

# Integrated Omics Approach for Crop Improvement

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July 13, 2023

# Content



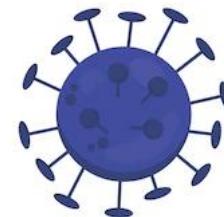
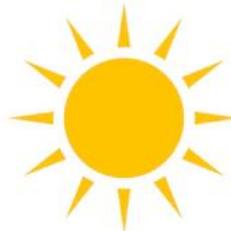
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# 1 | A little bit of context



# A little bit of context

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International Livestock Research Institute

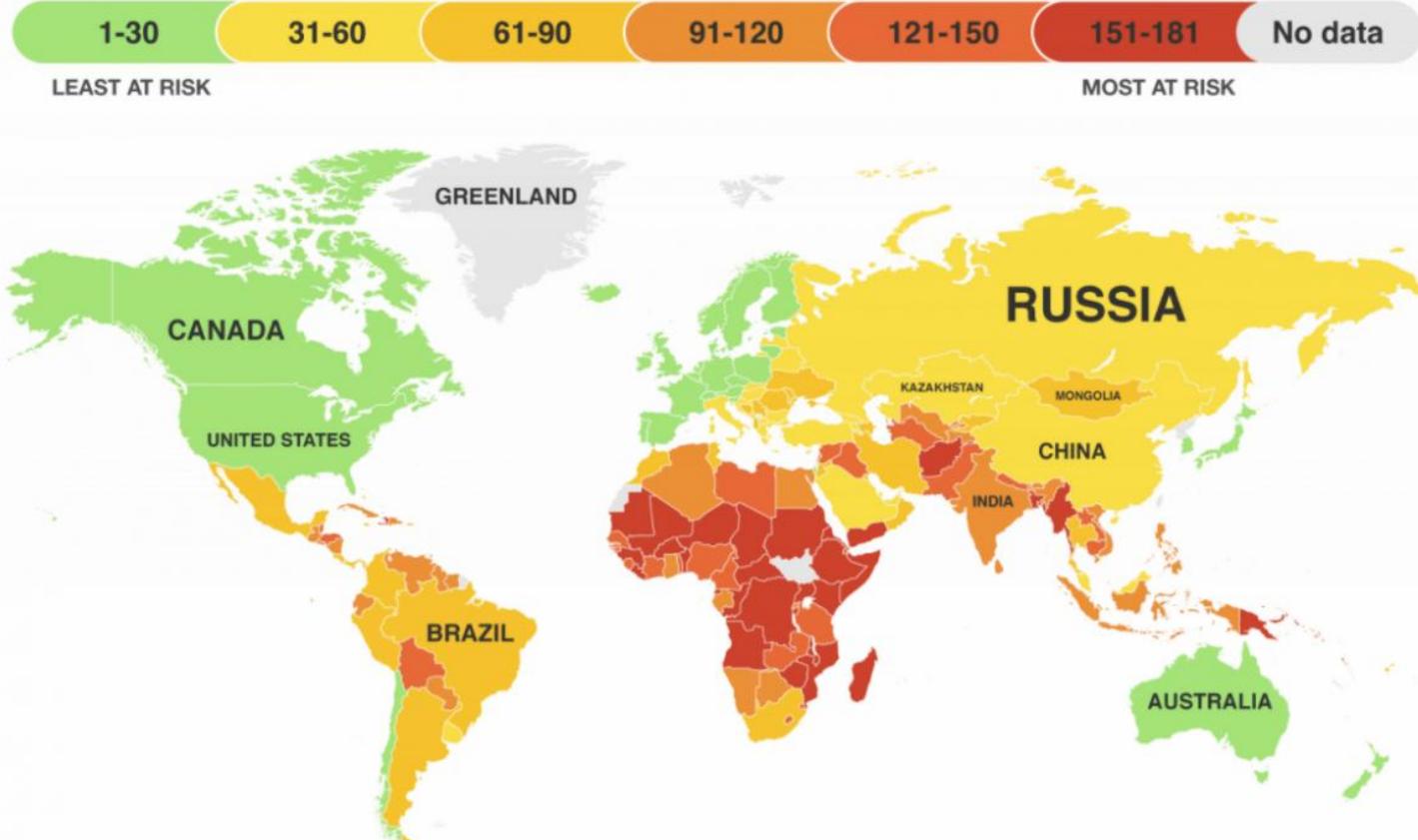
> NEWS & EVENTS > NEWS

## 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.

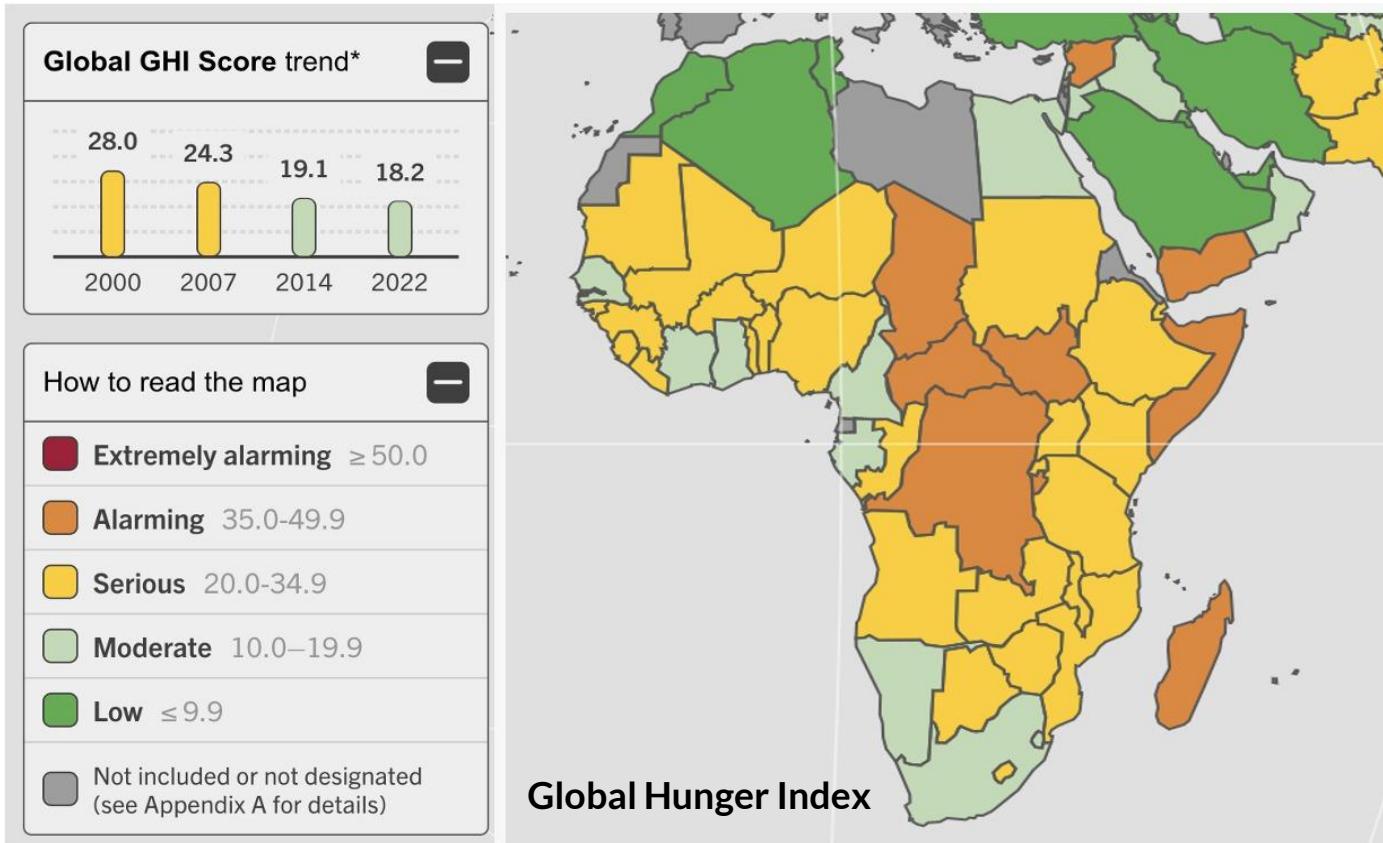
IFPRI RESEARCH MONOGRAPH | 2013 | PAGES: 408

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

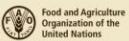
DOI : <http://dx.doi.org/10.2499/9780896292048>

