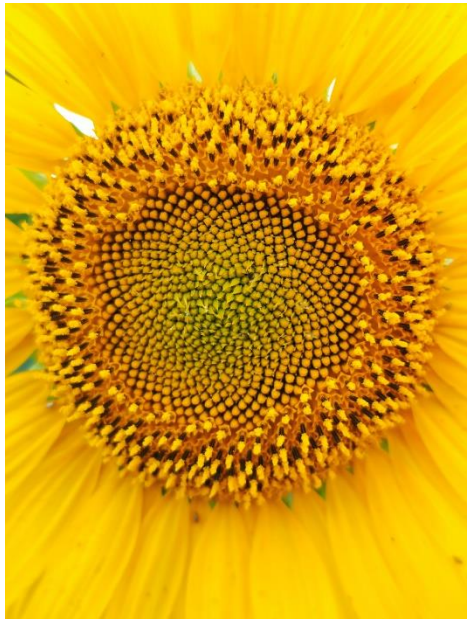
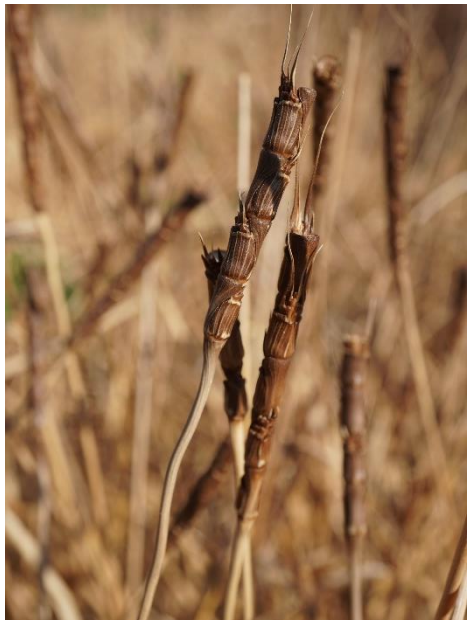
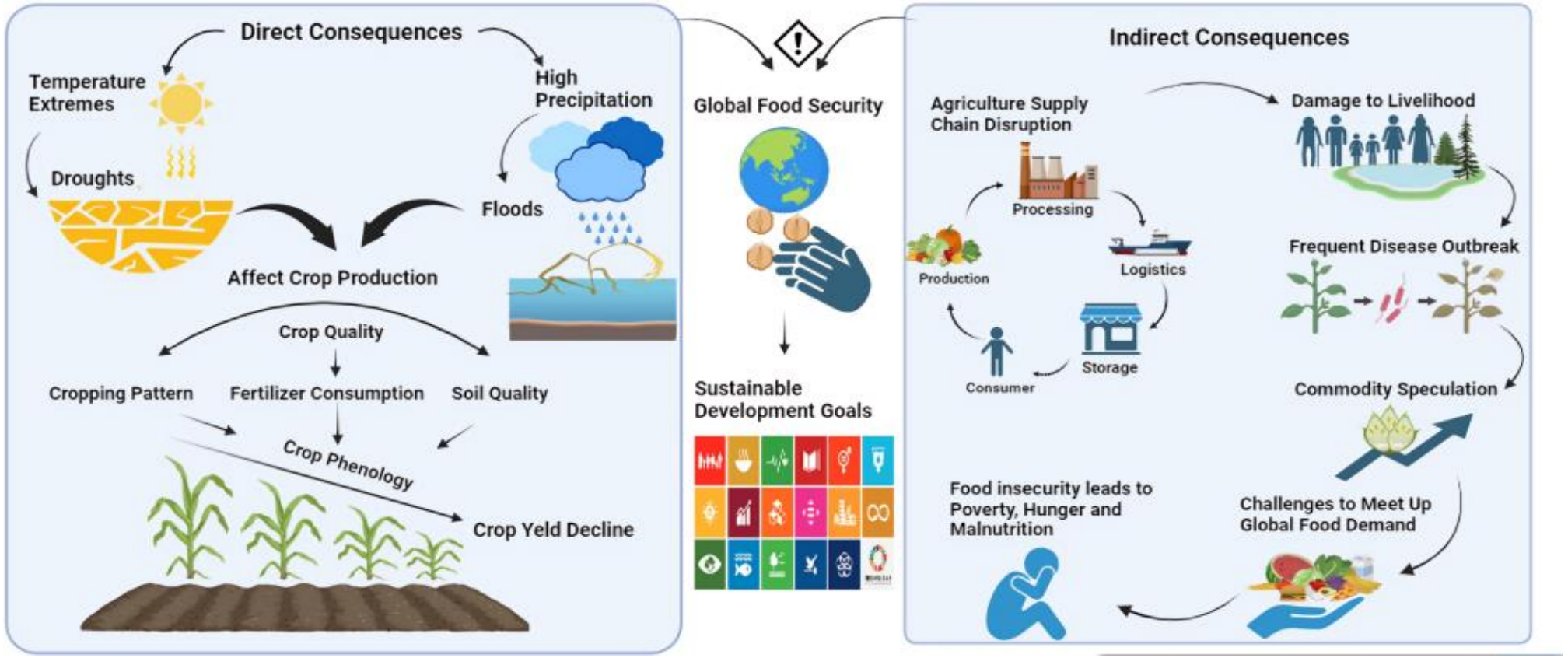
Pre-breeding and use of genetic resources

Sanja Mikić & Ana Marjanović Jeromela

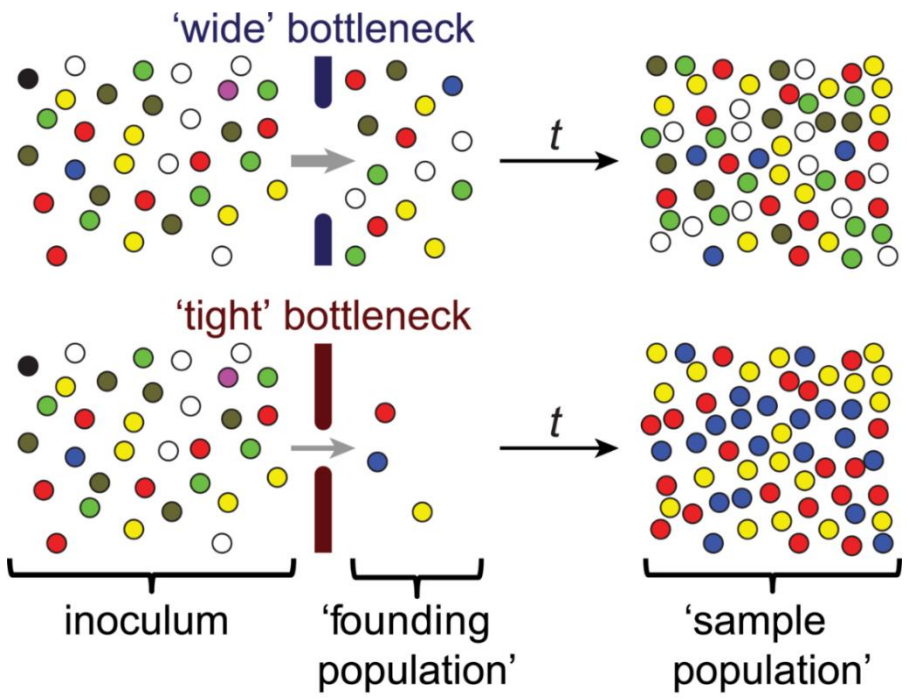
Part 1 – Context and importance

- Global interconnected challenges



Context and importance

- Modern breeding narrowed genetic diversity



https://openpress.wheatoncollege.edu/

Context and importance

- Pre-breeding as a way to bring new traits into elite lines.

