EXPLORING THE POTENTIAL OF *BRASSICA* CROP WILD RELATIVES: INSIGHTS FOR SUSTAINABLE AGRICULTURE AND BIODIVERSITY CONSERVATION

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USDA

BRASSICA CROP DIVERSITY IS UNMATCHED


















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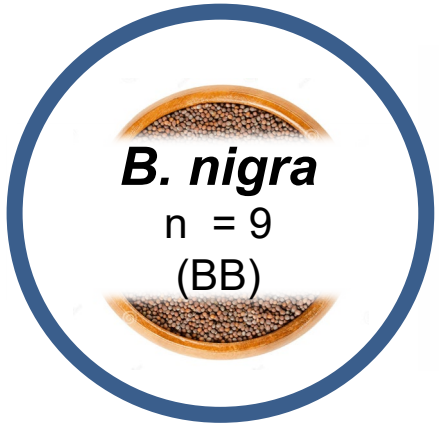

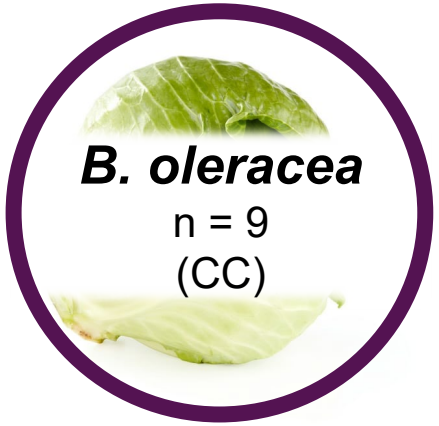

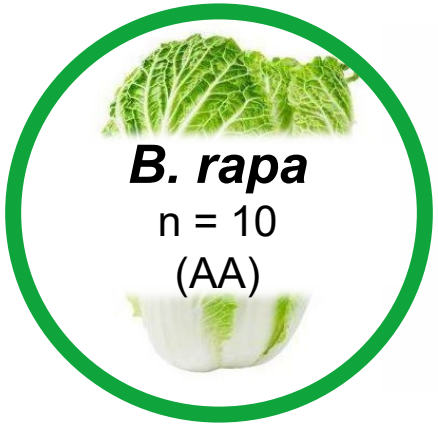

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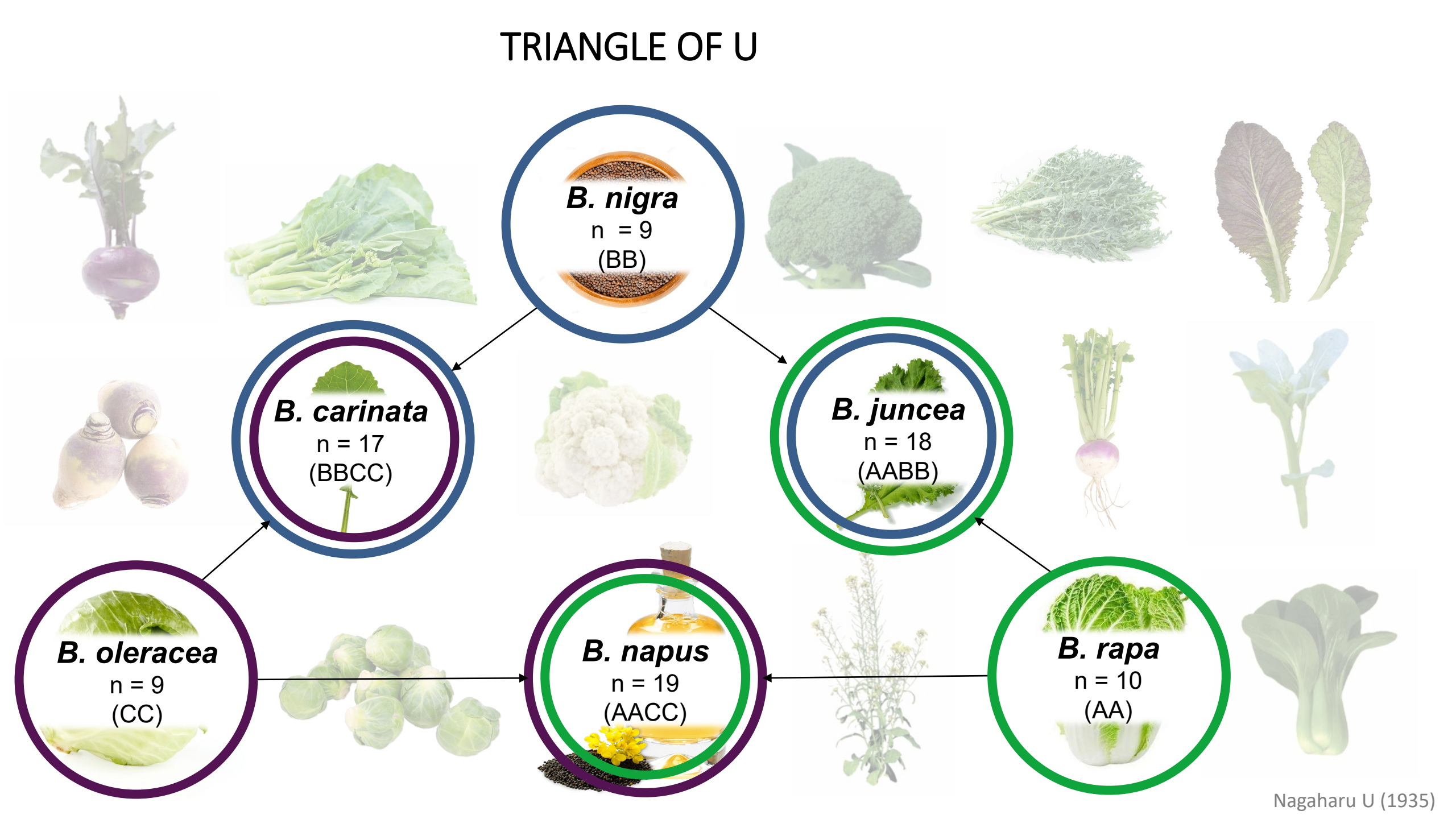

Nagaharu U (1935)

WILD BRASSICAS – CROP WILD RELATIVES (CWRs)

- A **crop wild relative (CWR)** is a wild plant closely related to a domesticated plant. It may be a wild ancestor of the domesticated (cultivated) plant or another closely related taxon.

WILD BRASSICAS – CROP WILD RELATIVES (CWRs)