OPEN ACCESS

# A little bit of context



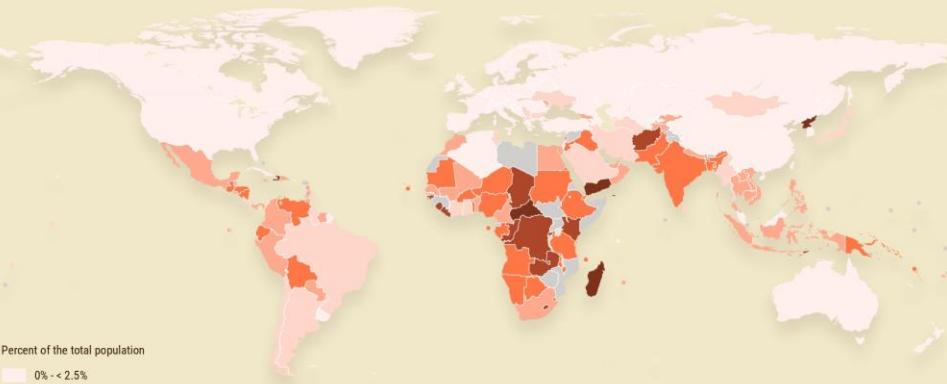
# A little bit of context



## FAO HUNGER MAP

Prevalence of Undernourishment 2019-2021  
SDG Indicator 2.1.1

SUSTAINABLE  
DEVELOPMENT  
GOALS



Percent of the total population

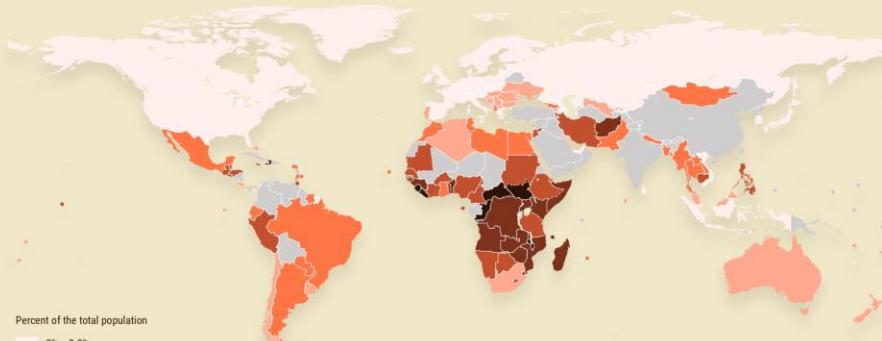
0% < 2.5%
2.5% - 4.9%
5% - 9.9%
10% - 24.9%
25% - 39.9%
40% - 60%
No data



## FAO FOOD INSECURITY MAP

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

SUSTAINABLE  
DEVELOPMENT  
GOALS



Percent of the total population

0% - 9.9%
10% - 24.9%
25% - 39.9%
40% - 59.9%
60% - 79.9%
80% - 100%
Data not available or not country validated

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>

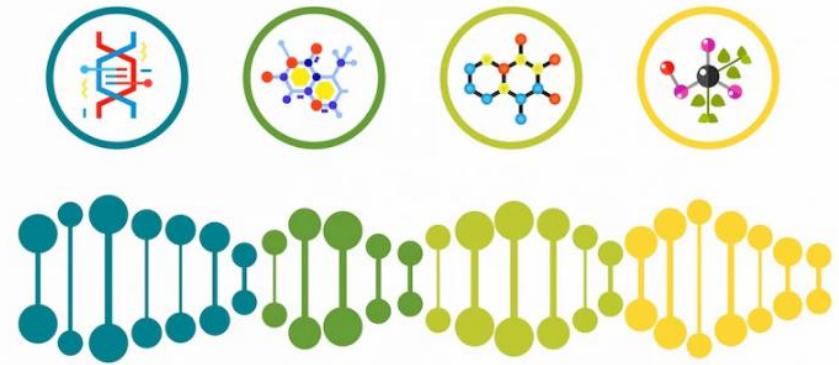


**Urgent to develop resistant crops with regards to biotic and abiotic factors**  
**Highly nutritive quality crops**



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## 2 | Multi Omics Core Concept



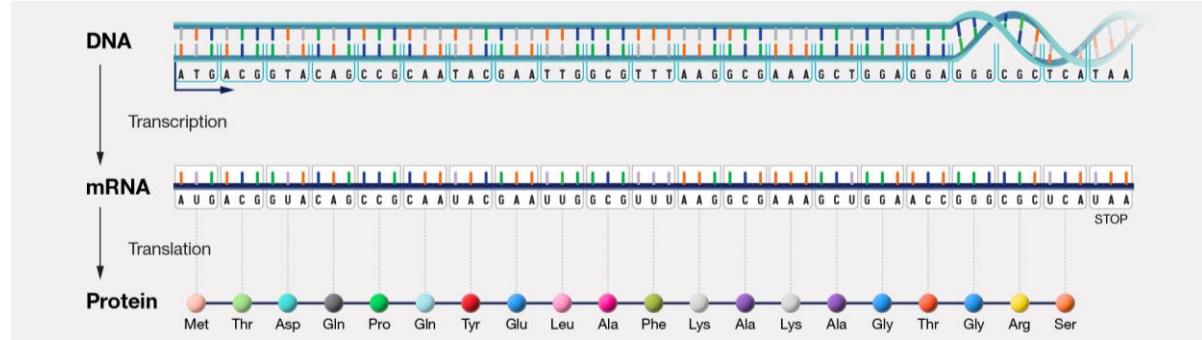
# Multi Omics Core Concept

## Central Dogma of Molecular Biology

Francis Crick



© <https://tinyurl.com/2jkb574e>

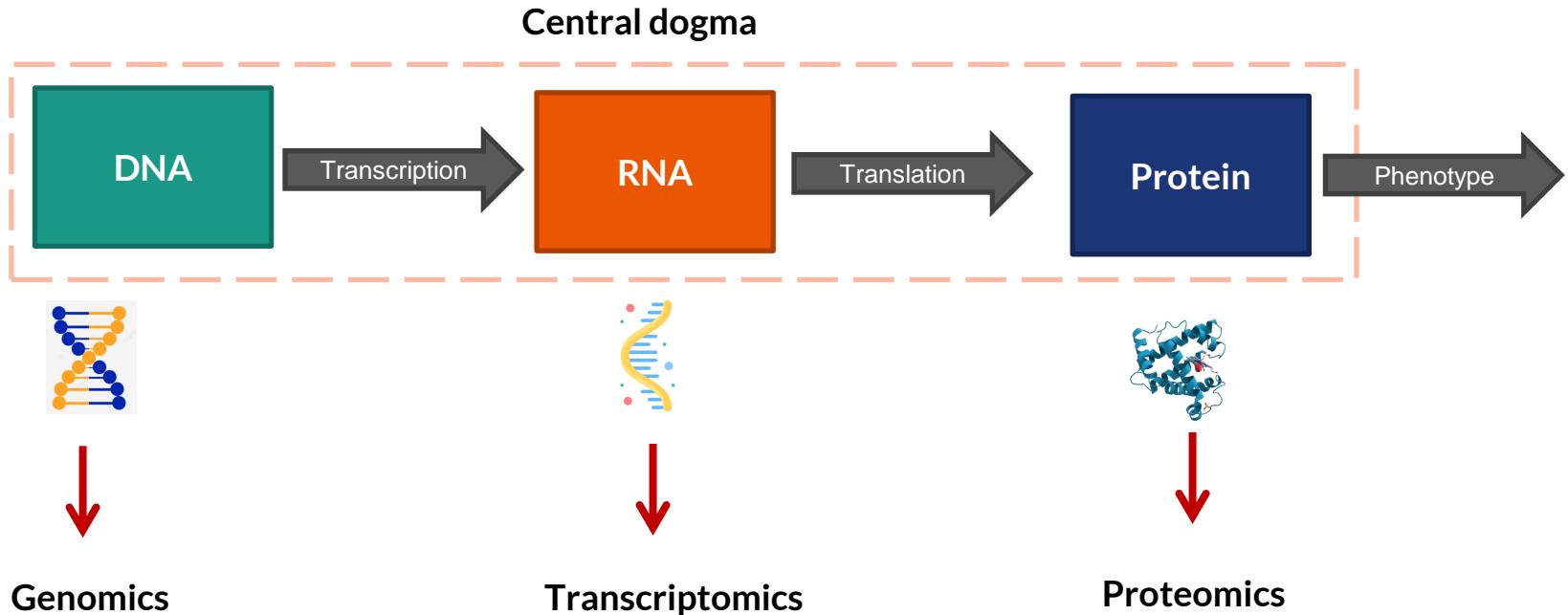


Trait (or Phenotype)