Definition of pre-breeding

Initial

- Identification useful traits
- Genetic resources
- Genebanks

Intermediate

- Transfer useful traits
- • Adapted material with the new traits
- Pre-breeding

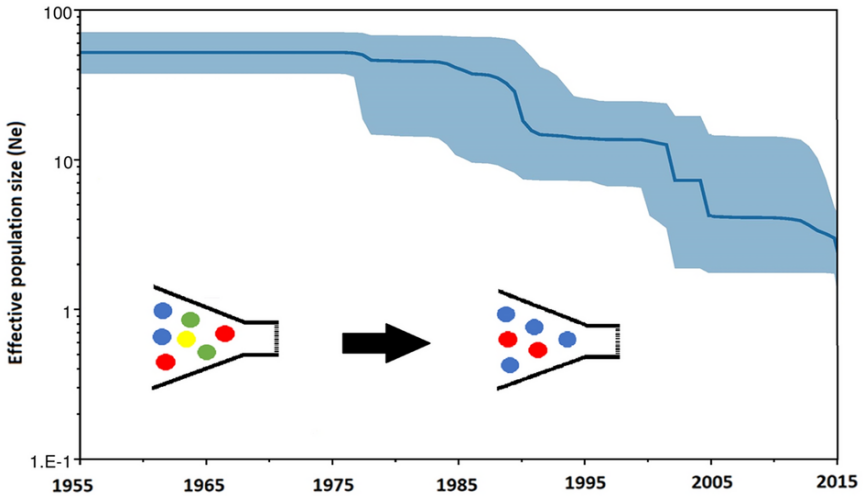
Final

- Elite breeding lines
- Crop improvement
- Breeding

Genetic resources – what are they?

- Landraces
- Obsolete cultivars
- Wild relatives
- Advanced breeding lines
- Modern cultivars

Why we need pre-breeding?



- Wheat genome-wide SNPs: **97% of allelic diversity** in older varieties **disappeared** within six decades of modern breeding!

Cseh et al. (2021) Scientific Reports

Pre-breeding recovers traits lost:
- **disease** resistance,
- tolerance to **drought**,
- tolerance to **heat**,
- **nutritional** improvements.

Without it, the same limited breeding gene pool
→ slow innovation
→ vulnerable crops
→ environmetal problems

The pre-breeding process

1. **Identify** a trait of interest.
2. **Select** source.
3. **Characterize** - phenotyping and genotyping.
4. **Crosses** with adapted material.
5. **Backcrossing** and selection with the desired trait.
6. Provide **intermediate lines** to breeders.

It takes approximately **5 to 10 years** before breeders use the material — but it's **crucial**!

Tools for effective pre-breeding

Traditional tools

Crossing and selection

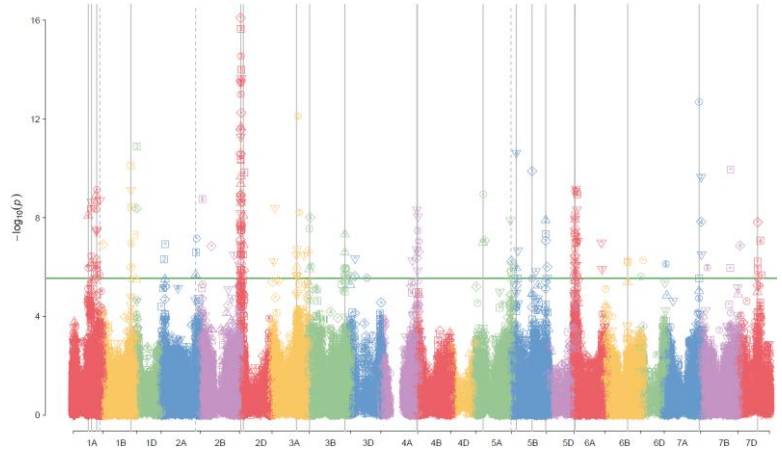
Modern tools

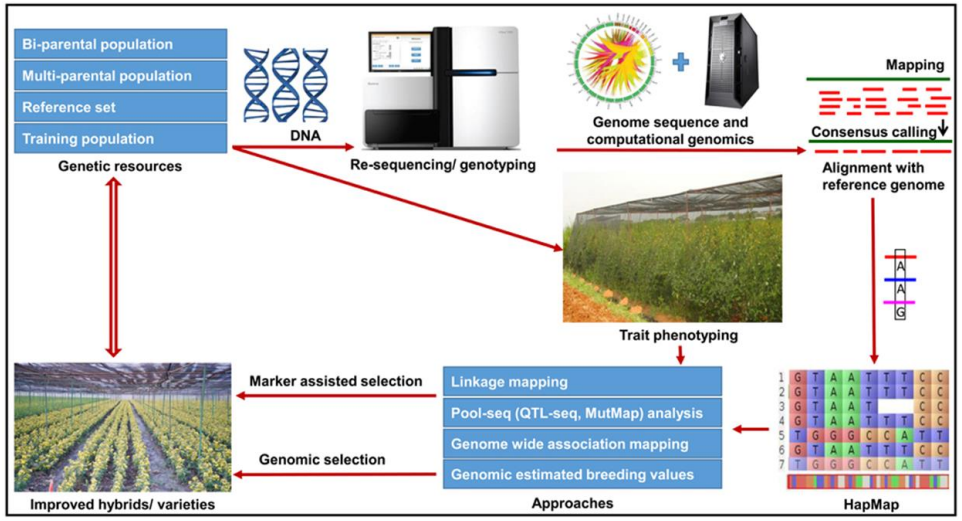
Marker-assisted selection

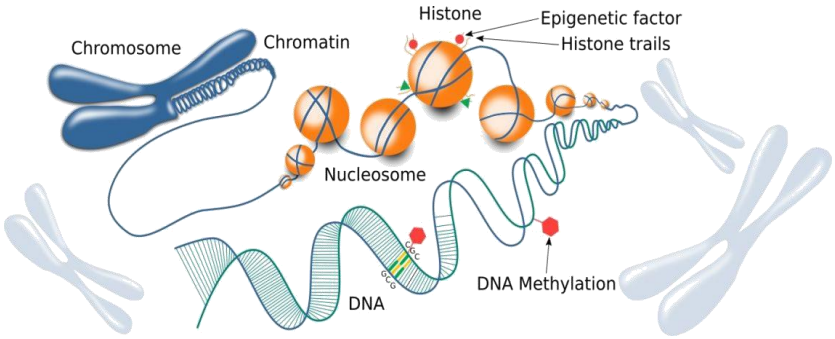
Genomic selection

High-throughput phenotyping

Gene editing



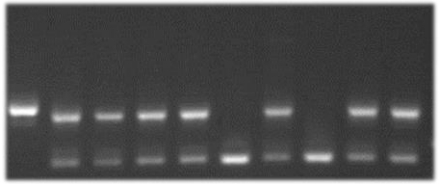




Challenges and opportunities

Challenges
• Linkage drag
• The long timelines
• Limited funding and lower visibility

Opportunities
• Climate change demands stress-resilient traits
• New genomic tools speed up progress
• Sharing resources & expertise

