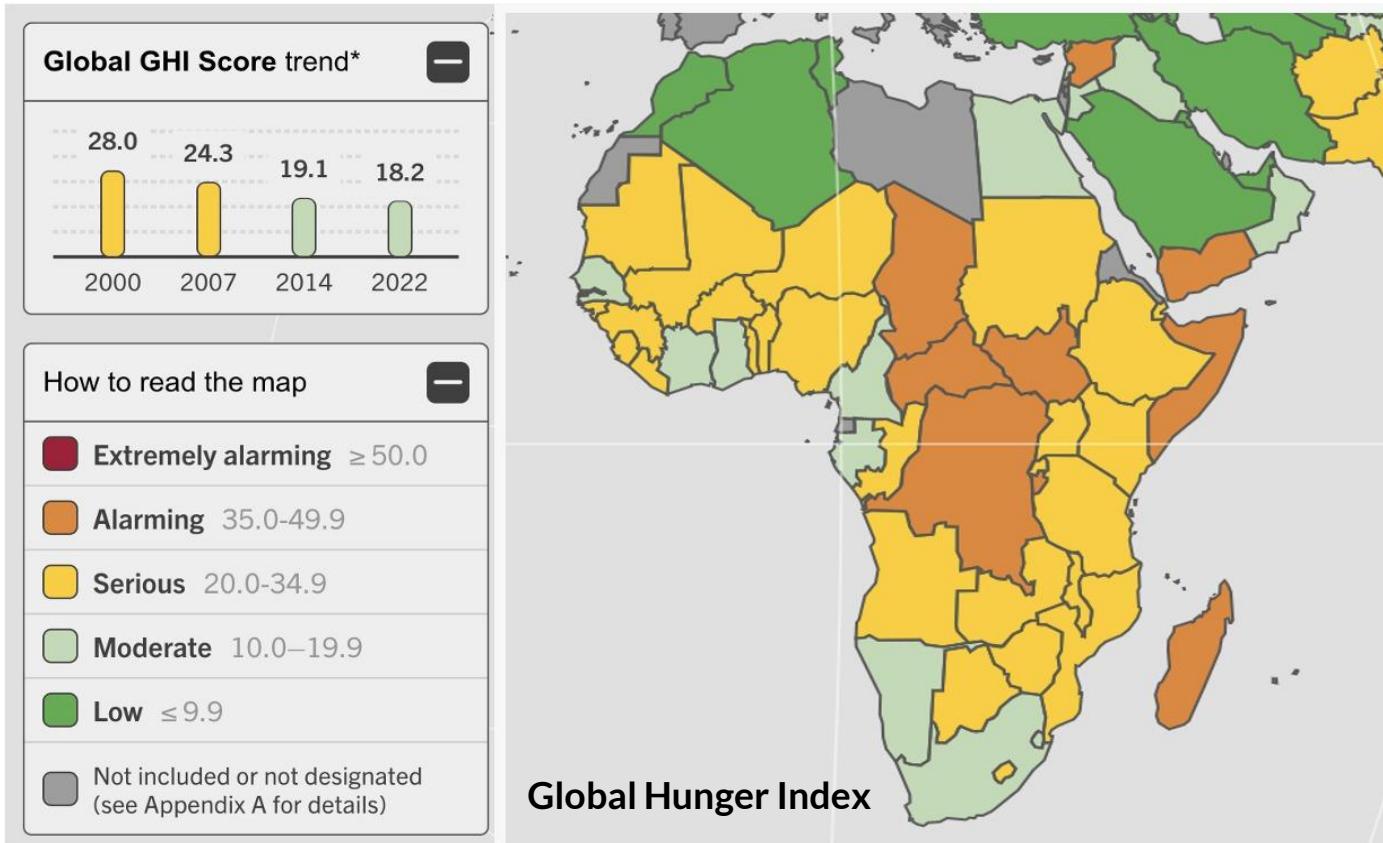
IFPRI RESEARCH MONOGRAPH | 2013 | PAGES: 408

PUBLISHER(S): INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE (IFPRI)

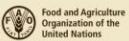
DOI : <http://dx.doi.org/10.2499/9780896292048>

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A little bit of context



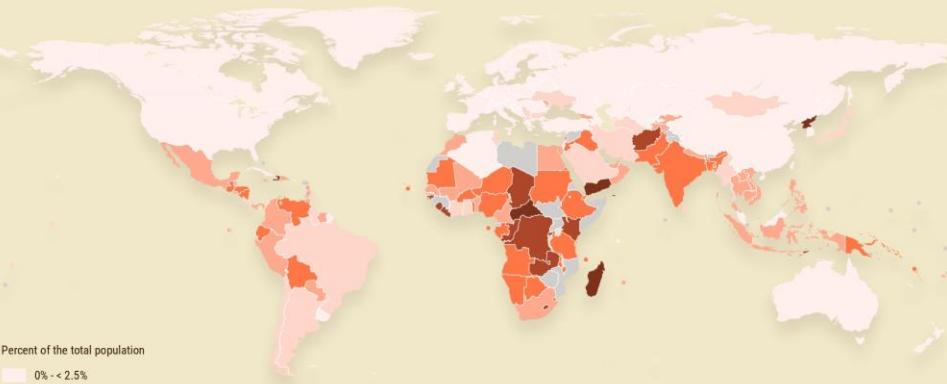
A little bit of context



FAO HUNGER MAP

Prevalence of Undernourishment 2019-2021
SDG Indicator 2.1.1

SUSTAINABLE
DEVELOPMENT
GOALS



Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. *The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable*. Data are available on FAOSTAT. (<https://www.fao.org/faostat/en/Data/S>)

The boundaries and names shown and the designations used on these maps do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

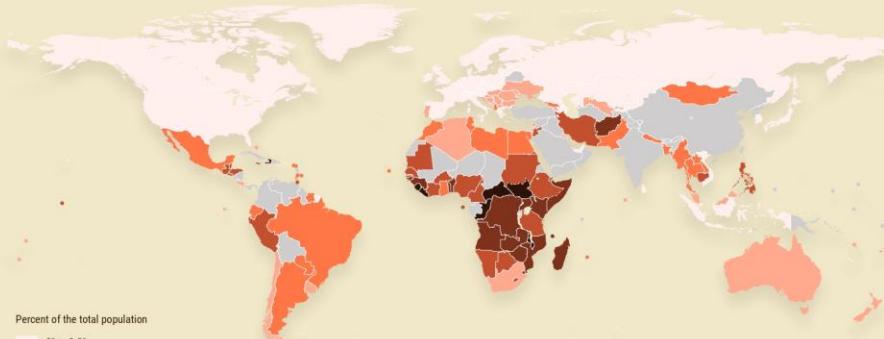
Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.



FAO FOOD INSECURITY MAP

Prevalence of Moderate or Severe Food Insecurity 2019-2021
SDG Indicator 2.1.2

SUSTAINABLE
DEVELOPMENT
GOALS



Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. *The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable*. Data are available on FAOSTAT. (<https://www.fao.org/faostat/en/Data/S>)

The boundaries and names shown and the designations used on these maps do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

A little bit of context

Drought stress



Quality nutrient rich food



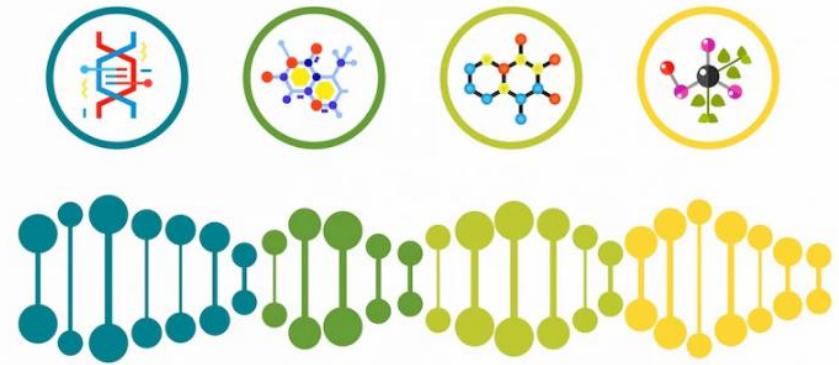
©USGS <https://tinyurl.com/2zckja24>



Urgent to develop resistant crops with regards to biotic and abiotic factors
Highly nutritive quality crops



2 | Multi Omics Core Concept



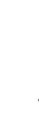
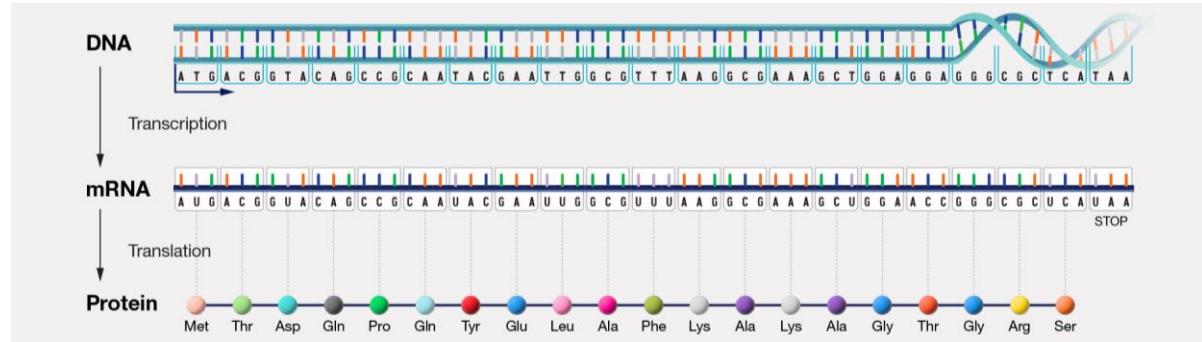
Multi Omics Core Concept