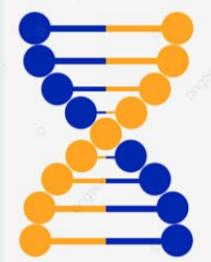


© <https://tinyurl.com/26mrtpcf>

# 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

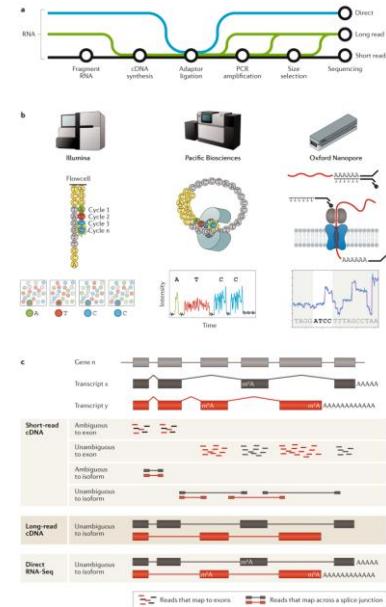


❑ RNA Sequencing

❑ Gene expression profiling

❑ Transcriptional regulation

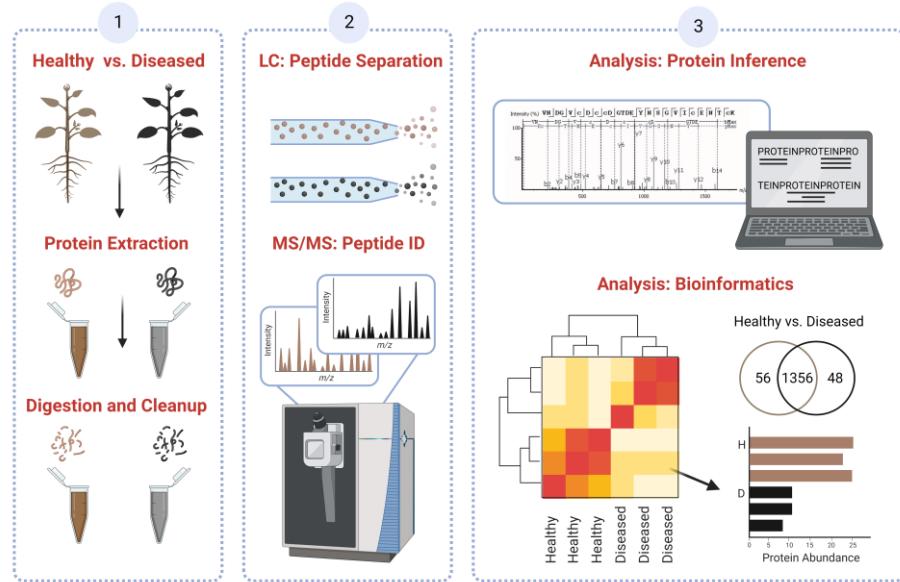
❑ Splicing



©Bawa *et al.* (2022)

© Stark *et al.* (2019)

# Proteomics



© UGUELPH

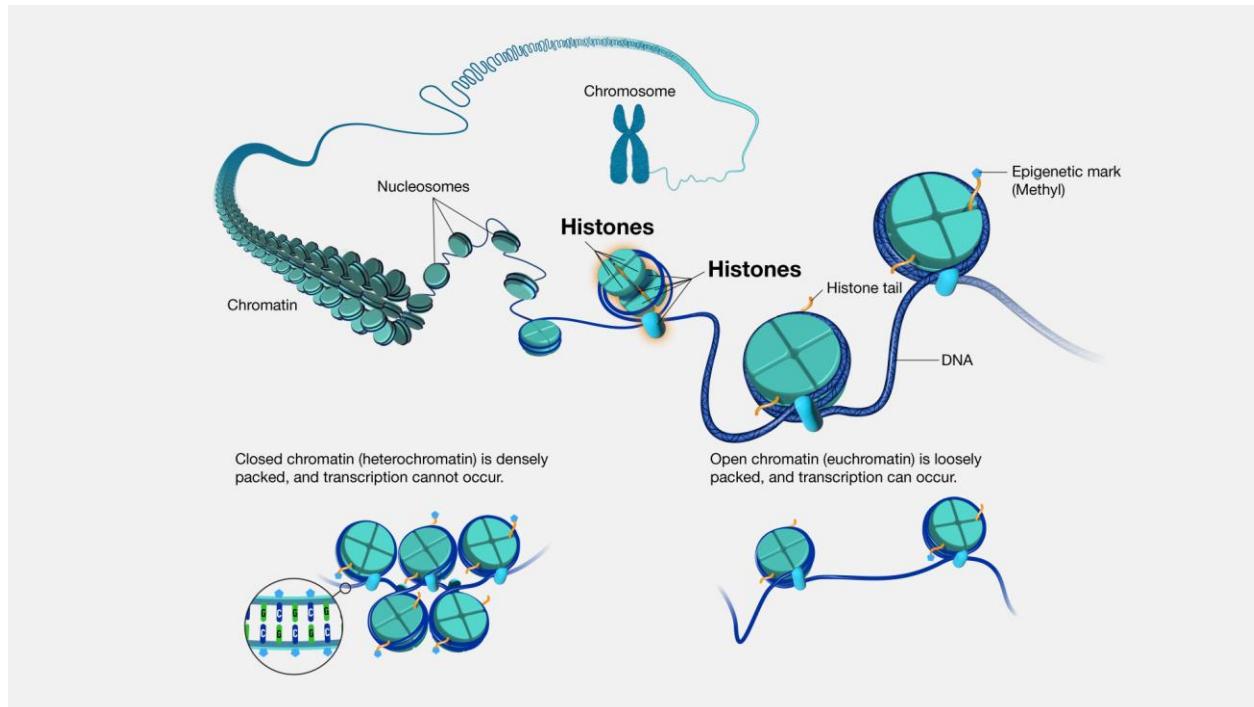
## Quantitative proteomics

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

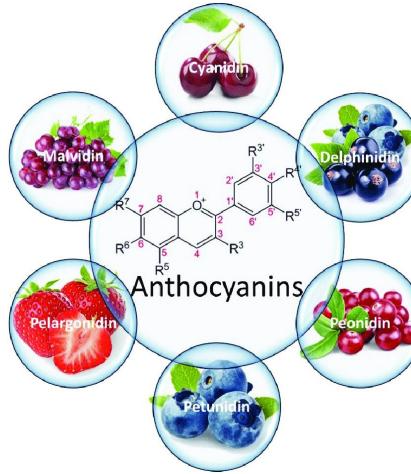
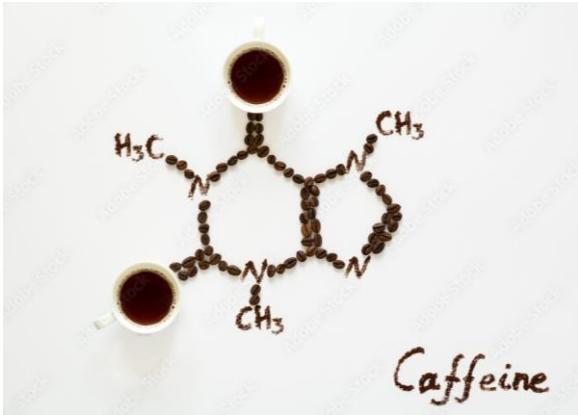
# Multi Omics Core Concept

## Epigenetics also influence gene expression

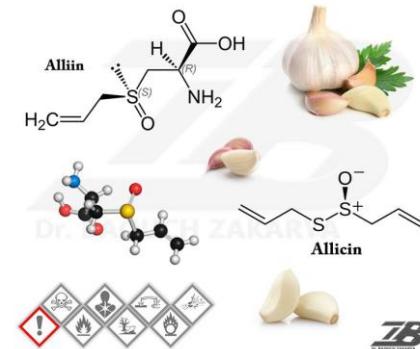
- Acetylation
- Methylation
- Phosphorylation
- Ubiquitination



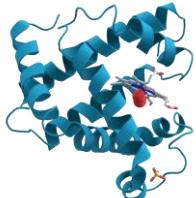
# Multi Omics Core Concept



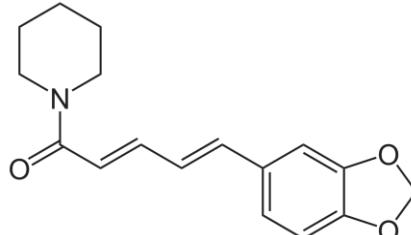
Alliin | C<sub>6</sub>H<sub>11</sub>NO<sub>3</sub>S  
Garlic.