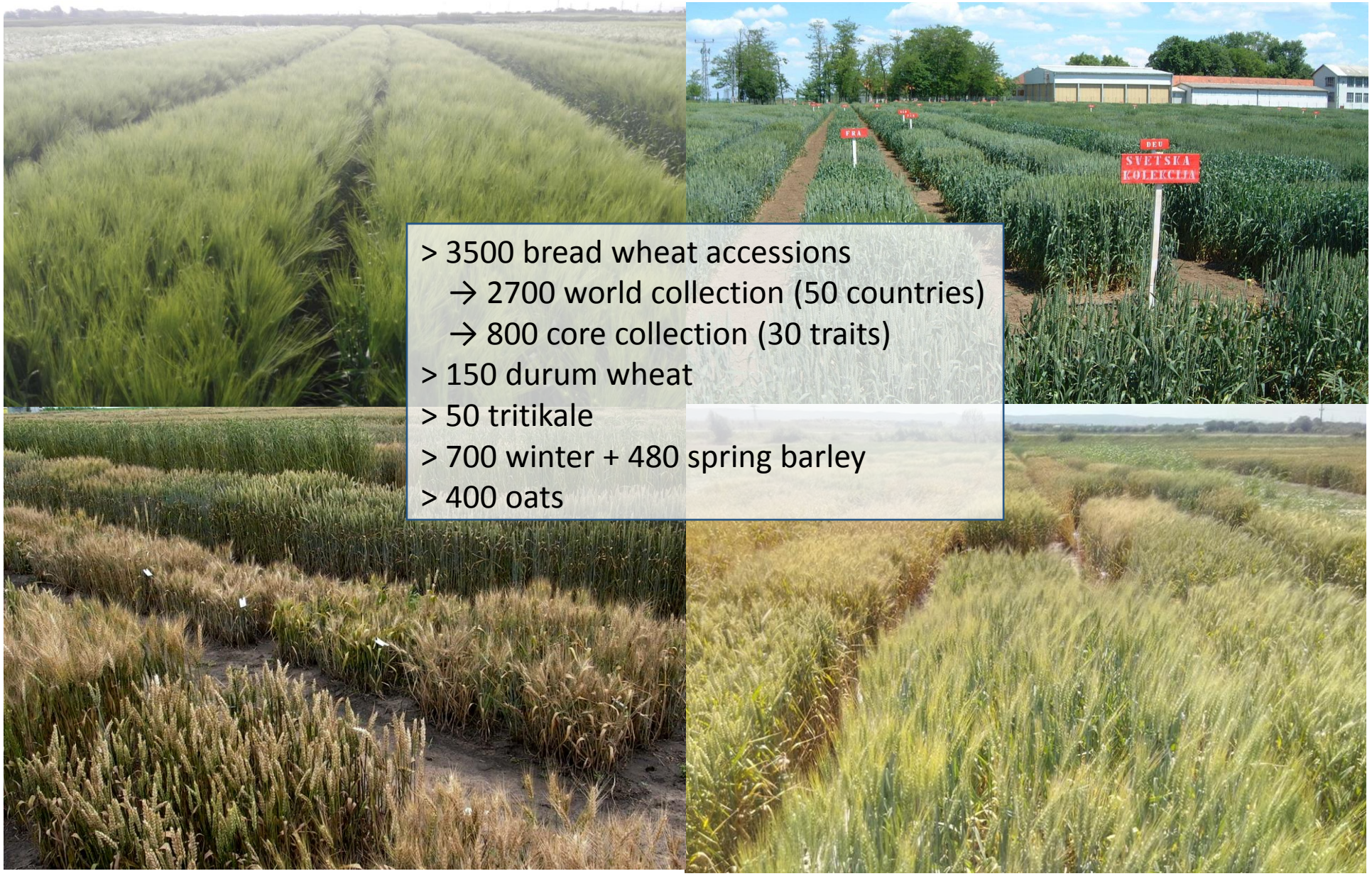


Part 2 – Wheat Examples

Why wheat needs pre-breeding?

- Wheat - 20% calories
- Threats: pathogens, drought, heat, etc.
- Changing consumer demands!
- Green Revolution - breeding relied on a narrow genetic base.
- Pre-breeding helps bring back many potentially useful traits.

Small grains collection at the IFVCNS

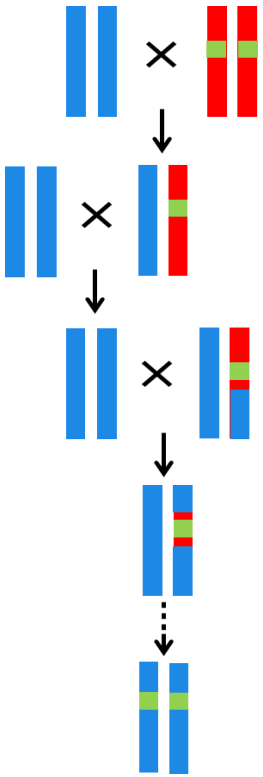


> 3500 bread wheat accessions
  → 2700 world collection (50 countries)
  → 800 core collection (30 traits)
> 150 durum wheat
> 50 tritikale
> 700 winter + 480 spring barley
> 400 oats

Case study 1: Rust resistance

1. Yr genes for yellow rust resistance from *Triticum dicoccoides*
2. Lr genes for leaf rust resistance *Aegilops tauschii*

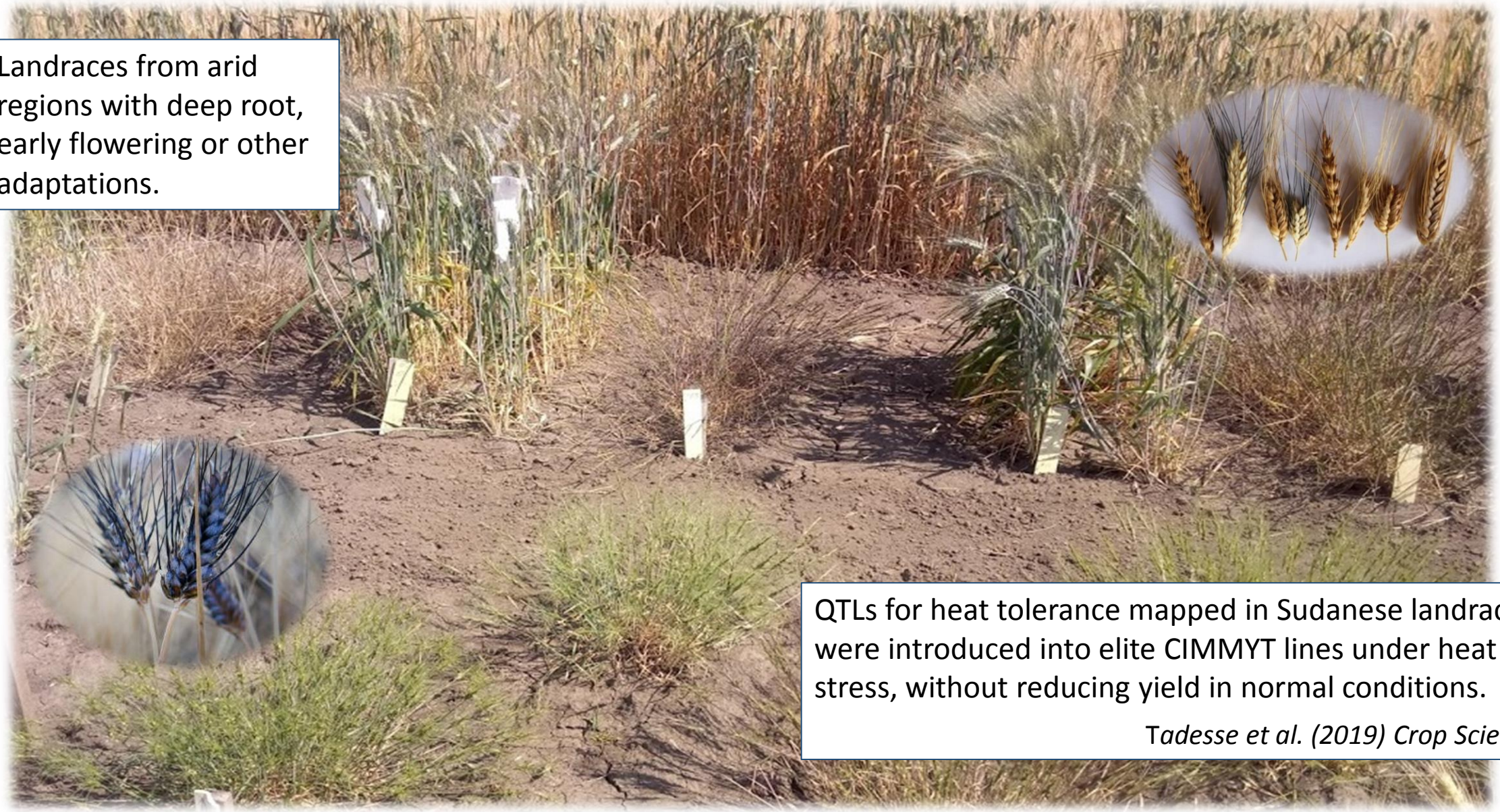
- Cross wild relatives and adapted wheat
- Backcross multiple generations