Includes 37 Accepted Species

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- *Brassica assyriaca*
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- *Brassica balearica*
- *Brassica barrelieri*
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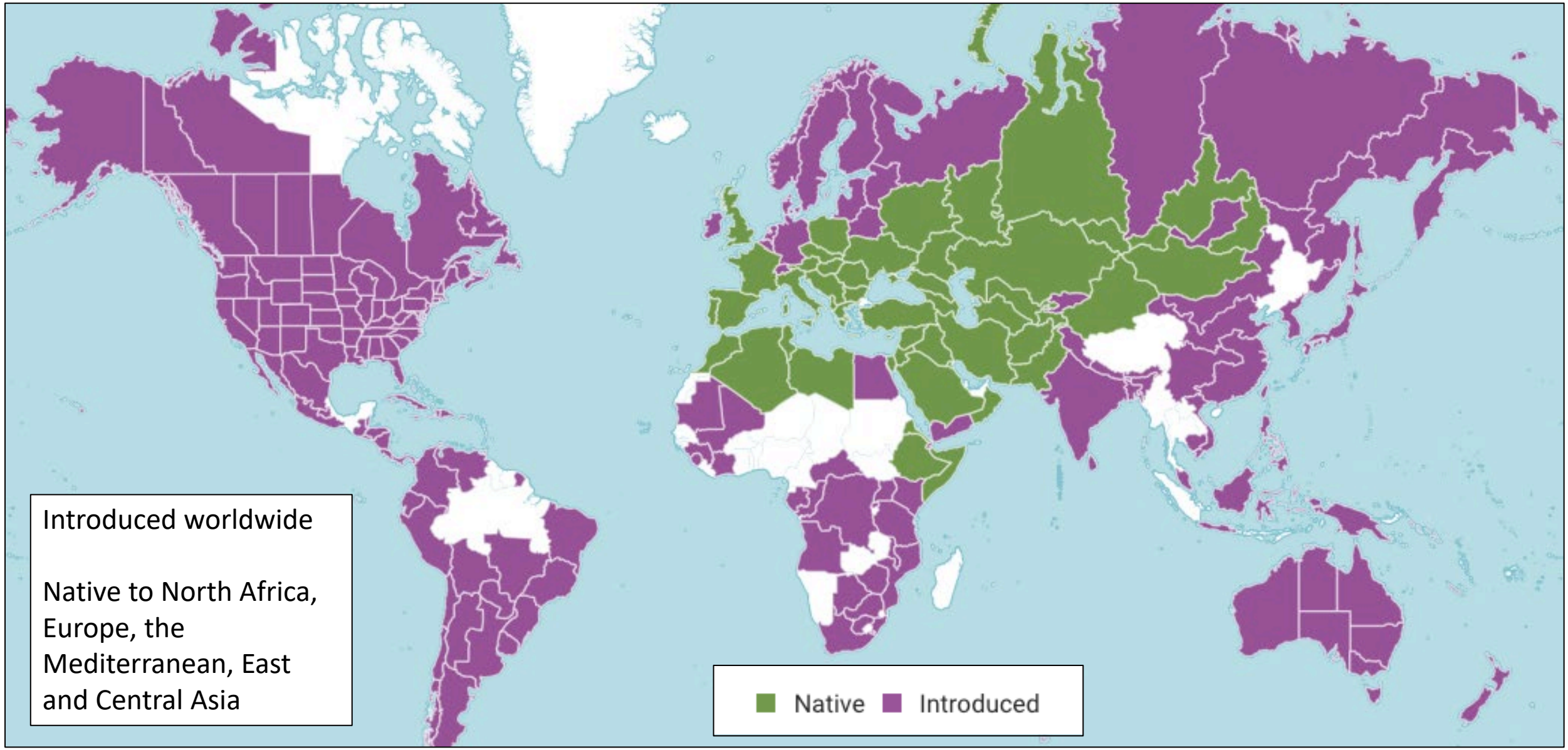
- *Brassica trichocarpa*
- *Brassica tyrrhena*
- *Brassica villosa*