Plant metabolites | Metabolomics



linked

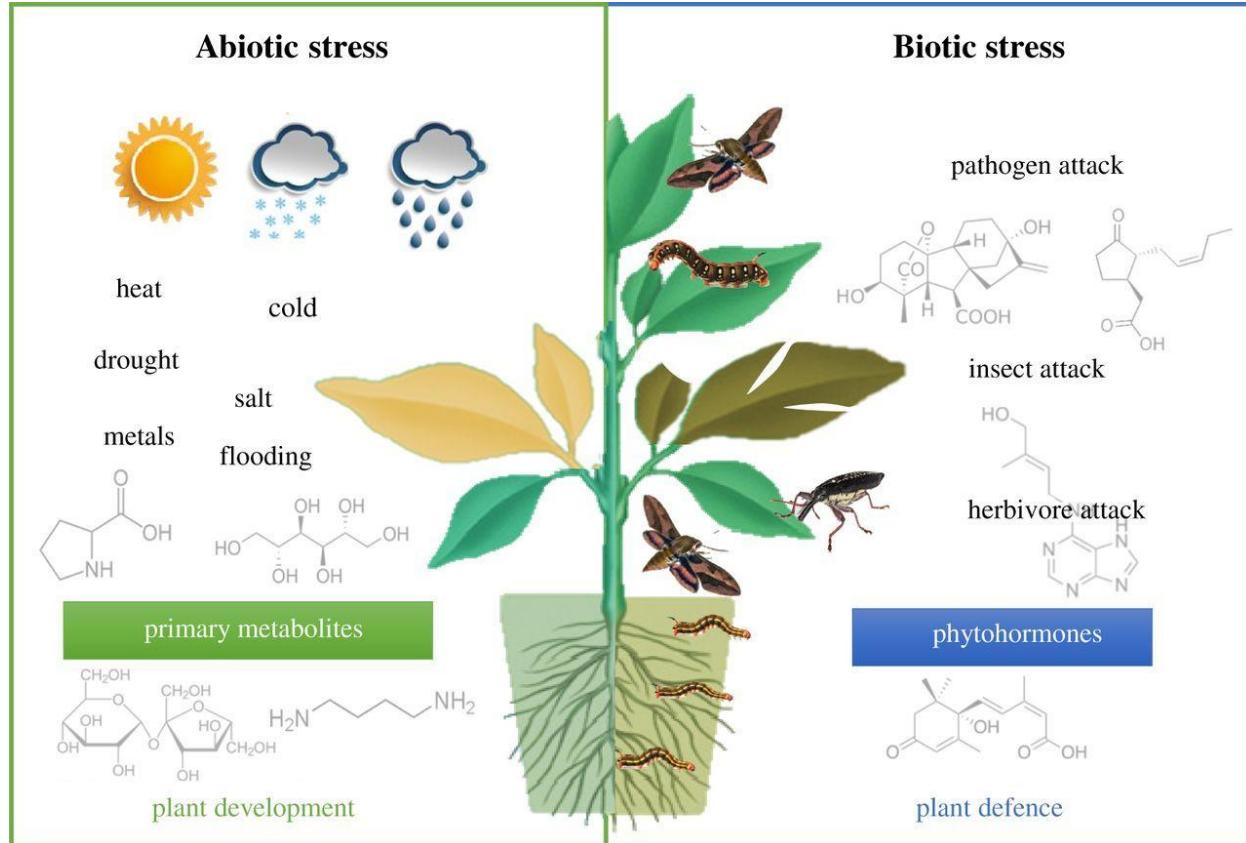


Piperine

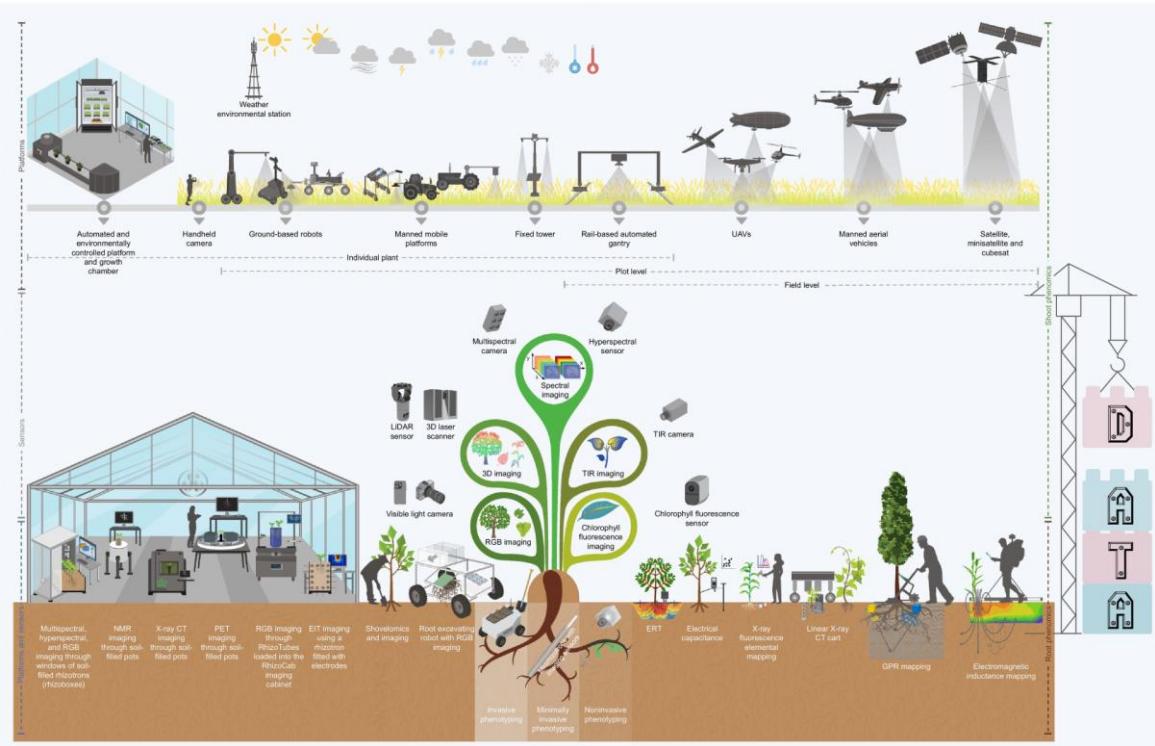


Black pepper

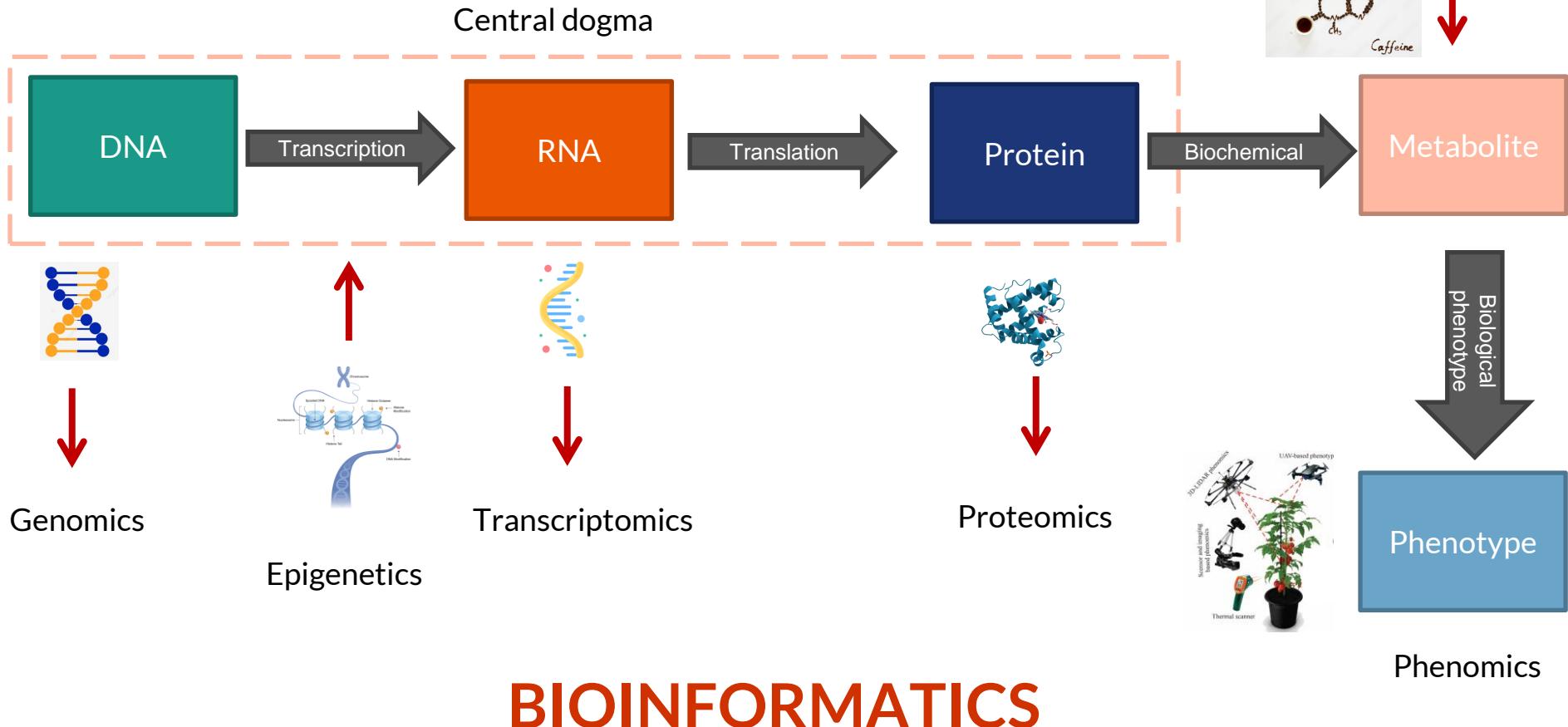
# Multi Omics Core Concept



# Multi Omics Core Concept



# Multi Omics Core Concept



# How can we integrate multiple omics for crop improvement?

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# 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)