1. *Triticum dicoccoides*

2. *Aegilops tauschii*

Case study 2: Abiotic stress tolerance



Landraces from arid regions with deep root, early flowering or other adaptations.

QTLs for heat tolerance mapped in Sudanese landraces were introduced into elite CIMMYT lines under heat stress, without reducing yield in normal conditions.

Tadesse et al. (2019) Crop Science

Case study 3: Grain quality

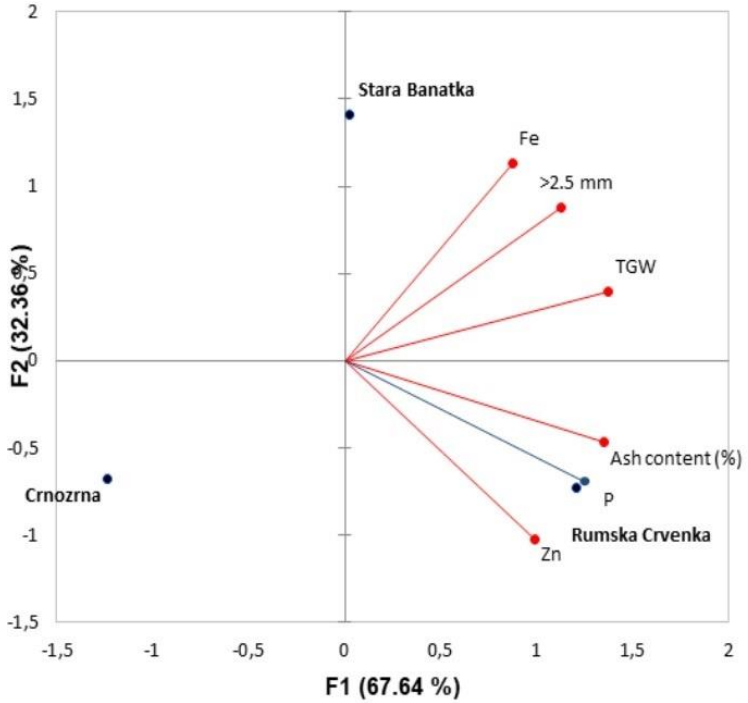
Wheat Cultivar	Ash content (%)	TGW (g d.b.)	>2.8 mm (%)	2.8/2.5 mm (%)	2.5/2.2 mm (%)	<2.2 mm (%)
Belgrade 1	1.73±0.03[a]	34.26±1.46[a]	29.53±1.25[b]	58.40±0.72[b]	7.50±0.35[de]	4.27±0.85[d]
Rumska Crvenka	1.69±0.01[a]	32.15±1.41[ab]	36.13±0.46[a]	49.63±1.60[d]	7.87±0.83[d]	6.03±0.64[d]
Crnozrna	1.65±0.03[ab]	27.31±0.77[b]	15.03±1.07[d]	59.53±0.65[b]	12.97±1.05[c]	12.53±0.06[c]
Crvenica	1.53±0.02[bc]	27.88±1.24[b]	6.80±0.10[e]	60.3±0.75[ab]	17.23±0.64[b]	15.27±0.91[b]
Ševićeva Šišulja	1.53±0.07[bc]	32.01±1.89[ab]	35.17±0.65[a]	54.03±1.29[c]	5.80±0.61[e]	4.67±0.21[d]
Stara Banatka	1.49±0.04[c]	31.03±1.54[ab]	24.60±0.10[c]	63.43±0.57[a]	7.10±0.10[de]	4.57±0.50[d]
Serbia 63	1.46±.0.06[c]	28.18±4.75[ab]	3.10±0.17[f]	49.97±1.77[d]	24.40±0.85[a]	22.23±1.00[a]

Old Banatka

- Ash content >1% dark flour
- Fe 54.9 mg/kg d. b.
- Avg. daily bread portion ~ 90% daily Fe intake

Rumska crvenka

- P 3503 mg/kg d. b.
- Zn 34.40 mg/kg d. b.