Central Dogma of Molecular Biology

Francis Crick



© <https://tinyurl.com/2jkb574e>

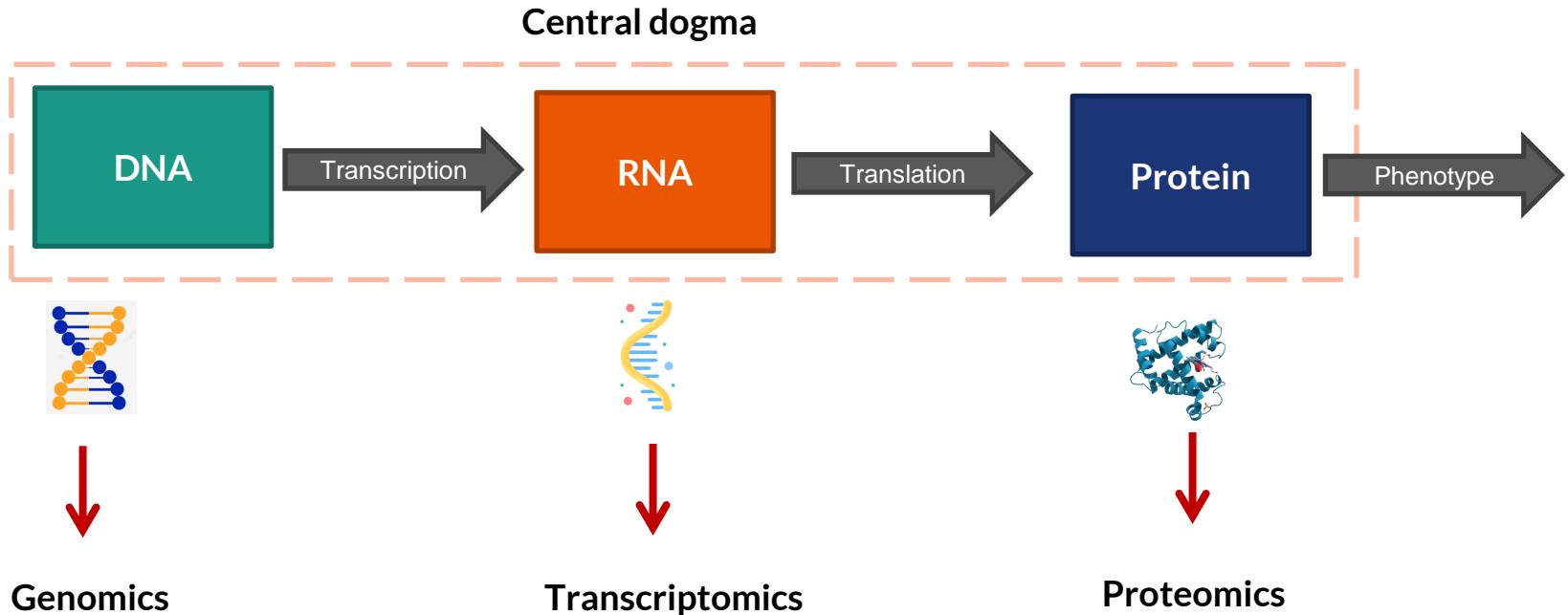


Trait (or Phenotype)

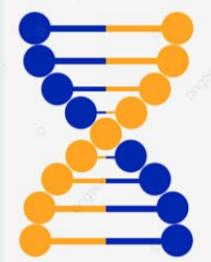


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Multi Omics Core Concept



Genomics



- ❑ DNA Sequencing
- ❑ Genetic profiling
- ❑ Structural variation detection
- ❑ Structure and functional analysis of genome
- ❑ Genetic mapping (GWAS, QTL, ...)



illumina



NovaSeq X DNBSEQ-T7

MGI



Element
Biosciences



AVITI

Transcriptomics

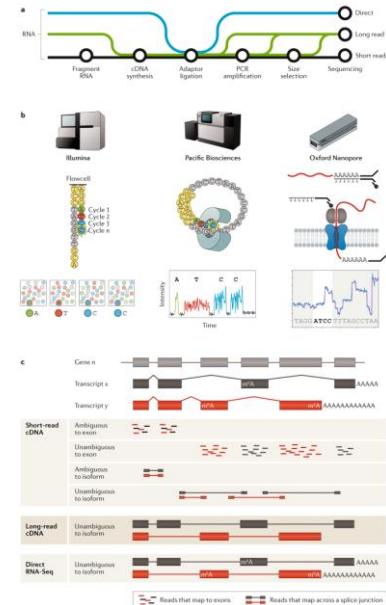


❑ RNA Sequencing

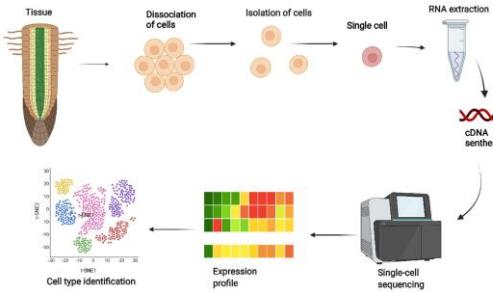
❑ Gene expression profiling

❑ Transcriptional regulation

❑ Splicing



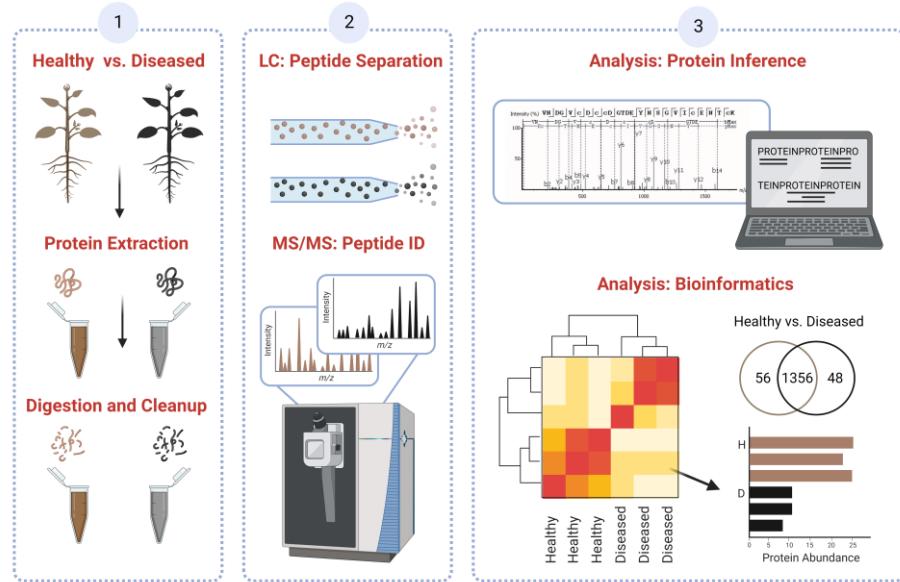
Single-cell RNA sequencing



©Bawa et al. (2022)

©Stark et al. (2019)