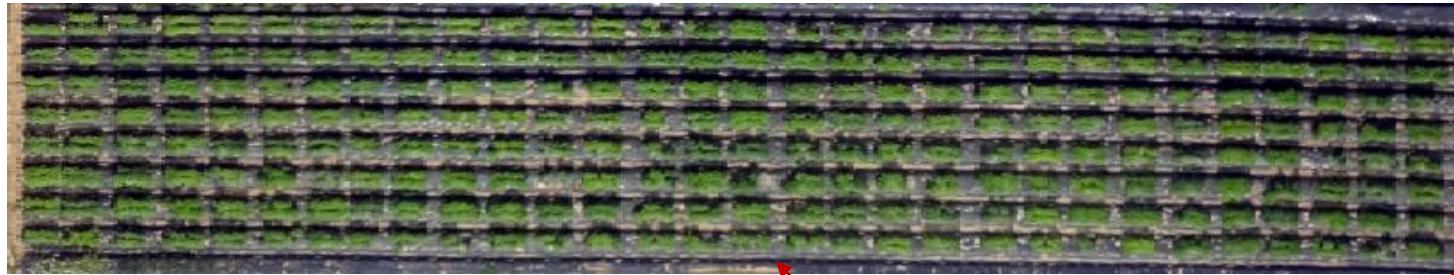
# Step 1: Know your genetic resources

Where ? Origin | Native? | Introduced?

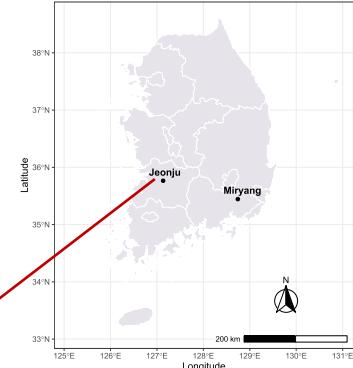
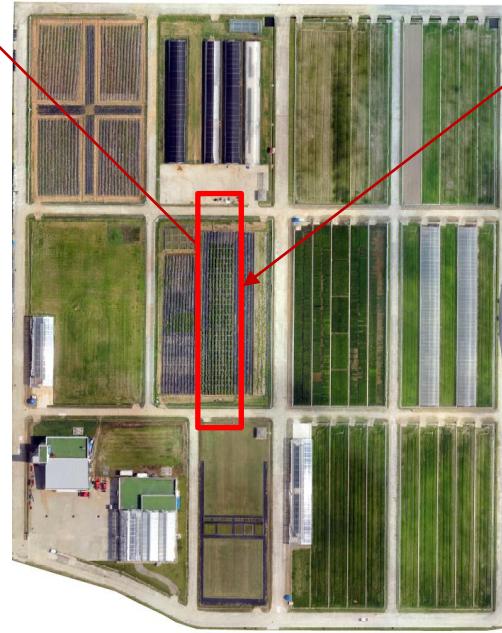


What ?	Wild Landrace Cultivar Variety	Pedigree Characteristic Trait Core collection Mapping population (RILS, MAGIC, ...)
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# Step 1: Know your genetic resources



- Federer Augmented Block Design
  - Checks replicated 8 times

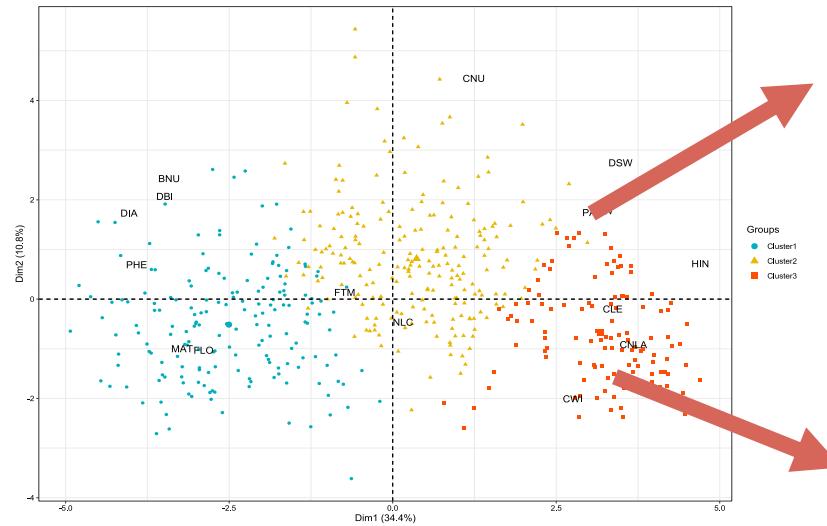
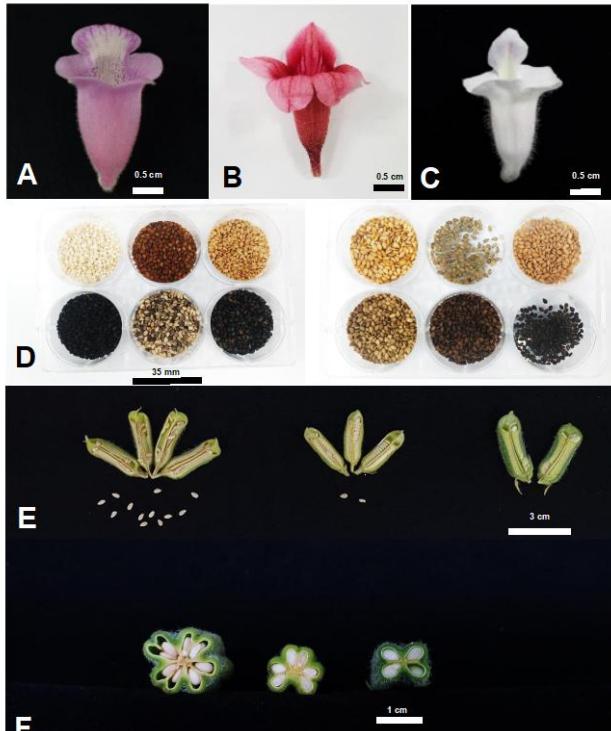


Total: 506 ccessions

Total: 24 traits

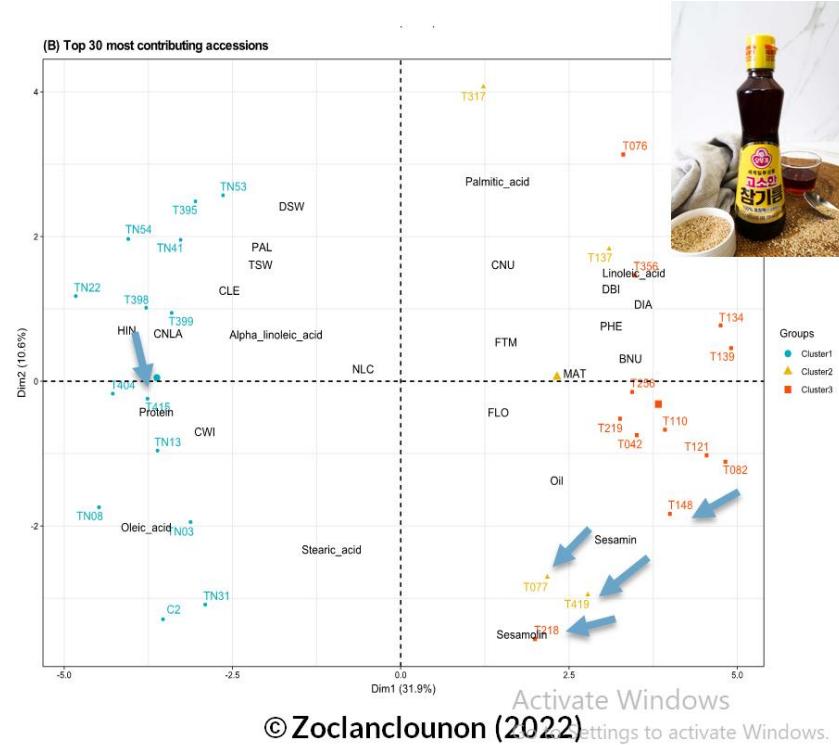
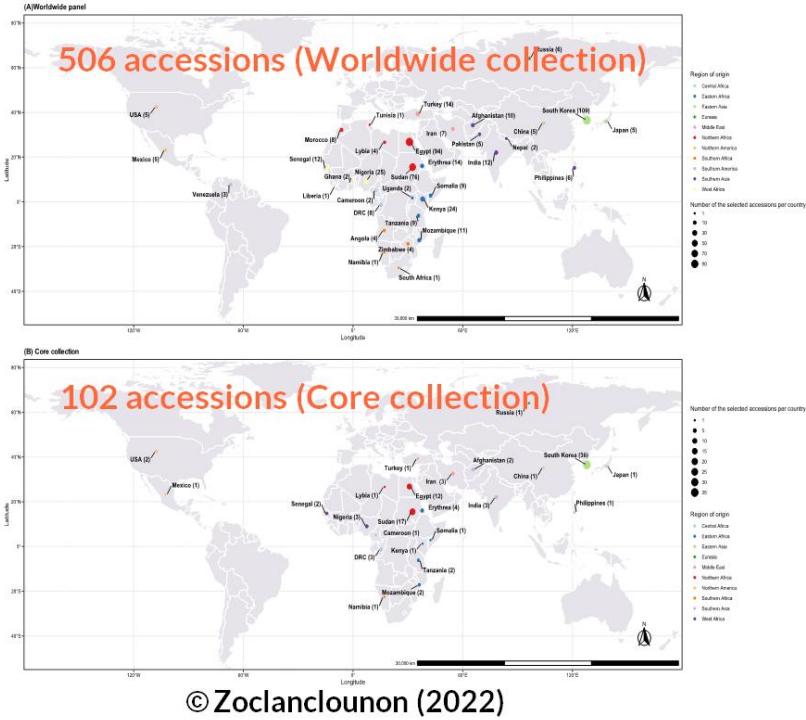
- Agronomic (18)
- Seed quality (06)
  - oil
  - fatty acids
  - sesamin
  - sesamolin