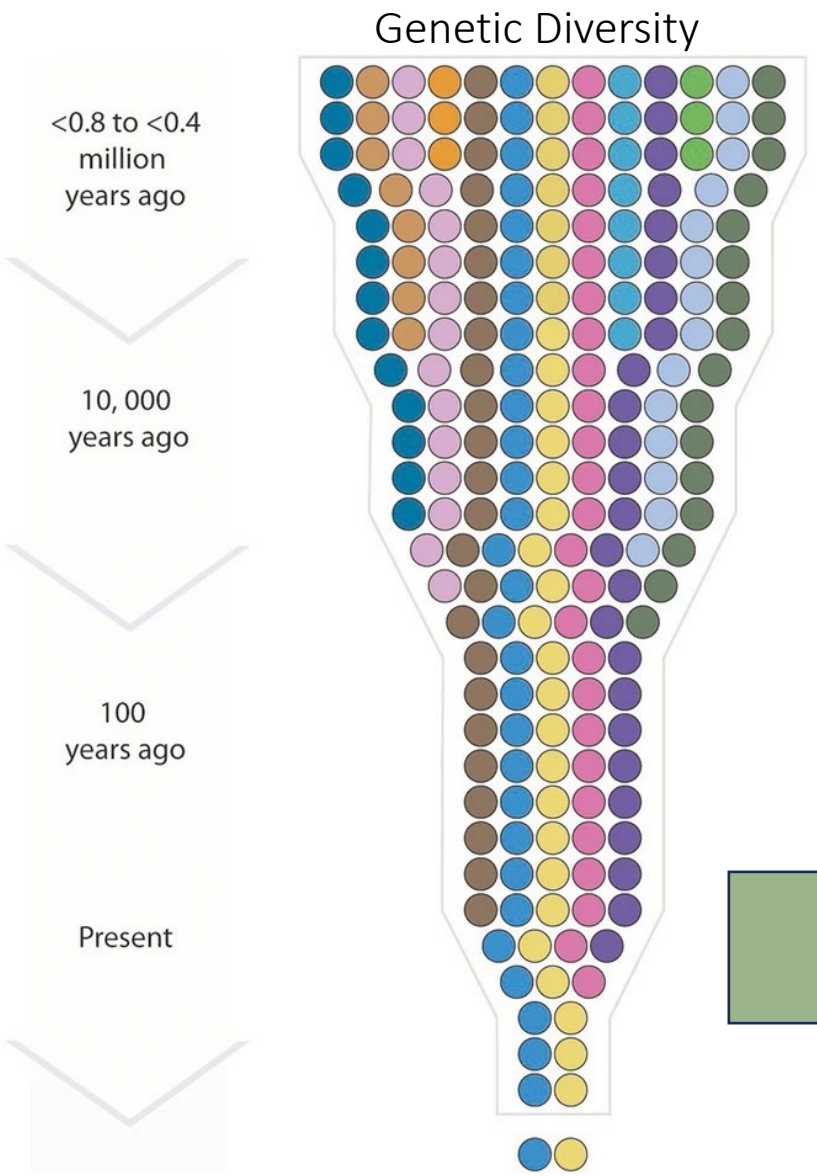
Plants of the World Online

WILD BRASSICAS – WORLDWIDE DISTRUBUTION