Proteomics



© UGUELPH

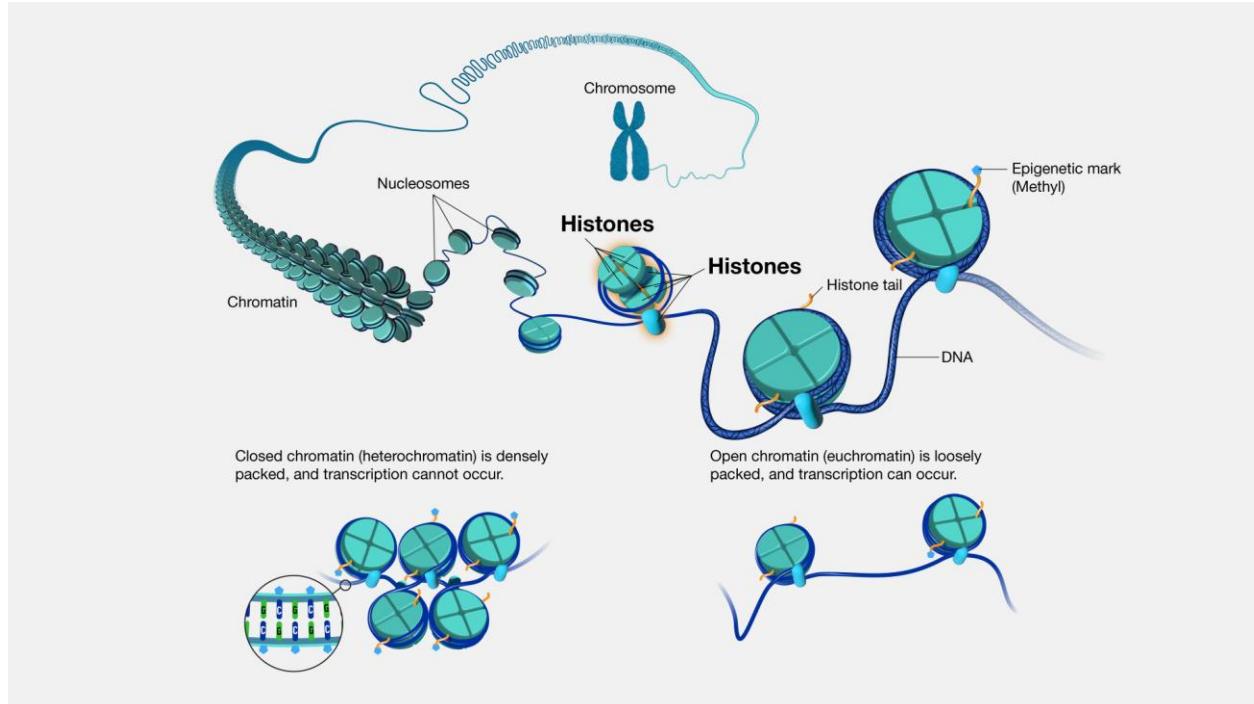
Quantitative proteomics

- ❑ Liquid-chromatography (LC)-based separation
- ❑ High-resolution mass spectrometry (MS)
- ❑ Identify proteins from biological samples
- ❑ Quantify relative changes in protein expression

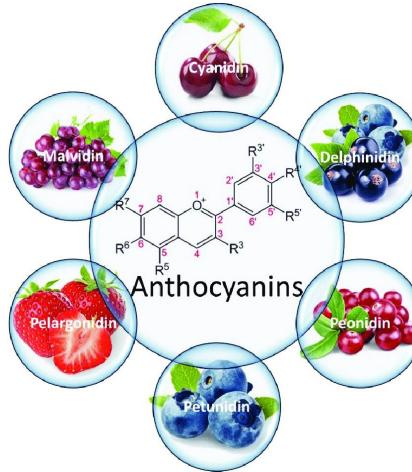
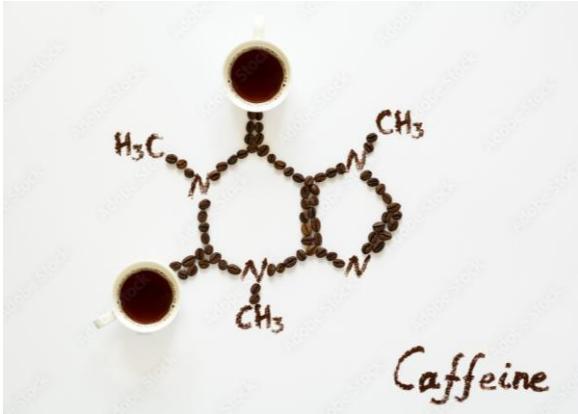
Multi Omics Core Concept

Epigenetics also influence gene expression

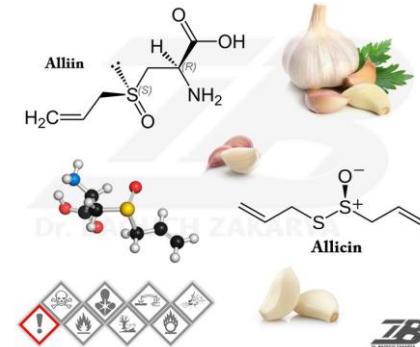
- Acetylation
- Methylation
- Phosphorylation
- Ubiquitination



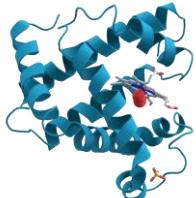
Multi Omics Core Concept



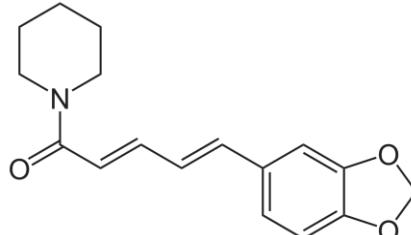
Alliin | C₆H₁₁NO₃
Garlic.