# 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

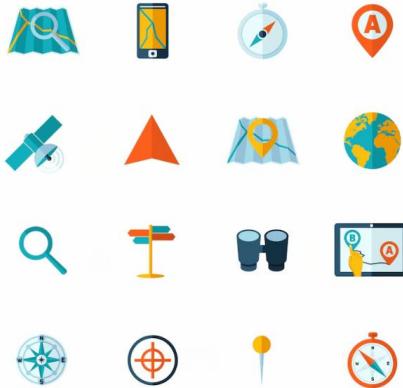
**NGS-based:** GBS – DArT-seq – RAD-seq – ddRAD – REST-Seq

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

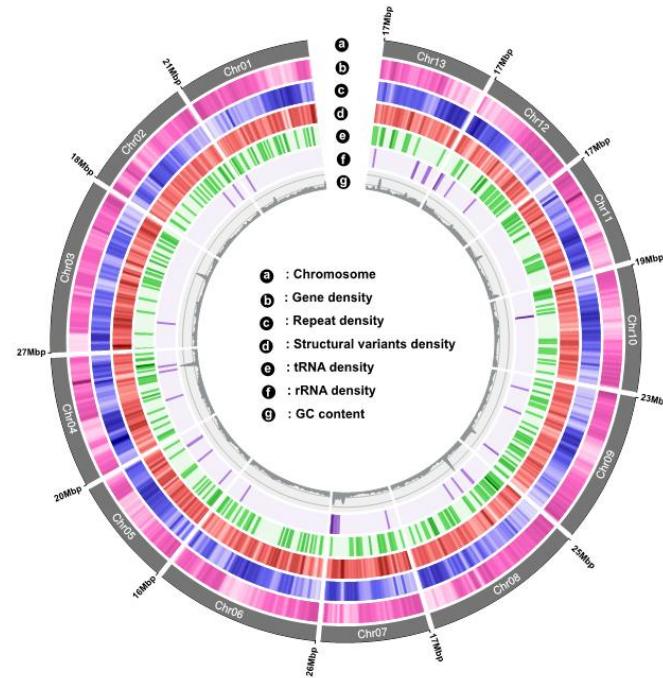
Genome assembly  
**Genes** SSRs QTL  
Database SNPs  
Annotated genome  
Molecular markers

# 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%**

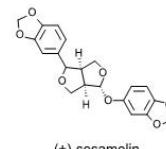
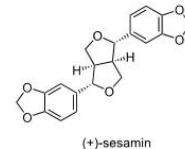


*Sesamum indicum* cv Goenbaek  
©Zoclanclounon (2022)



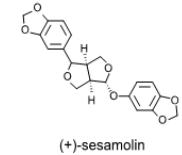
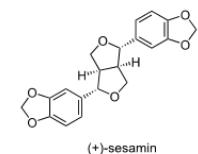
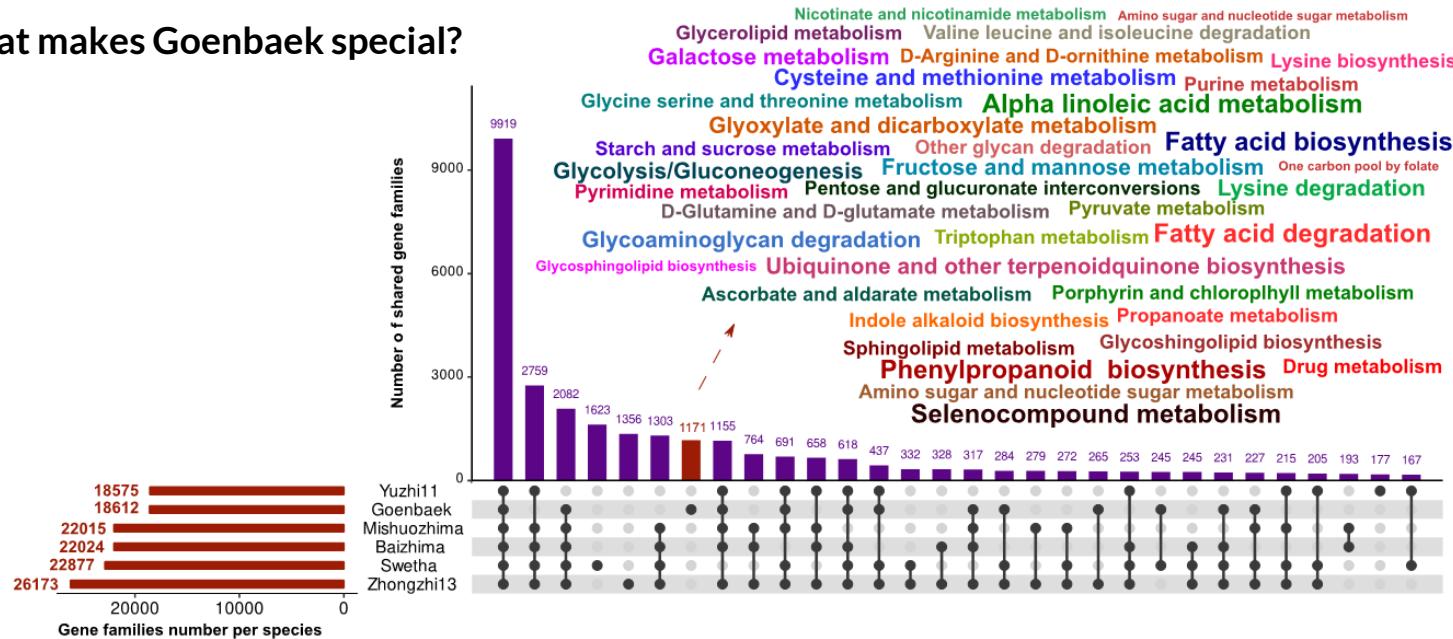
## Circos plot of Goenbaek genome

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



# Step 2: Generate genomic resources

What makes Goenbaek special?

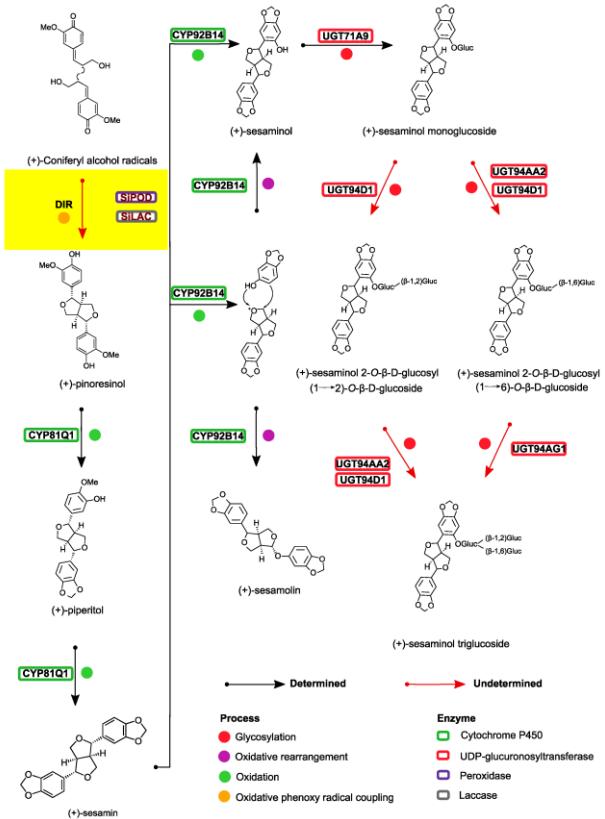


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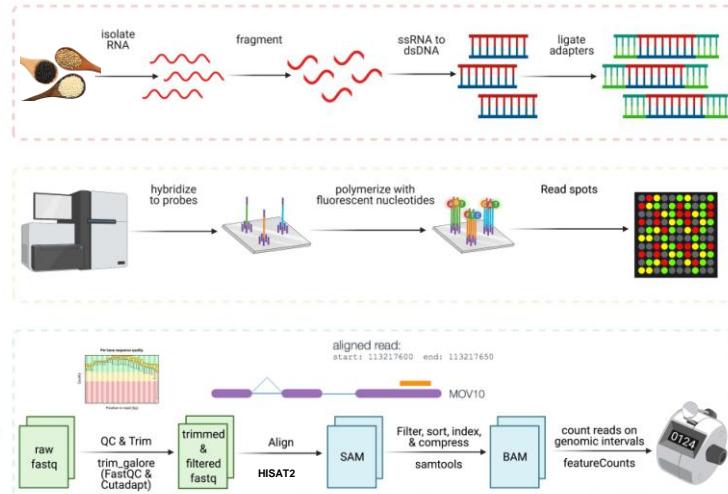
**Step 3: Investigate key  
genes of interest**