Plants of the World Online

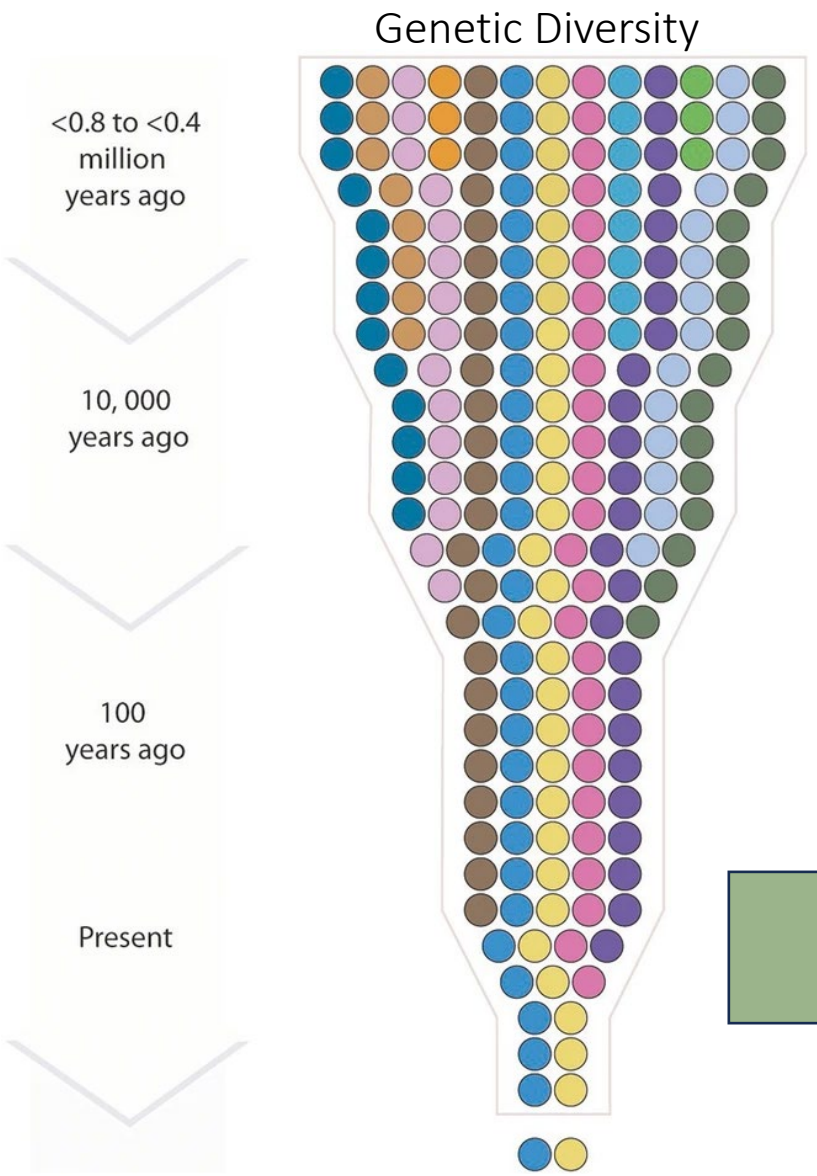
WILD BRASSICAS HAVE HIGH GENETIC DIVERSITY