Plant metabolites | Metabolomics



linked

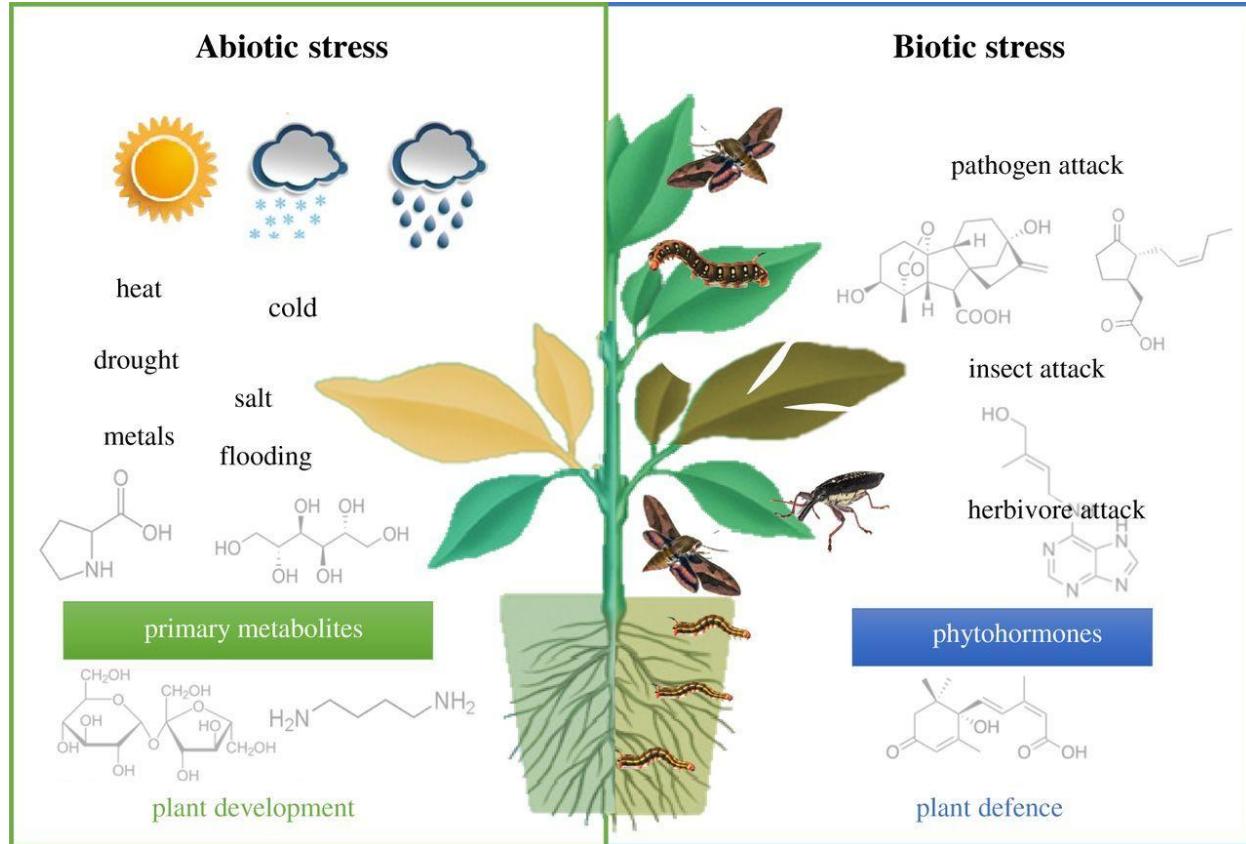


Piperine

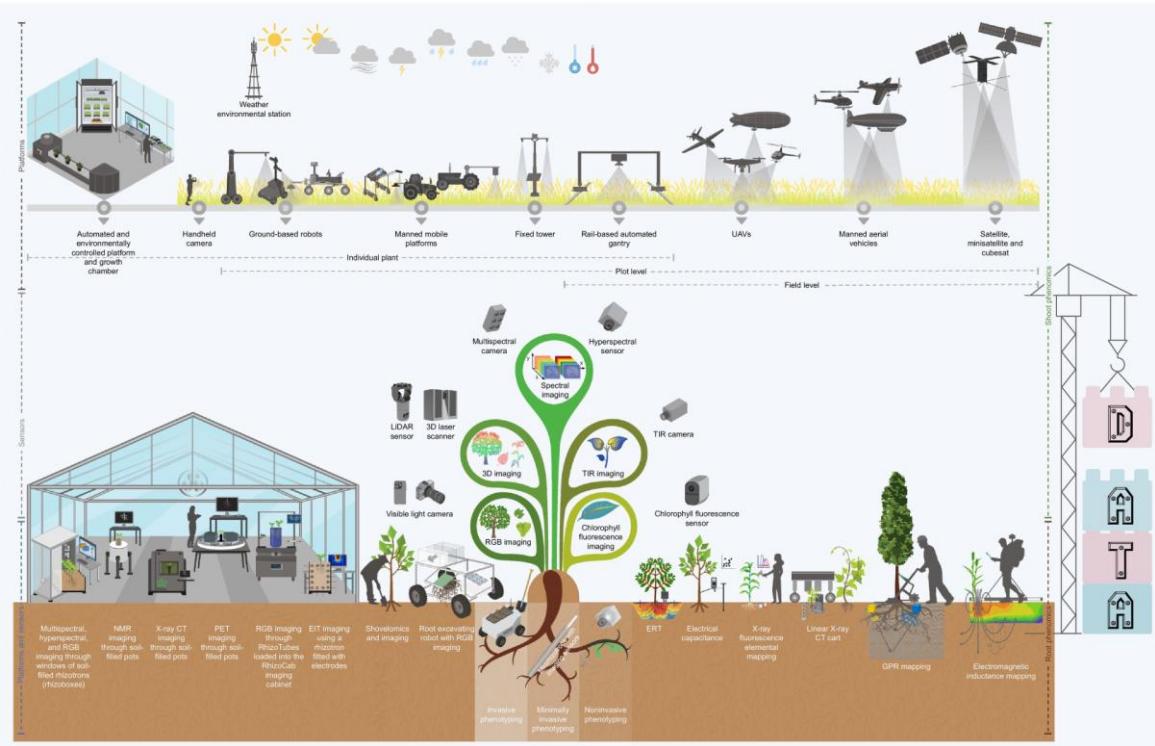


Black pepper

Multi Omics Core Concept



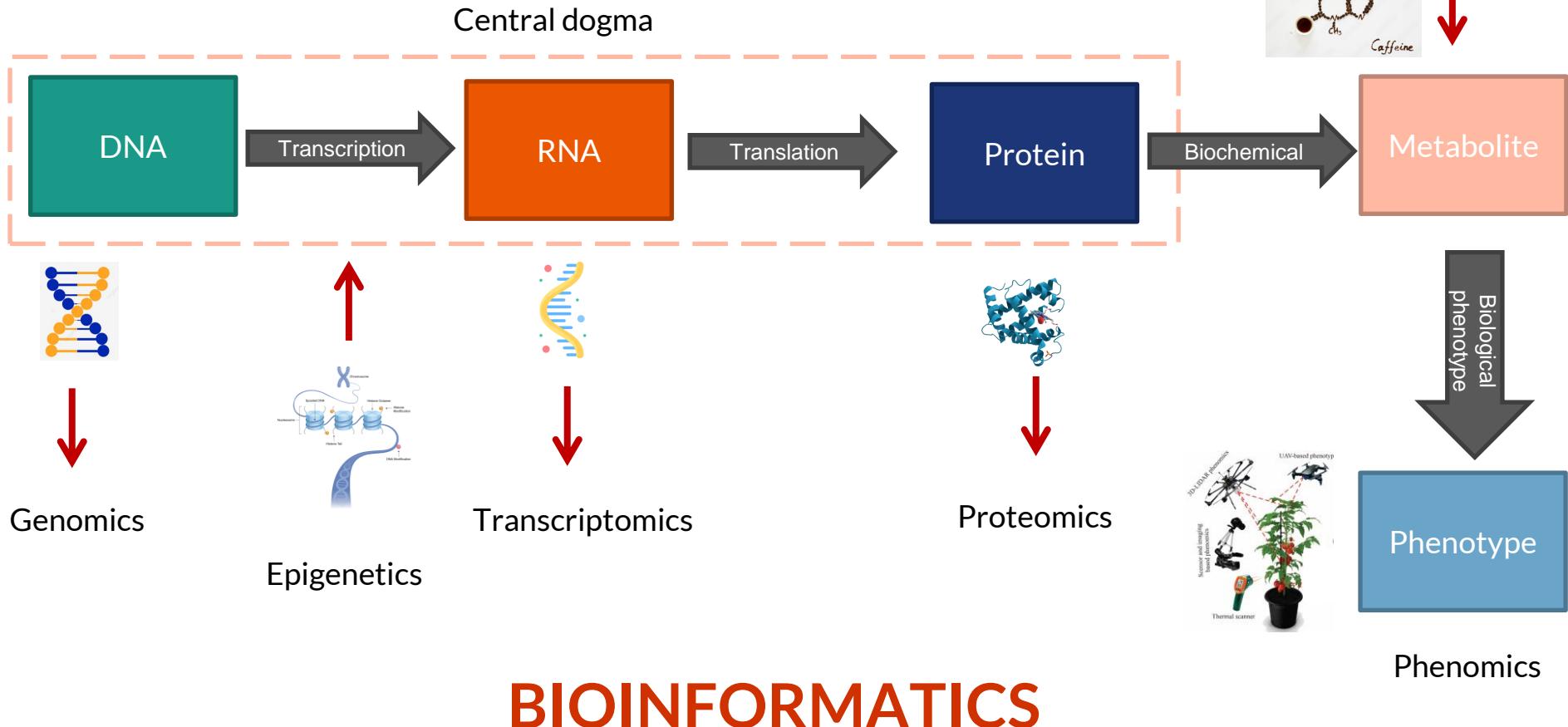
Multi Omics Core Concept



© Harfouche et al. (2023)



Multi Omics Core Concept



How can we integrate multiple omics for crop improvement?

3 | Case Study



Sesame
Sesamum indicum



Sesame world trade

- 2014 USD 2500 per tonnes
- 2017 USD 2300 million Import
- 2017 USD 2100 million Export
- 2020 USD 373.3 million (Lignans)



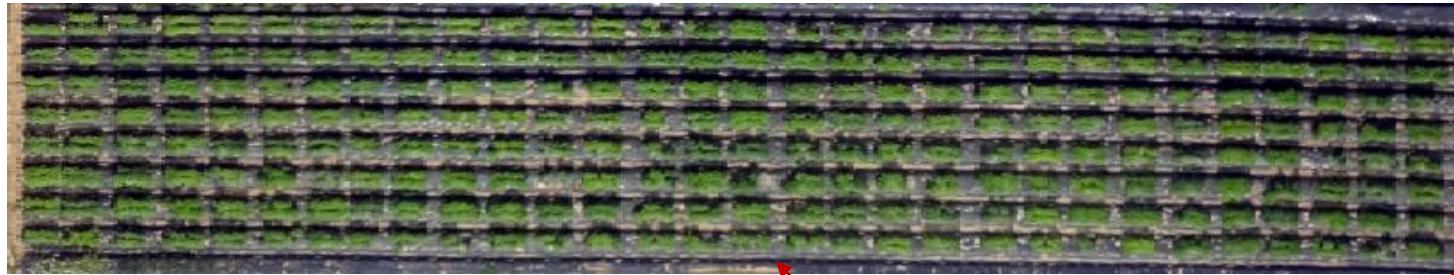
Step 1: Know your genetic resources

Where ? Origin | Native? | Introduced?

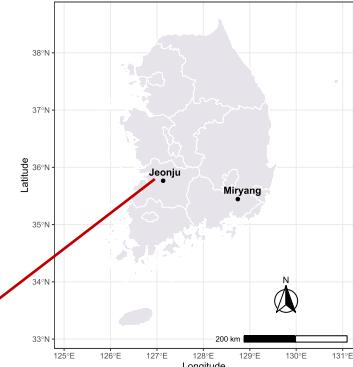
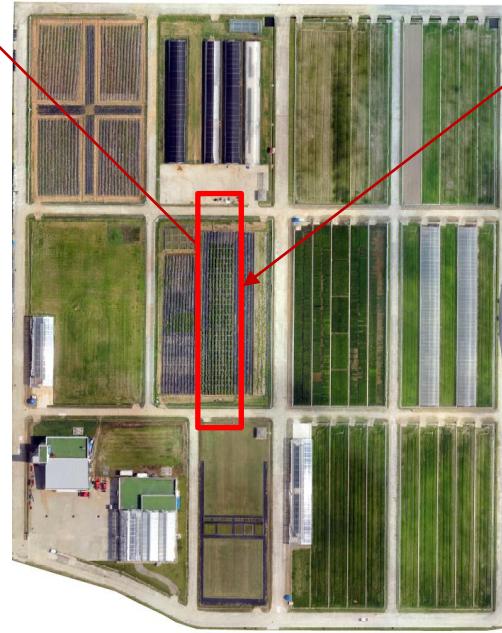


What ?	Wild Landrace Cultivar Variety	Pedigree Characteristic Trait Core collection Mapping population (RILS, MAGIC, ...)
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Step 1: Know your genetic resources