Zivancev et al. (2023) Food and Feed Research

Part 3 – Utilization of oilseed genetics

Rapeseed

Safflower

Wild sunflower

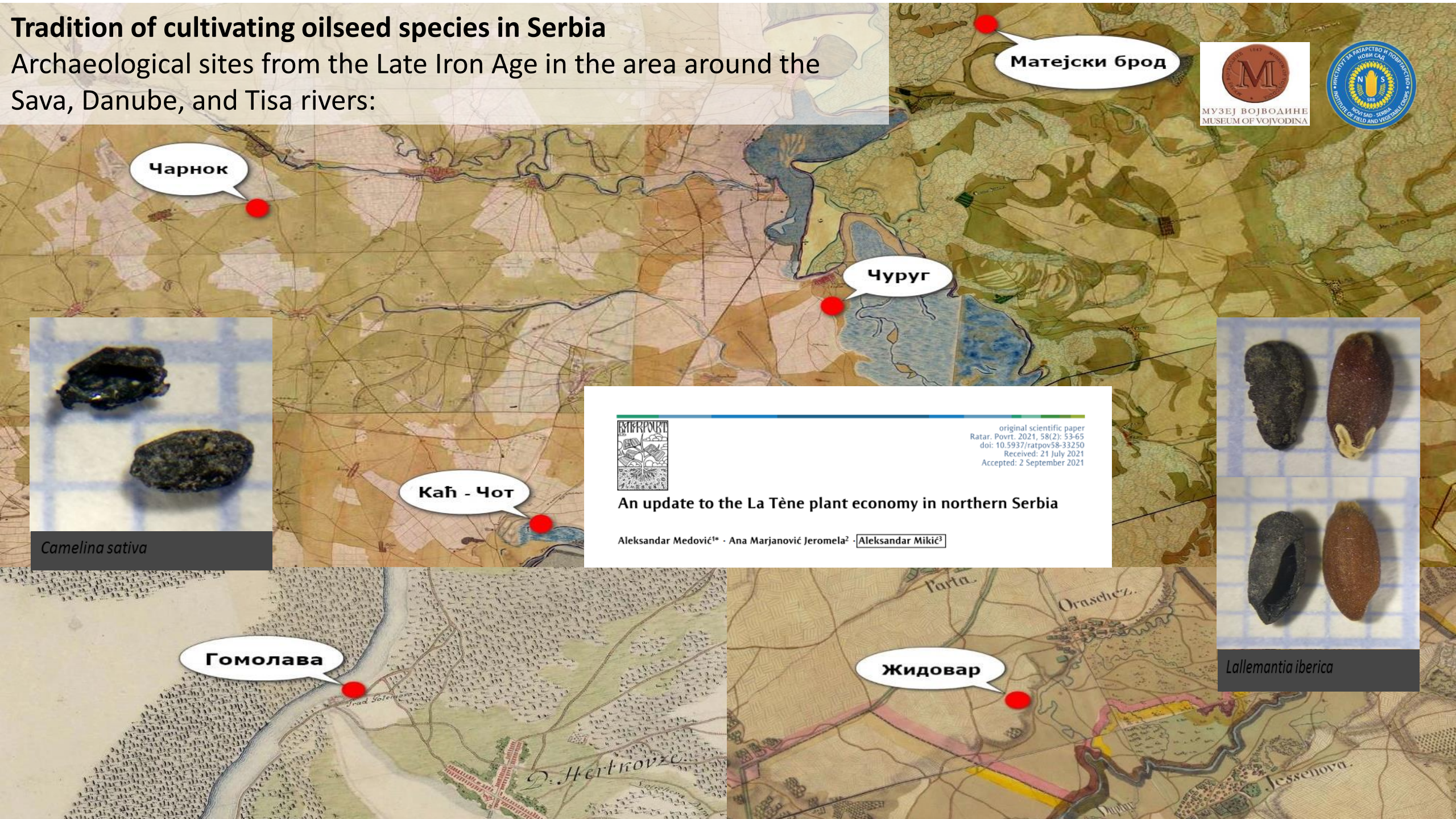
Camelina

Castor

Mary thistle

Tradition of cultivating oilseed species in Serbia

Archaeological sites from the Late Iron Age in the area around the Sava, Danube, and Tisa rivers:



Papaver somniferum

Linum usitatissimum

Archaeobotanical Garden
(Vojvodina Museum)

Camelina sativa

Lallemantia iberica

Genetic resources of sunflower

- Origin: North America
- “Domestication bottleneck” → CWR are a vast genetic pool for crop improvement
- *Helianthus* 53 species = 14 annuals + 39 perennials
- Collections of both cultivated and wild forms
- Most wild accessions ecotypes of wild *H. annuus*, but also 52 other species of *Helianthus* sp.

IFVCNS gene bank

- IFVCNS - One of the largest collections in the world, >7,000 sunflower inbred lines and 27 wild *Helianthus* species (21 perennial, 8 annuals)
- Challenges in overwintering, different soil type, low self-fertility
- Discovery of *cms* and restoration fertility enabled introduction of hybrids
- Sources of resistance to diseases and broomrape, herbicide tolerance
- Improvement of agronomic and morphological traits

Collection of wild species

The biggest collection in Europe

- 447 populations
- Collected mainly in USA

Wild species in NS breeding program

worldwide use of CWR

59% for pest and disease resistance

13% for abiotic stress tolerance

11% for quality improvement

10% for yield increase

4% cms sterility and fertility restoration

Testing populations of wild species to broomrape

Testing F1 hybrids

- Backcrossing F1 with cultivated line
- Sowing F1 and producing F2....

Broomrape (*Orobanche cumana*)

Races, genes and differential lines

Helianthus tuberosus L.

Helianthus maximiliani Schrad.

Helianthus debilis Nutt.

Broomrape races
A, B, C, D, E, F?, G?, H?...

Genes
Or_1, Or_2, Or_3, Or_4, Or_5, Or_6?, Or_7?, Or?...

Differential lines
Set of differential lines for *Or_1, Or_2, Or_3, Or_4, Or_5*

Use of resistant genotypes → **New races of broomrape**

Wild relatives provide **resistance genes** (e.g., OrDeb2) for broomrape.

- **Molecular markers** allow early selection of resistant plants.
- **Gene pyramiding** combines multiple resistance genes for broader protection.
- Advanced tools (phenotyping, genomics, gene editing) **enhance pre-breeding efficiency**.
- Highlights the importance of **wild genetic diversity** in developing resistant sunflower lines.

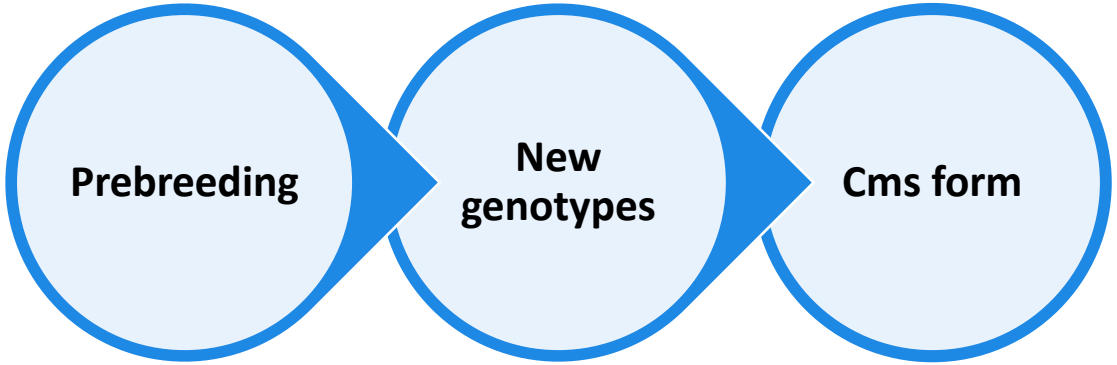
HA-26 (hand emasculation)

×

- *H. debilis* 1848
- *H. praecox* 1341
- *H. petiolaris* 2119
- *H. annuus* 2168
- *H. neglectus* 1181

B-lines

4–5 years 6–8 years



Prebreeding material		RHA lines
F1 S1 DEB 1848	3-6 years →	Ts-s-1-17
F1 S1 DEB 1848	3-6 years →	Ts-s-1-22
F1 S1 PRA 1341	3-6 years →	Ts-s-1-192
F1 S1 PRA 1341	3-6 years →	Ts-s-1-200
F1 S1 PRA 1341	3-6 years →	Ts-s-1-202
BC2 PET 2119	3-6 years →	Ts-bc-30
BC2 PET 2119	3-6 years →	Ts-bc-31
BC2 S2 ANN 2168	3-6 years →	Ts-bc-44
BC2 S2 ANN 2168	3-6 years →	Ts-bc-45