Low genetic diversity

Voss-Fels et al. 2019

WILD BRASSICAS HAVE HIGH GENETIC DIVERSITY



Wild Brassicas

High genetic diversity

Low genetic diversity

Voss-Fels et al. 2019

WILD BRASSICAS – CROP WILD RELATIVES (CWRs)

Brassica cretica

Brassica montana

Brassica tournefortii

Plants with high tolerance for drought, heat, salinity, etc.

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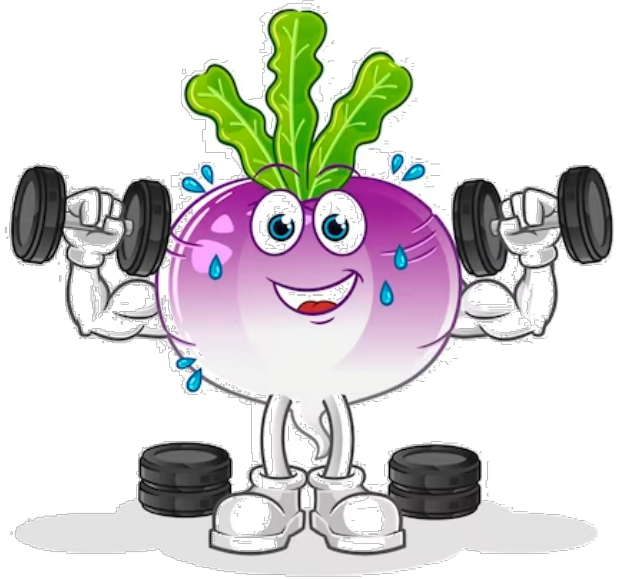
Breeding Resilient Crop Breeds or Climate Ready Crops



In order to fully leverage CWRs,
we must first work to understand their relationships
to the crop of interest.

THE ROLE OF CWRs IN DOMESTICATION

1 – Brassica oleracea

illustrations by Andi Kur

2 – Brassica rapa

Brassica napus

THE EVOLUTIONARY HISTORY OF WILD, DOMESTICATED, AND FERAL *BRASSICA OLERACEA* (BRASSICACEAE)

Molecular Biology and Evolution, Volume 38, Issue 10, October 2021, Pages 4419–443