- Federer Augmented Block Design
 - Checks replicated 8 times

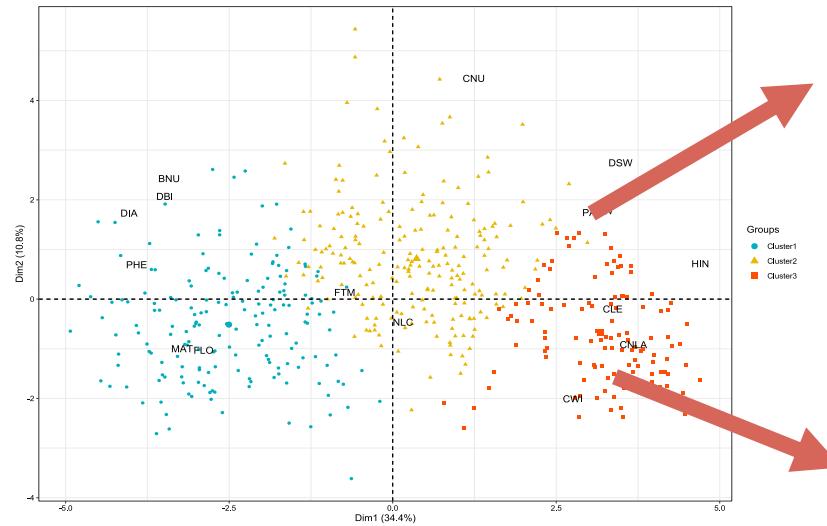
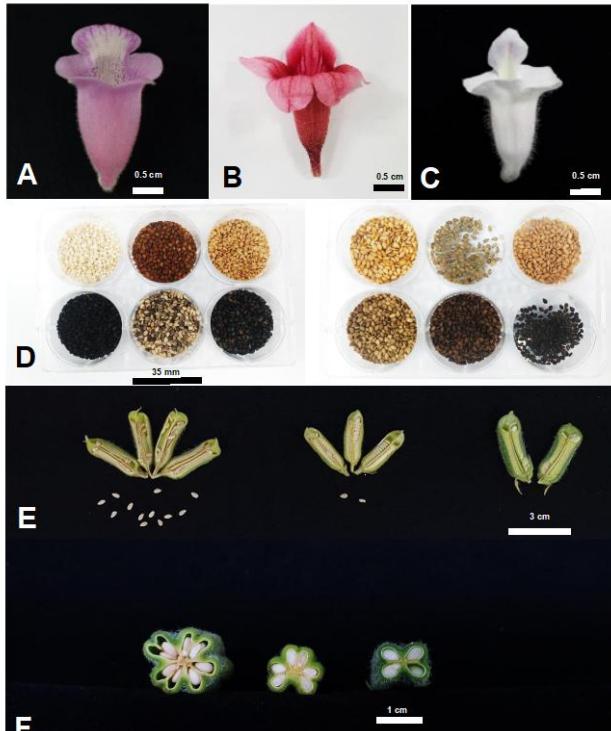


Total: 506 ccessions

Total: 24 traits

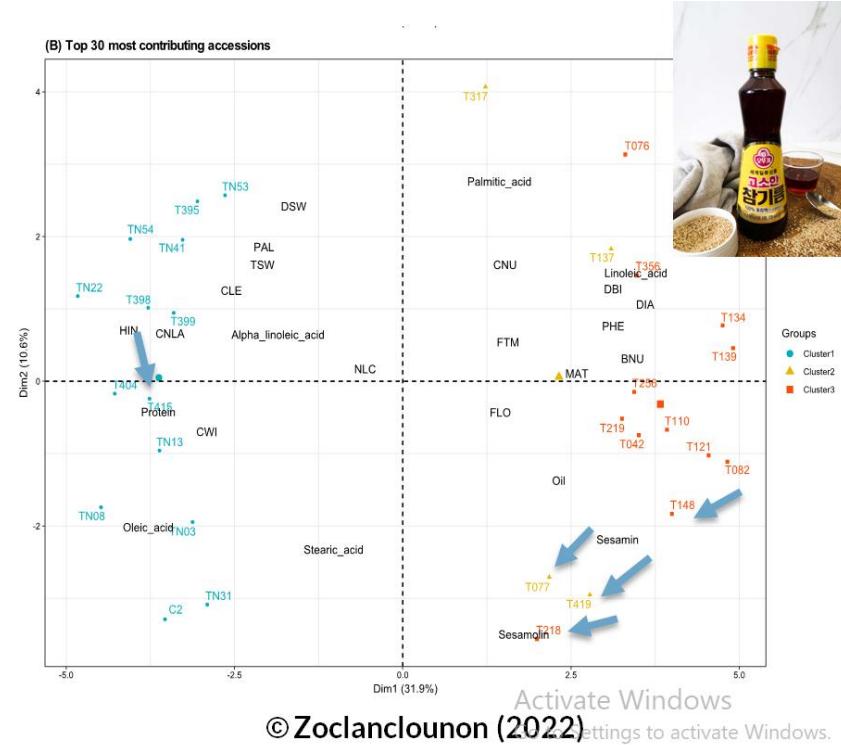
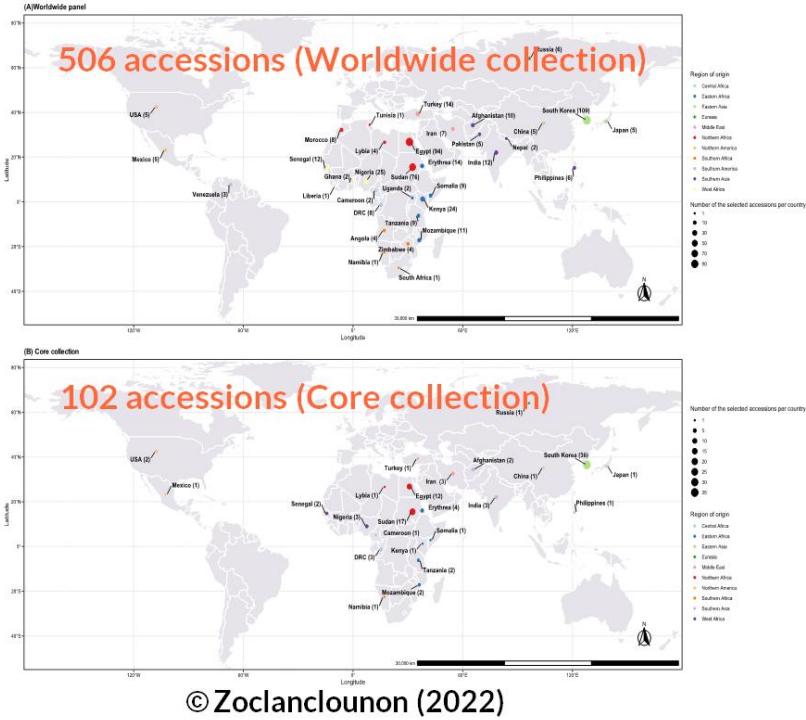
- Agronomic (18)
- Seed quality (06)
 - oil
 - fatty acids
 - sesamin
 - sesamolin

Step 1: Know your genetic resources



Eastern and Northern Africa also contribute to the high yield accessions in the cluster 3

Step 1: Know your genetic resources



Crude Oil - Fatty acids [Palmitic, Stearic, Oleic, Linoleic, alpha linoleic] – TN03 & T415 Lignan [sesamin, sesamolin] - T218, T077, T419, & T148

Step 1: Know your genetic resources

Which omics concept have we covered so far?

Their utility

Array-based: Affymetrix axiom – Affimetrix GeneChip – Illumina Infinium Beadchip

Genotyping

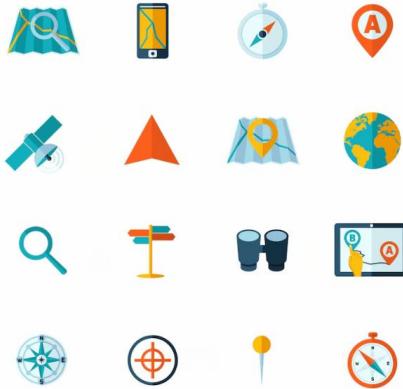
NGS-based: GBS – DArT-seq – RAD-seq – ddRAD – REST-Seq

Whole genome sequencing – Pangenomes – Structural Variations

Trait mapping: GWAS – QTL detection

Step 1: Know your genetic resources

Find a gene?
Where?