## Step 3: Investigate key genes of interest

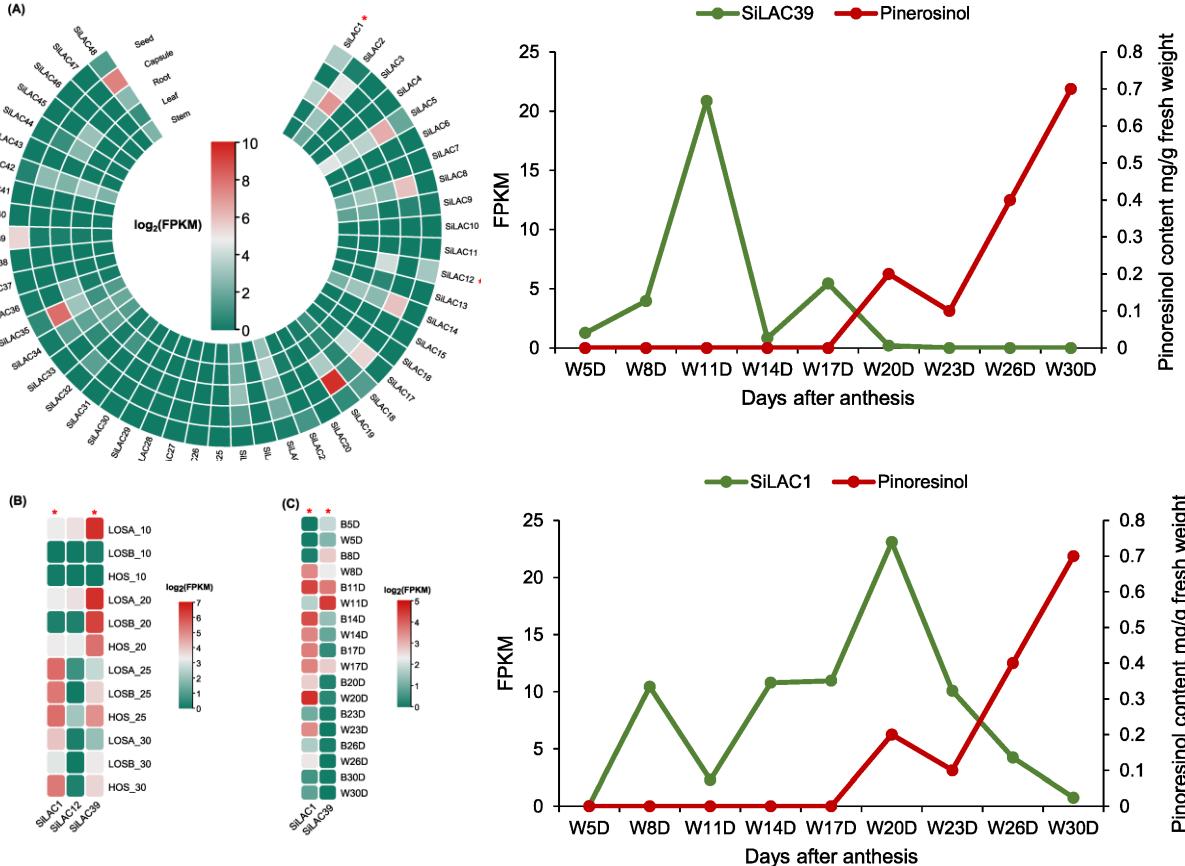


# Transcriptomics in action



*White vs Black | Rich oil vs Low oil*

# Step 3: Investigate key genes of interest



*SiLAC39*

*SiLAC1*

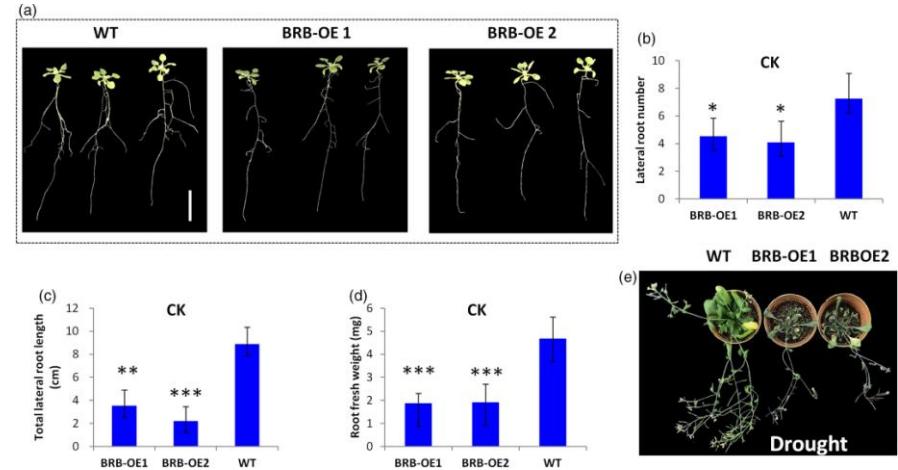
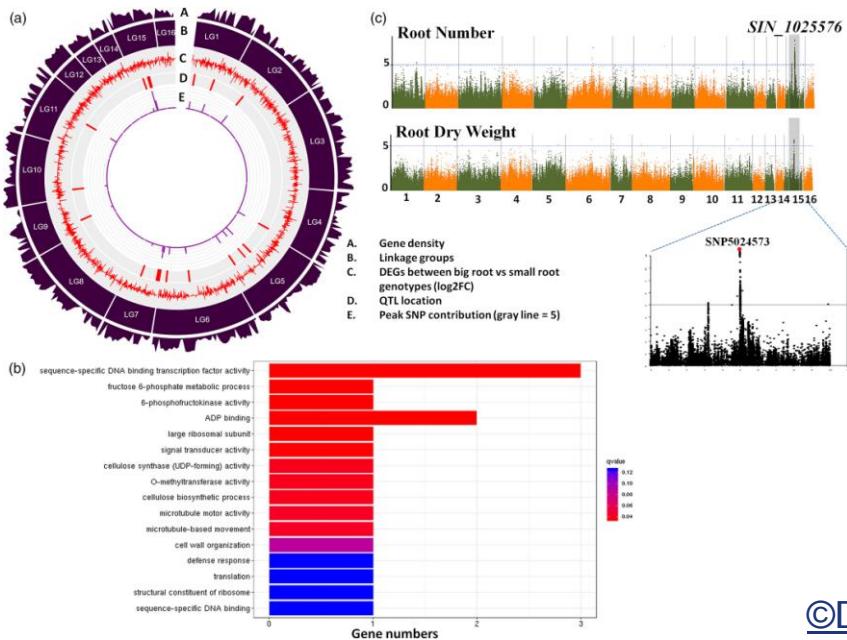
*qPCR to check the expression*