Cvejic et al., 2020. Genes 11, 152

Herbicide tolerance

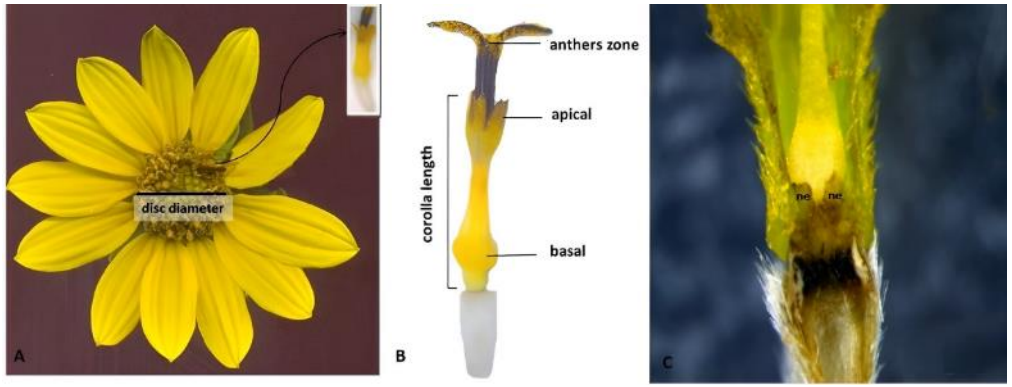
AHAS (AcetoHydroxyAcid Synthase) /
ALS (AcetoLactate Synthase) herbicides
control broadleaf weeds and annual grasses

- Dominant genes or with a modifier

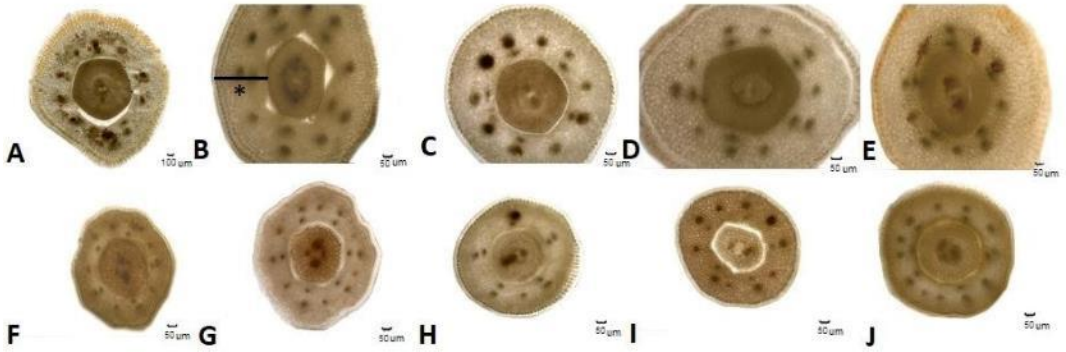
IMI, SUMO

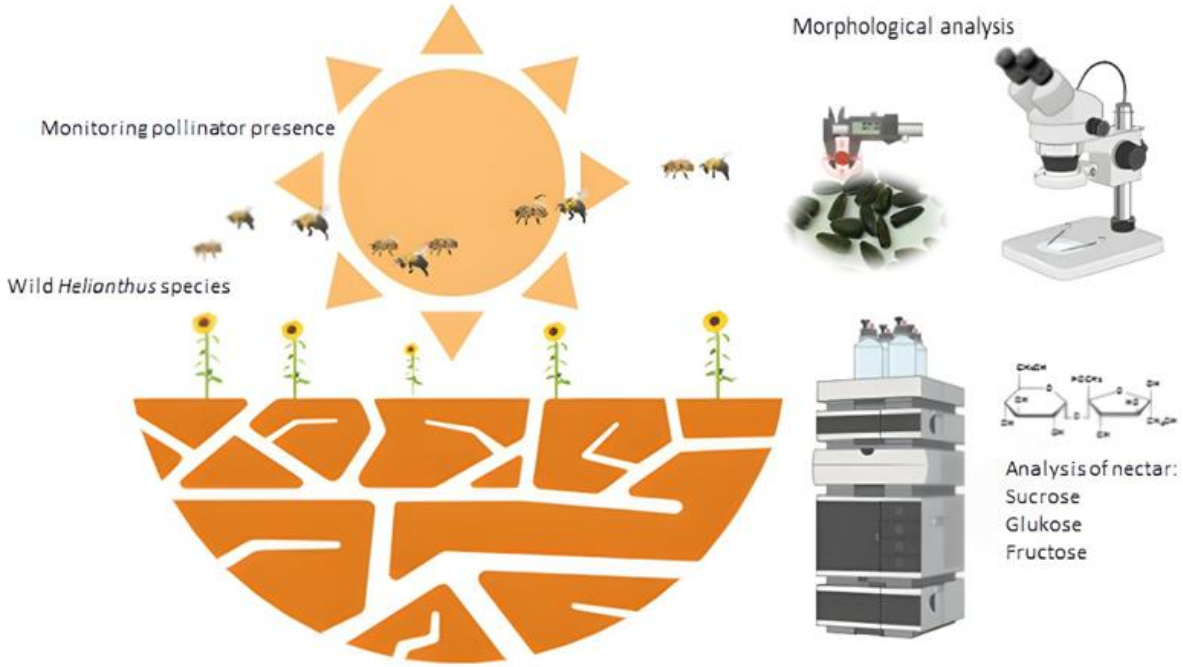
Secretory organs and volatile organic compounds significant for flower attractiveness to pollinators

Attractiveness of the reproductive region of wild sunflower species for drought adaptation and cultivated sunflower improvement



H. mollis





plants MDPI

Article

Secretory Tissues and Volatile Components of Disc Florets in Several Wild *Helianthus* L. Species

Jelena Jocković [1,*], Nemanja Rajčević [2], Lana Zorić [3], Milan Jocković [1,*], Aleksandra Radanović [1], Sandra Cvejić [1], Siniša Jocić [1], Ljubodrag Vujisić [4], Dragana Miladinović [1], Vladimir Miklič [1] and Jadran