Sarah Turner-Hissong


Evan Gallagher


Alex McAlvay


Hong An


Patrick Edger

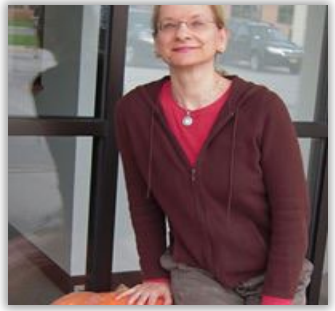

Jonathan Moore


David Pink


Graham Teakle


Chris J. Stevens


Guy Barker


Joanne Labate


Dorian Fuller


Robin Allaby


Timothy Beissinger


Jared Decker


Michael Gore


J. Chris Pires

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BRASSICA OLERACEA – THE DOG OF THE PLANT WORLD

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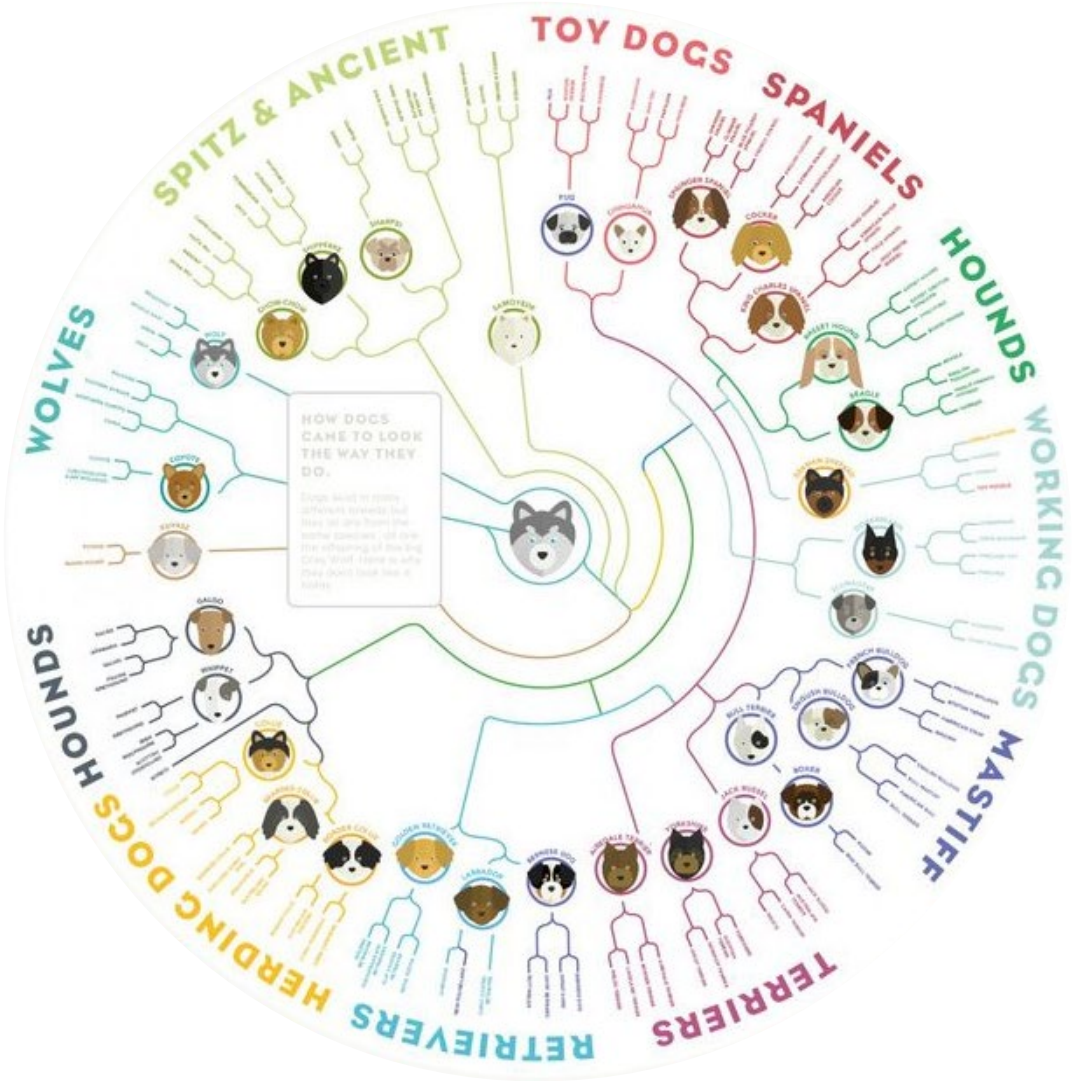