Step 2: Generate genomic resources

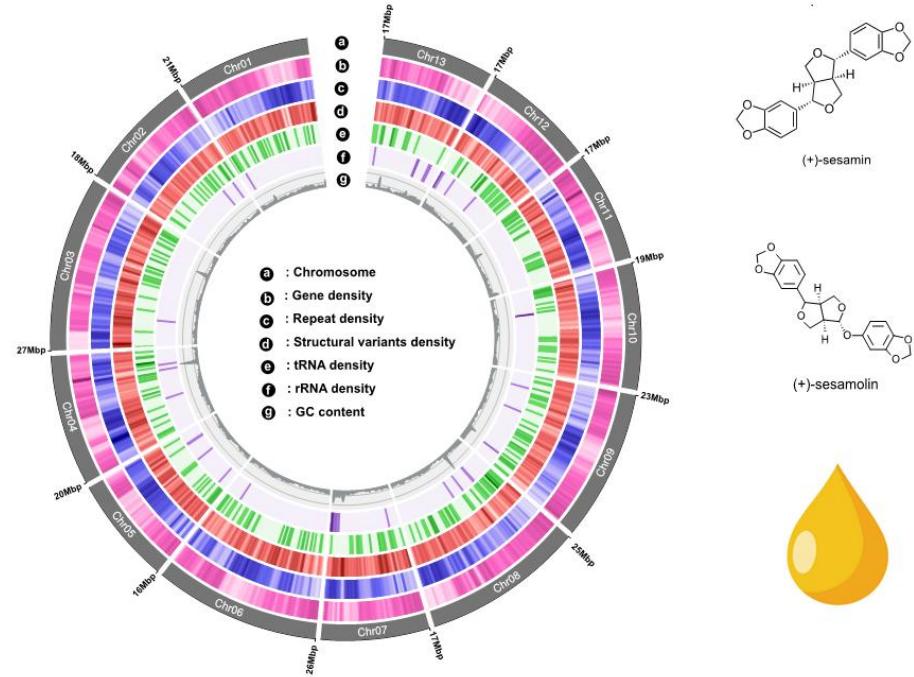
Genome assembly
Genes SSRs QTL
Database SNPs
Annotated genome
Molecular markers

Step 2: Generate genomic resources

1.16 ton per hectare | high oil content of 50.2% | sesamin : 3.96 mg/g sesamolin 2.57mg/g | Linoleic acid: 44.5%

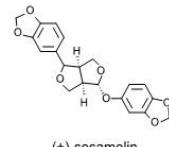
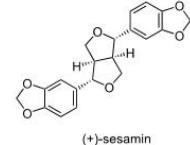


Sesamum indicum cv Goenbaek
©Zoclanclounon (2022)



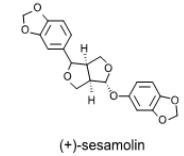
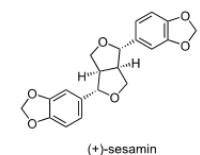
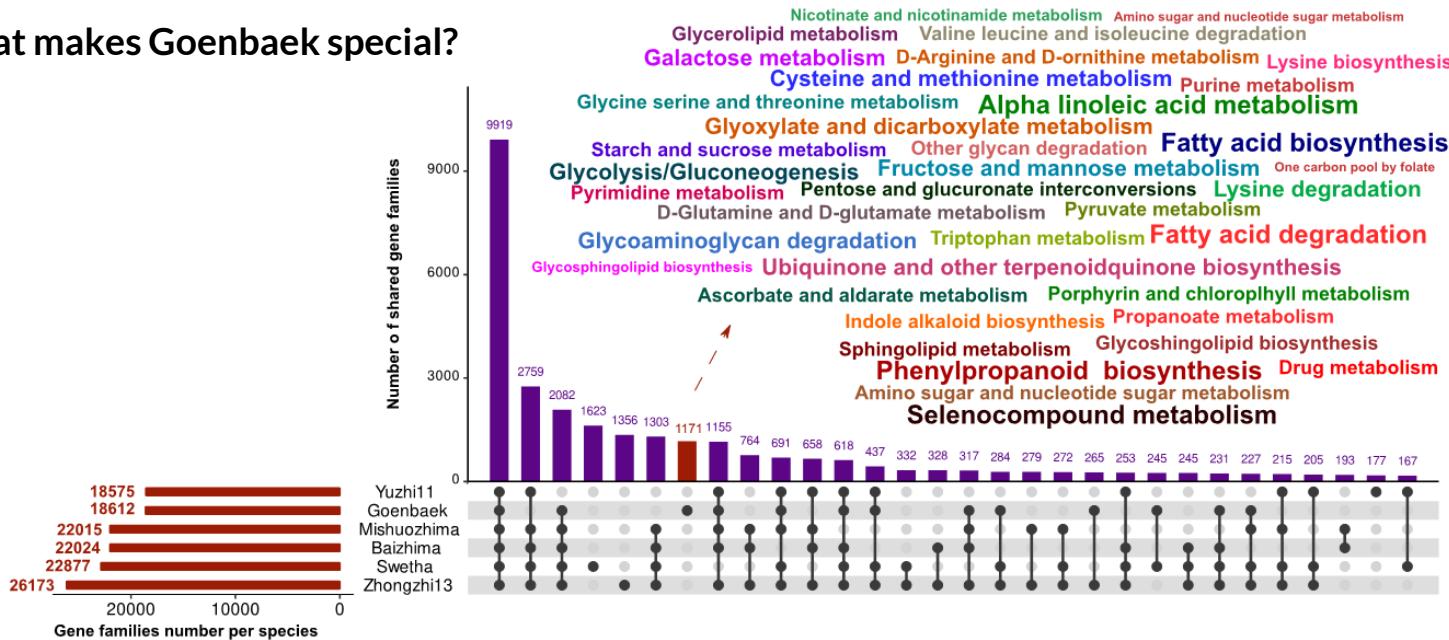
Circos plot of Goenbaek genome

Data: <https://www.ncbi.nlm.nih.gov/bioproject/810203>



Step 2: Generate genomic resources

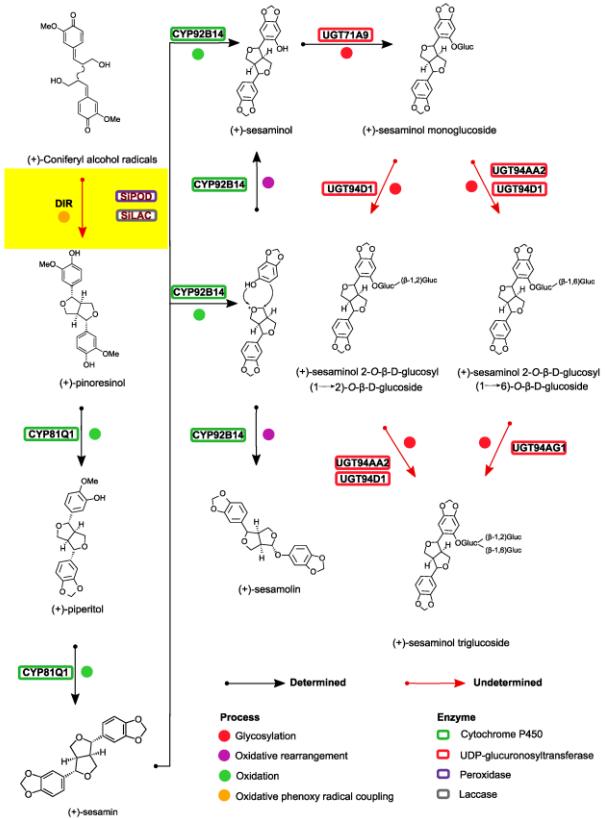
What makes Goenbaek special?



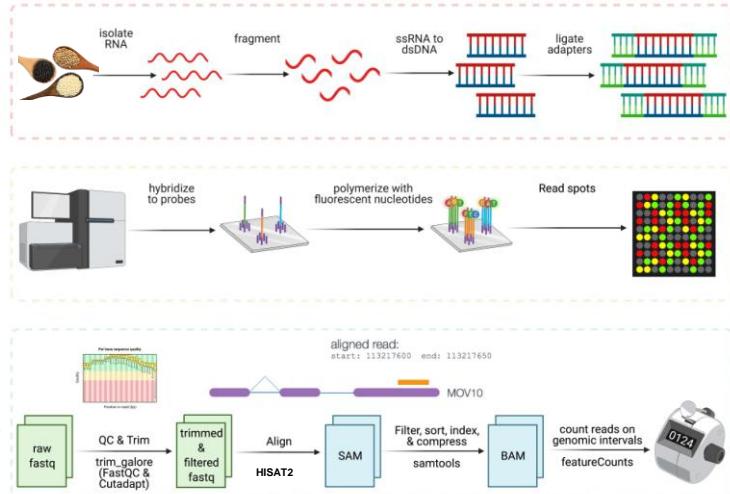
**Step 3: Investigate key
genes of interest**