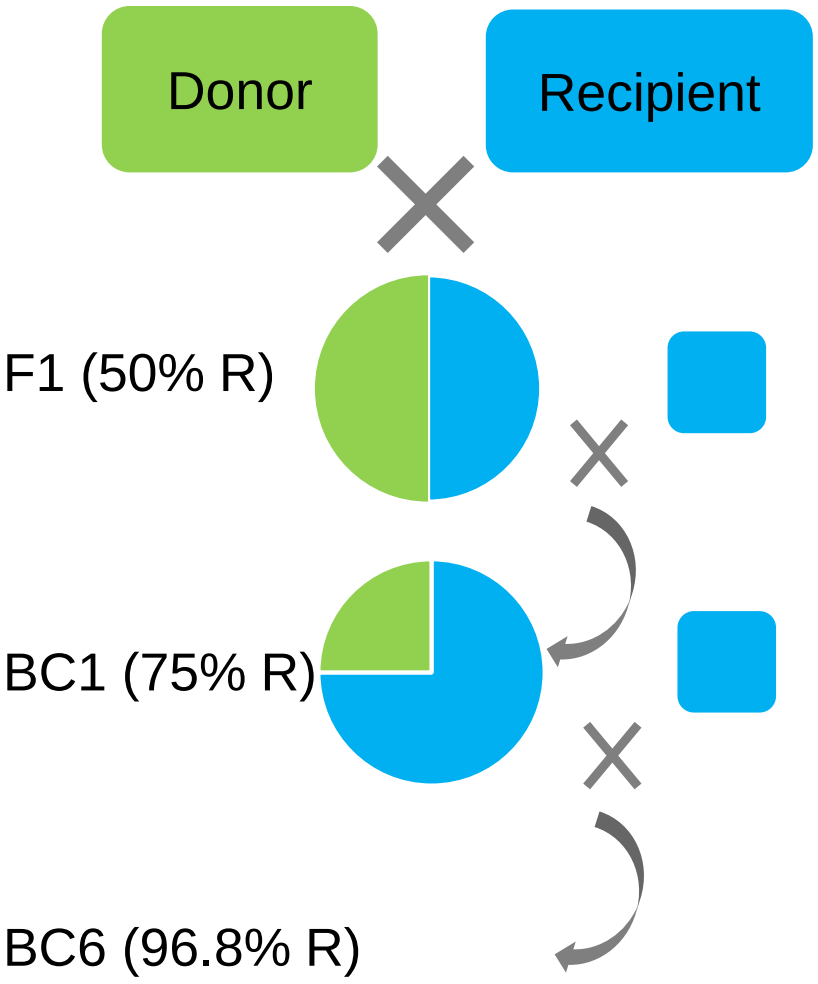
Genetic resources of rapeseed

- *Brassica napus* = *B. rapa* x *B. oleracea*, no wild forms
- Origin: Europe
- Modern breeding material-narrow genetic diversity
- ECPGR Database passport data for 3,500+ *B. napus* accessions
- IFVCNS collection: 11 varieties + 20 lines (spring), 56 varieties + 980 lines (winter)
- Phenotypically and cytogenetically characterized
- To develop productive genotypes for food and non-food oils,

esp. low-input systems, marginal soils, for conventional and organic farming.

Rapeseed - expending genetic variability

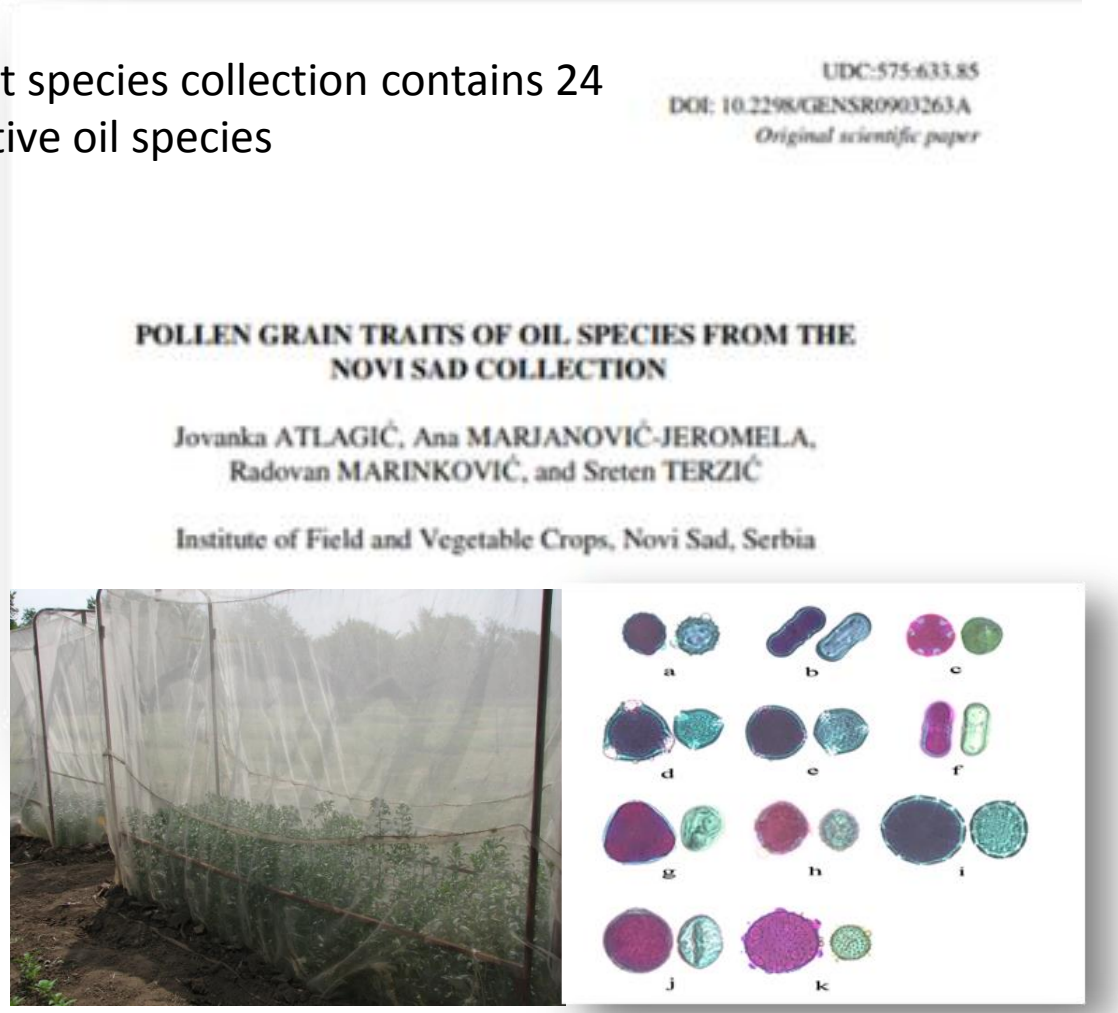
- Interspecific hybridisation
- Production of resynthesized rapeseed
- Transfer of blackleg, clubroot resistance



Collection maintenance

Experimental field of IFVCNS at Rimski Šančevi, Novi Sad

Oil plant species collection contains 24 alternative oil species



UDC:575:633.85
DOI: 10.2298/GENSR0903263A
Original scientific paper

POLLEN GRAIN TRAITS OF OIL SPECIES FROM THE NOVI SAD COLLECTION

Jovanka ATLAGIĆ, Ana MARJANOVIĆ-JEROMELA, Radovan MARINKOVIĆ, and Sreten TERZIĆ

Institute of Field and Vegetable Crops, Novi Sad, Serbia

- Alternative species of interest are those that combine positive agronomic traits
- Seed and oil yield, nutritive value, pathogen tolerance and suitable vegetation length
- With various usage options as edible oils or byproducts (industrial processing)