*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

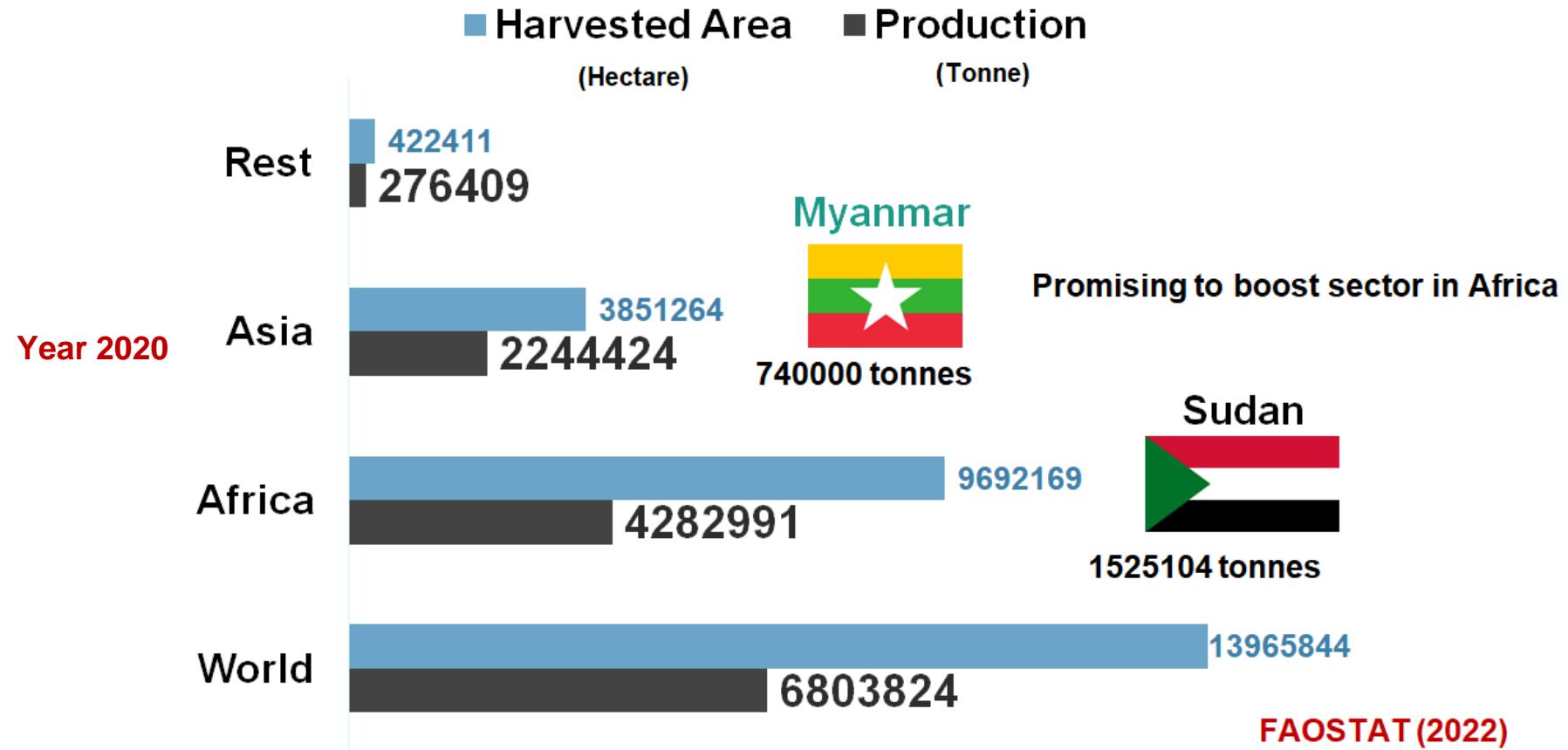


Sesame field in Senegal  
©rikolto  
25 ha Covered



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*

nature

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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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[Nature](#) **618**, 1017–1023 (2023) | [Cite this article](#)

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# Step 4: R & D

## Golden rice



©IRRI  
Beta carotene gene  
(precursor vitamine A)

## nature communications

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Article | [Open Access](#) | Published: 04 March 2020

## 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

aab  
Association of Applied Biologists

SEB  
Society for  
Experimental Biology

*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

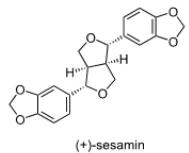
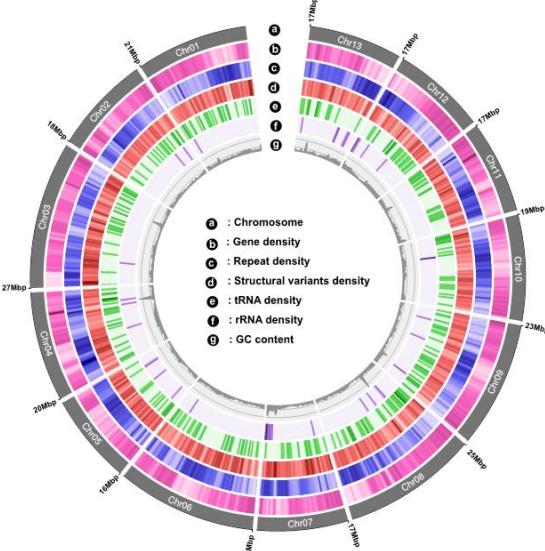
Jinrui Shi\*, Huirong Gao, Hongyu Wang, H. Renee Lafitte, Rayeann L. Archibald, Meizhu Yang, Salim M. Hakimi, Hua Mo and Jeffrey E. Habben

*DuPont Pioneer, Johnston, IA, USA*

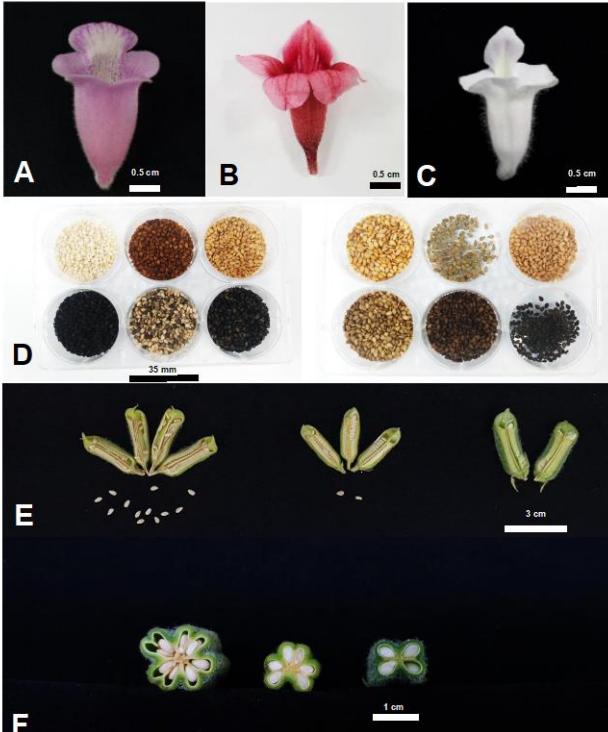
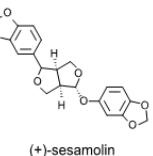
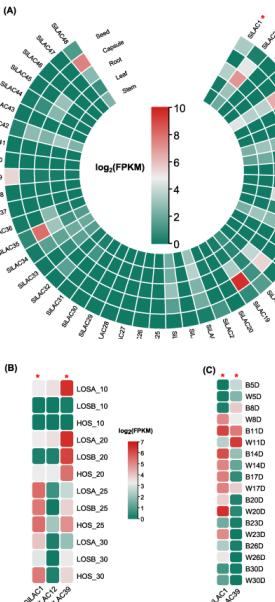
# 4 | Summary



# 4 | Summary

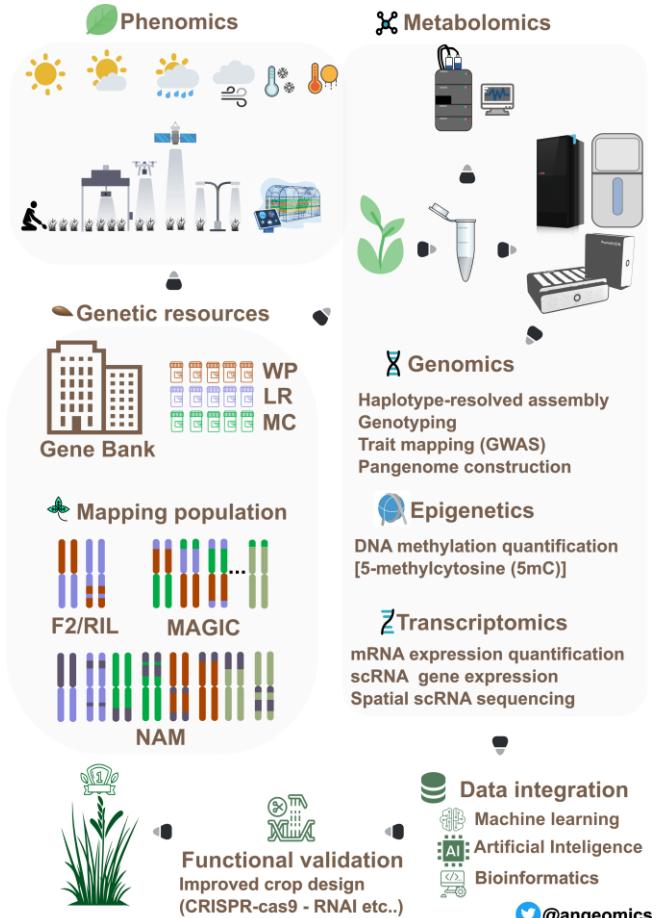


© Zoclancloounon (2022)



# 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





Scann me