Step 3: Investigate key genes of interest

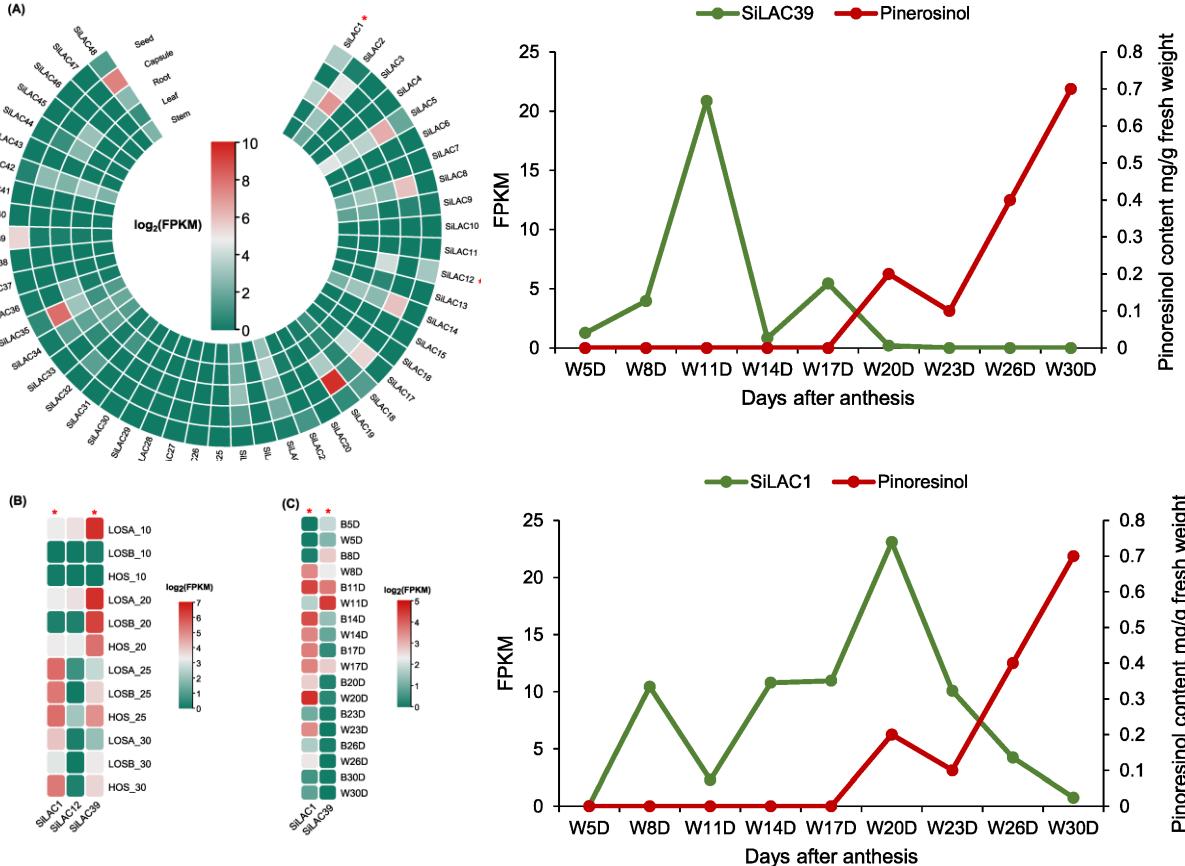


Transcriptomics in action



White vs Black | Rich oil vs Low oil

Step 3: Investigate key genes of interest



SiLAC39

SiLAC1

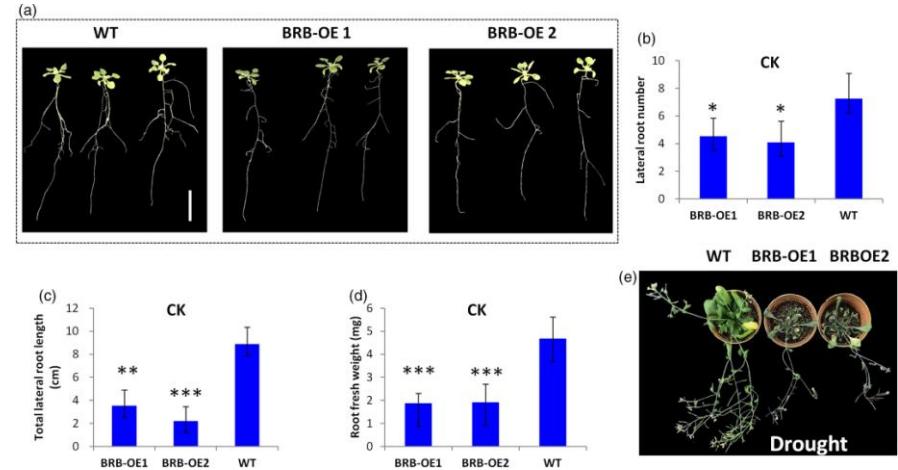
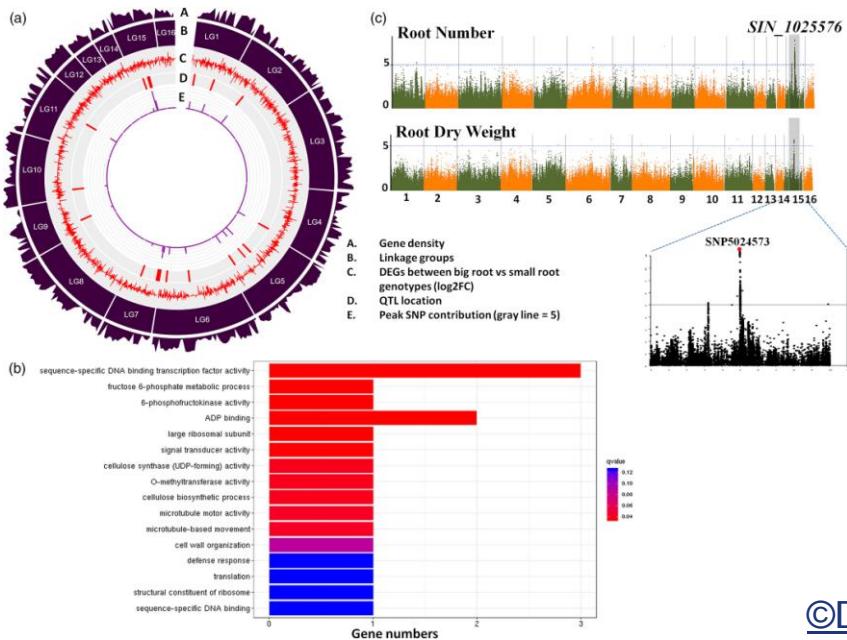
qPCR to check the expression

Functional validation [Ongoing]

Hairy roots method [Perspective]

Step 3: Investigate key genes of interest

Developing crops with improved root system is crucial in current global warming scenario.



©Dossa et al. 2020

GWAS Experiment
19 QTLs - 32 candidate genes – Validation in *Arabidopsis* system

Step 4: R&D



Step 4: R & D

Health CARE



Taiwan Patent
No. 1404797



India Patent
No. 281776

Cosmetics Industry



U.S Patent
No. US8481761 B2

Food Industry



Japan Patent
No. 5553201

Step 4: R & D

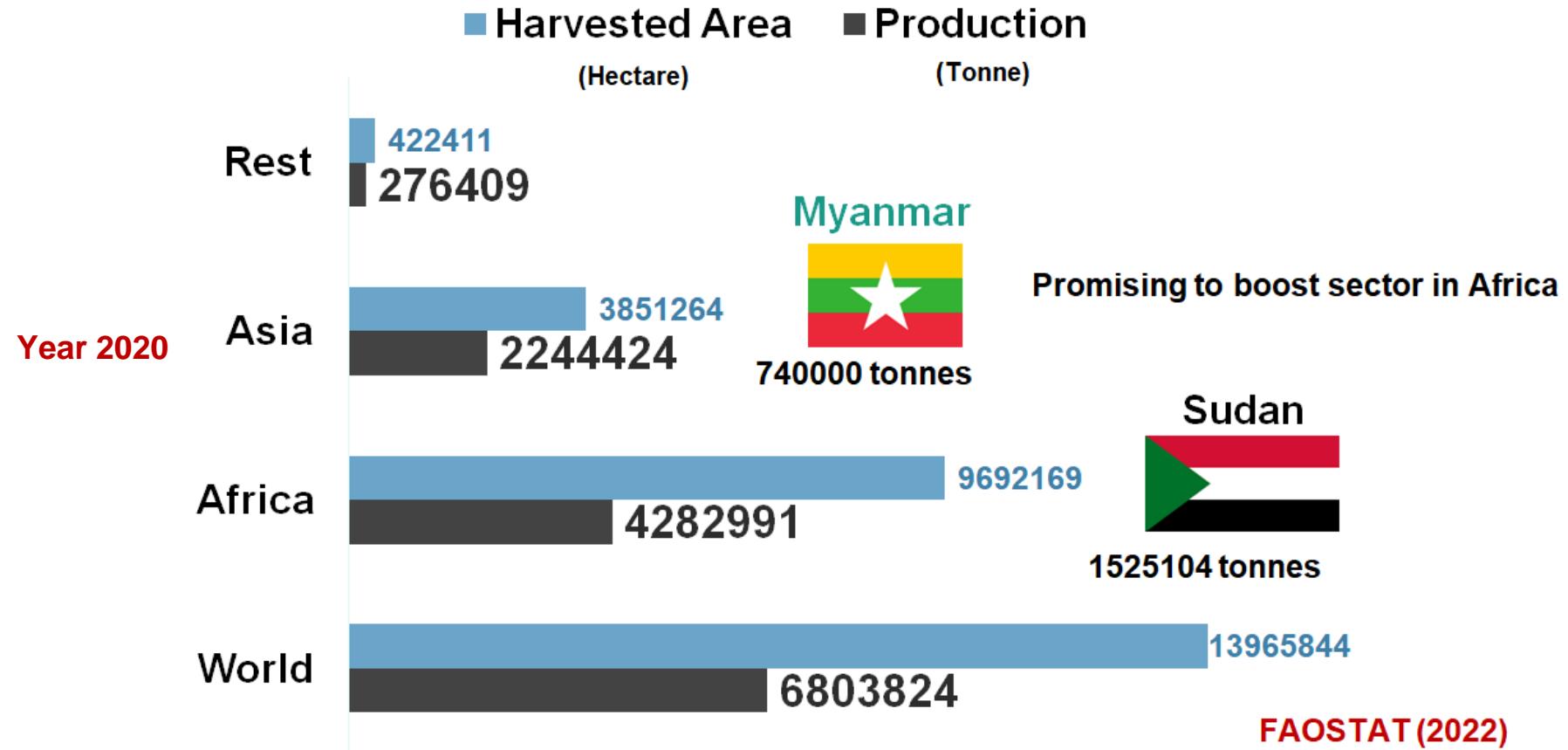


Sesame field in Senegal
©rikolto
25 ha Covered



Ethiopia
Sesame Screening And Cleaning
Plant Module
©AKYUREK Technology

Step 4: R & D



Step 4: R & D

Rice Blast disease



©UCANR

Rice blast in a California rice crop.
High-yielding rice variety resistant

Oryza sativa cv *Kitaake*

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Article | [Published: 14 June 2023](#)