Brassica accessions collected in Serbia in 2021

No.	Family	Genus	Subnomen	Subspecies	Location 1	Location 2	Location 3	UTM	Habitat	Substrate	Altitude	Legator	Determinator
1	Brassicaceae	Alyssoides Mill.	*Alyssoides utriculata (L.) Medik.*	*utriculata*	Serbia	Klisura reke Jerme	Odorovačko zdrelo						
2	Brassicaceae	Alyssum	*Alyssum orientale*		Serbia	Klisura reke Jerme	Poganovski manastir						
3	Brassicaceae	Aurinia Desv.	*Aurinia corymbosa* Griseb.		Serbia	Sićevačka klisura	Sićevo, bran						
4	Brassicaceae	Aurinia Desv.	*Aurinia saxatilis* (L.) Desv.	*orientalis* (Ard.) T. R.	Serbia	Klisura reke Jerm	Manastir Sv van, kod r						
5	Brassicaceae	Brassica	*Brassica rapa* L.	*campestris*	Serbia		emska						
6	Brassicaceae	Brassica	*Brassica rapa* L.	*campestris*	Serbia	Stara planina	Temska						
7	Brassicaceae	Brassica	*Brassica rapa* L.	*campestris*	Serbia	Stara planina	Temska						
8	Brassicaceae	Brassica	*Brassica rapa* L.	*campestris*	Serbia	Stara planina	Temska						
9	Brassicaceae	Brassica	*Diplotaxis tenuifolia* (L.) DC.	*tenuifolia*	Serbia	Niš	Klinički cent						
10	Brassicaceae	Diplotaxis DC.	*Diplotaxis tenuifolia* (L.) DC.	*tenuifolia*	Serbia	Niš	Klinički cent						
11	Brassicaceae	Diplotaxis DC.	*Diplotaxis tenuifolia* (L.) DC.	*tenuifolia*	Serbia	Niš	Klinički cent						
12	Brassicaceae	Diplotaxis DC.	*Diplotaxis tenuifolia* (L.) DC.	*tenuifolia*	Serbia	Niš	Romsko nas						
13	Brassicaceae	Diplotaxis DC.	*Diplotaxis tenuifolia* (L.) DC.		Serbia	Sićevačka klisura	između tune						
14	Brassicaceae	Diplotaxis DC.	*Diplotaxis tenuifolia* (L.) DC.		Serbia	Niš	Trošarina						
15	Brassicaceae	Isatis L.	*Isatis tinctoria* L.	*tinctoria*	Serbia								
16	Brassicaceae	Isatis L.	*Isatis tinctoria* L.	*tinctoria*	Serbia	Klisura reke Jerme	Manastir Sv, Jovan, kod m						
17	Brassicaceae	Lunaria L.	*Lunaria annua* L.	*pachyrhiza* (Borbás) Hayek	Serbia	Sićevačka klisura	Sićevo, brana						
18	Brassicaceae	Lunaria L.	*Lunaria annua* L.	*pachyrhiza* (Borbás) Hayek	Serbia	Sićevačka klisura	Sićevo, brana						
19	Brassicaceae	Raphanus L.	*Raphanus raphanistrum* L.		Serbia	Niš	Klinički centa						
20	Brassicaceae	Raphanus L.	*Raphanus raphanistrum* L.		Serbia	Niš	Niška banja						
21	Brassicaceae	Sinapis L.	*Sinapis arvensis* L.	*arvensis*	Serbia	Dimitrovdrad	Radejna						
22	Brassicaceae	Sinapis L.	*Sinapis arvensis* L.	*arvensis*	Serbia	Dimitrovdrad	Donji Krivodol	22.905408	arable soil				
23	Brassicaceae	Sinapis L.	*Sinapis arvensis* L.		Serbia	Novi Sad	ul. Marije Bursać	45.236370, 19.791623	arable soil				
24	Brassicaceae	Sisymbrium	*Sisymbrium loiselii* L.		Serbia	Niš	Niška banja	43°17'37"N, 22°00'29"E	ruderal area		230	Marković, M.	
25	Brassicaceae	Sisymbrium	*Sisymbrium loeselii* L.		Serbia	Novi Sad	ul. Marije Bursać	45.235172, 19.792977	nearby road at the orchard		75	Rajković, D.	Rajković, D., Marković, M.

Alternative crops - opportunities and risks

- Promotion of biodiversity and human health
- Economic benefits
- New market opportunities
- Environmental protection

- Lack of cultivars
- Limited information on cultural practices
- Marketing and handling issues
- Policy and research issues

Avg temp Jan, 19	2016.	2018.	2019.	2020.	2021.	2022.	2023.	2024.	2025.
	-3,6	5,4	0,7	-0,5	-1,5	-0,4	6,7	3,3	-2,2

Photo: Marjanović Jeromela & Milovac

Camelina sativa L.

- Camelina is cultivated for its seed and above-ground biomass
- Suitable for cultivation
  - on soils of lower natural fertility and in arid areas.
  - under reduced and conservation tillage systems.
- A short-season crop, can be sown at different times (winter, early spring, subsequent, or stubble crop).

agronomy MDPI
Article

Yield-Related Traits of 20 Spring Camelina Genotypes Grown in a Multi-Environment Study in Serbia

Boris Kuzmanović [1], Sofija Petrović [1], Nevena Nagl [2], Velimir Mladenov [1], Nada Grahovac [2], Federica Zanetti [3], Christina Eynck [4], Johann Vollmann [5] and Ana Marjanović Jeromela [2,*]

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Editorial

Camelina germination under osmotic stress – Trend lines, time-courses and critical points

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REVIEW ARTICLE

Camelina, an ancient oilseed crop actively contributing to the rural renaissance in Europe. A review

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Camelina - future perspectives

Funded by the European Union

- A considerable agronomic potential, a unique fatty acid composition
- Seed yield and oil content the breeding targets
- Competitiveness with other oilseed crops
- New varieties with broad genetic variability
- Research and crop management practices
- Specific agroecological conditions, production systems, the processing industry requirements.

Why safflower?

Carthamus tinctorius L.
annual crop, *Asteraceae (Compositae)* family.

- ✓ Seasons alternating droughts - floods
- ✓ Important for adaptation & agrobiodiversity

source	C14:0 Myristic	C16:0 Palmitic	C18:0 Stearic	C18:1 Oleic	C18:2 Linoleic	C18:3 Linolenic	C20:0 Arachidic	C20:1 Eicosapentaenoic	C22:0 Behenic	C22:1 Erucic	C24:0 Lignoceric
Sunčana	0.13	5.54	2.43	11.46	79.62	0.19	0.24	0.15	0.13	0.00	0.07
Bird 1	0.13	5.47	2.44	16.08	74.57	0.53	0.29	0.18	0.19	0.00	0.07
Liman	0.12	6.27	3.53	15.98	72.48	0.62	0.40	0.20	0.24	0.00	0.09
Bird 2	0.13	5.92	2.43	12.24	77.98	0.58	0.25	0.17	0.17	0.00	0.06
'Remzibey'	0.11	5.62	2.52	29.53	61.18	0.22	0.31	0.20	0.21	0.00	0.08
'Dinçer'	0.12	6.03	2.14	13.19	77.66	0.23	0.25	0.12	0.17	0.00	0.07
'Yenice'	0.12	5.92	3.18	9.60	80.24	0.22	0.31	0.15	0.18	0.00	0.08
Literature	01-0.5	4-8.6	1.7-2.80	8.1-18.4	71.5-83.7	0.07-0.1	0-0.4	0-0.2			

Safflower - further breeding objectives

Objectives:

↑ oleic acid - extended shelf life

↓ lowering hull content

↑ protein content

↑ disease resistance

↑ tolerance to abiotic factors

Added value:

- crop rotation
- small areas/households
- additional income
- agrobiodiversity
- food diversity…

Take-home messages

- **Pre-breeding bridges the gap between genetic resources and breeding programs.**
- **Genetic diversity is essential for crop resilience and continued yield improvement.**
- **The old genes can solve new problems.**
- **Many traits breeders need already exist in landraces or wild relatives — need to be reintroduced.**
- **Our examples show how pre-breeding delivers real benefits, from disease resistance to improved quality.**

Thank you for your attention!

Any questions?

Photo: Filip Franeta