Genome editing of a rice CDP-DAG synthase confers multipathogen resistance

[Gan Sha](#), [Peng Sun](#), [Xiaojing Kong](#), [Xinyu Han](#), [Qiping Sun](#), [Laetitia Fouillen](#), [Juan Zhao](#), [Yun Li](#), [Lei Yang](#), [Yin Wang](#), [Qiuwen Gong](#), [Yaru Zhou](#), [Wenqing Zhou](#), [Rashmi Jain](#), [Jie Gao](#), [Renliang Huang](#), [Xiaoyang Chen](#), [Lu Zheng](#), [Wanying Zhang](#), [Ziting Qin](#), [Qi Zhou](#), [Qingdong Zeng](#), [Kabin Xie](#), [Jiandi Xu](#), [Tsan-Yu Chiu](#), [Liang Guo](#), [Jenny C. Mortimer](#), [Yohann Bouteé](#), [Qiang Li](#), [Zhensheng Kang](#), [Pamela C. Ronald](#)✉ & [Guotian Li](#)✉

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Step 4: R & D

Golden rice



©IRRI
Beta carotene gene
(precursor vitamine A)

nature communications

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Marker-free carotenoid-enriched rice generated through targeted gene insertion using CRISPR-Cas9

[Oliver Xiaou Dong](#), [Shu Yu](#), [Rashmi Jain](#), [Nan Zhang](#), [Phat Q. Duong](#), [Corinne Butler](#), [Yan Li](#), [Anna Lipzen](#),
[Joel A. Martin](#), [Kerrie W. Barry](#), [Jeremy Schmutz](#), [Li Tian](#) & [Pamela C. Ronald](#)

[Nature Communications](#) 11, Article number: 1178 (2020) | [Cite this article](#)

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Step 4: R & D

Drought resistant Maize



Plant Biotechnology
Journal



Plant Biotechnology Journal (2017) **15**, pp. 207–216

doi: 10.1111/pbi.12603

ARGOS8 variants generated by CRISPR-Cas9 improve maize grain yield under field drought stress conditions

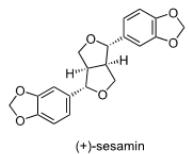
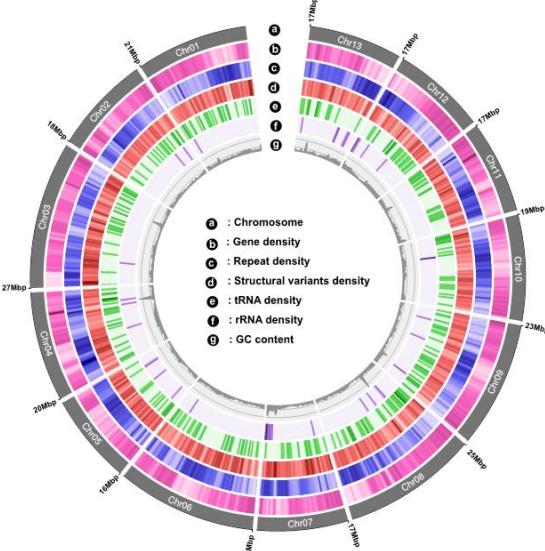
Jinrui Shi*, Huirong Gao, Hongyu Wang, H. Renee Lafitte, Rayeann L. Archibald, Meizhu Yang, Salim M. Hakimi, Hua Mo and Jeffrey E. Habben

DuPont Pioneer, Johnston, IA, USA

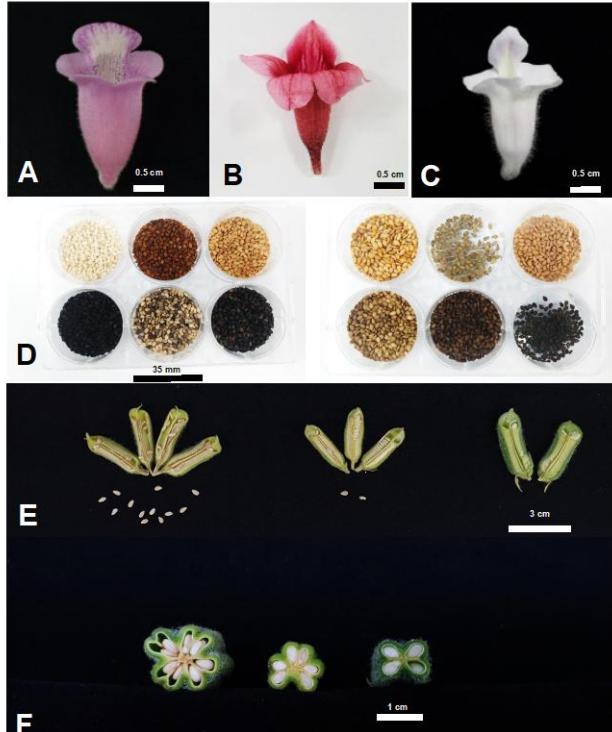
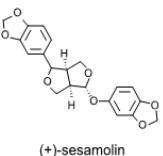
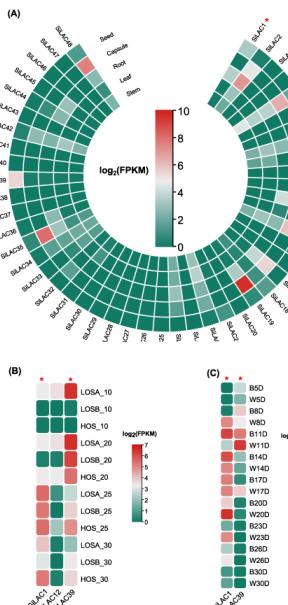
4 | Summary



4 | Summary

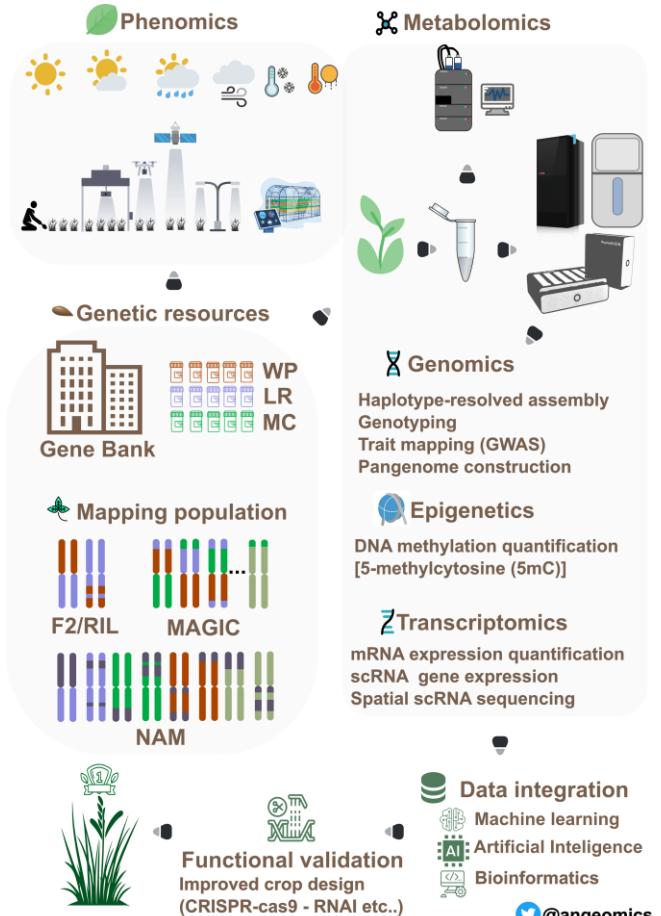


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Take out message

- ❑ Omics enables fast-forward breeding for a food-secure world
- ❑ Genetic diversity is a paramount
- ❑ Big data – Bioinformatics – Machine learning
- ❑ Genetic engineering – Gene editing



Thank you