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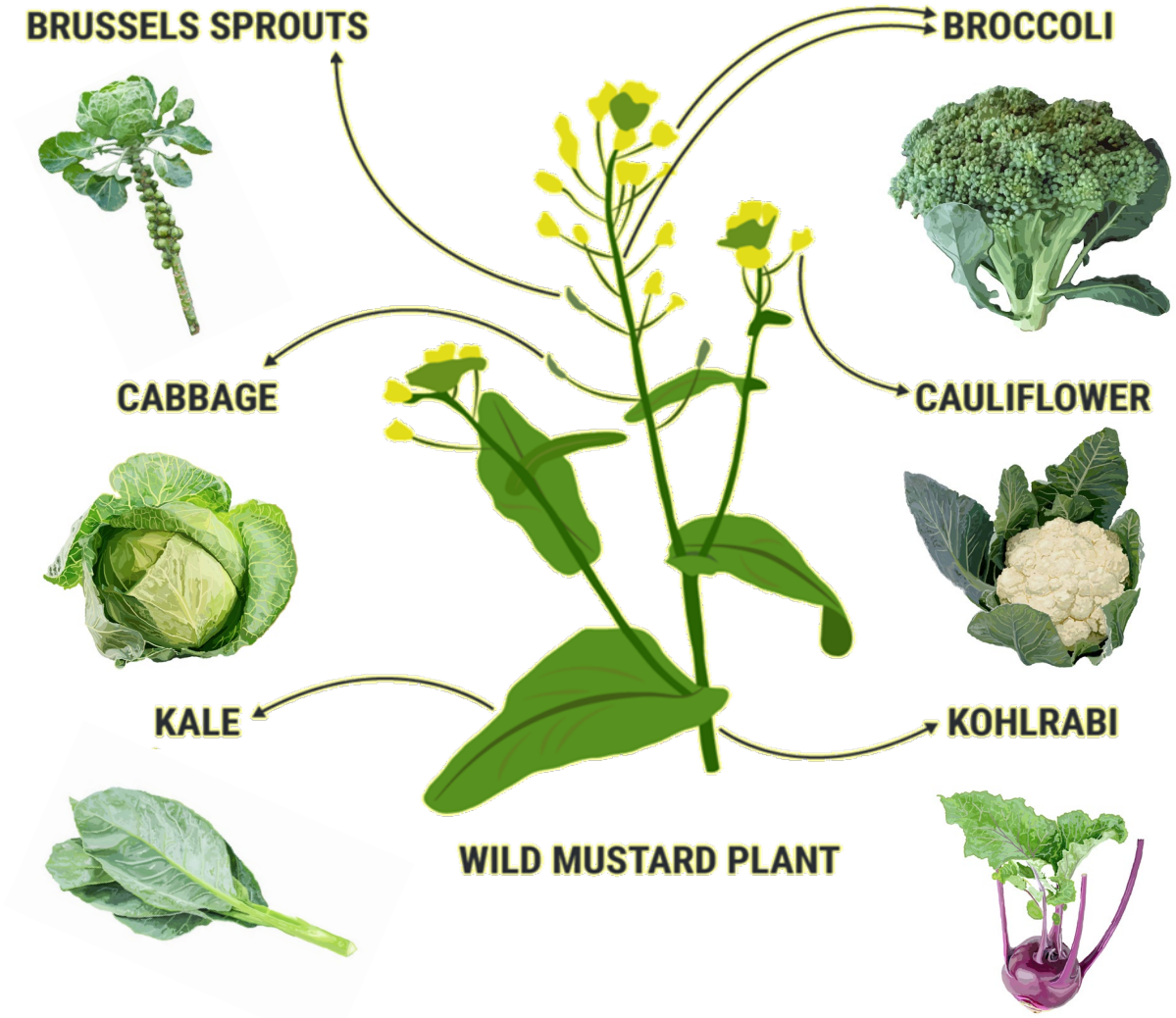
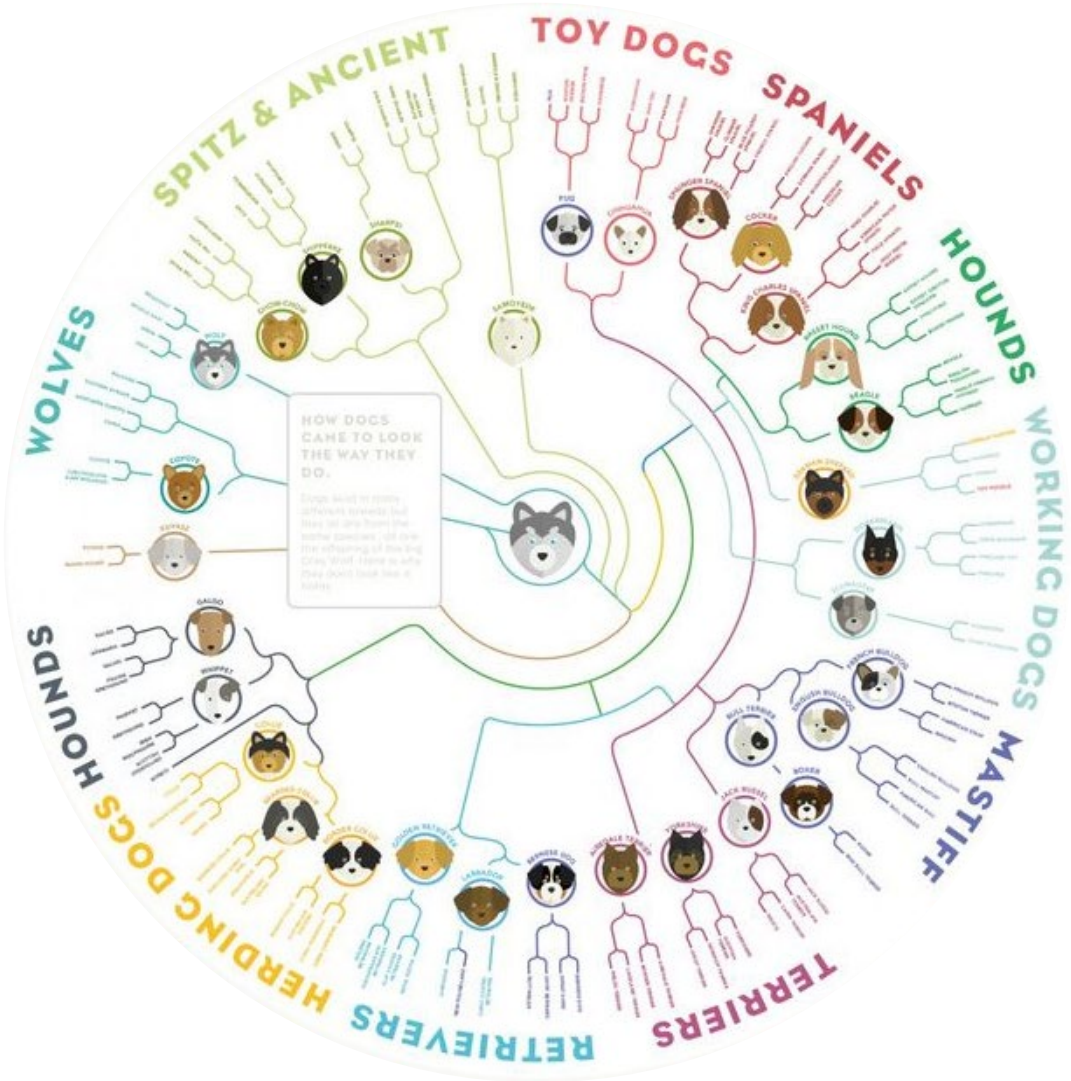
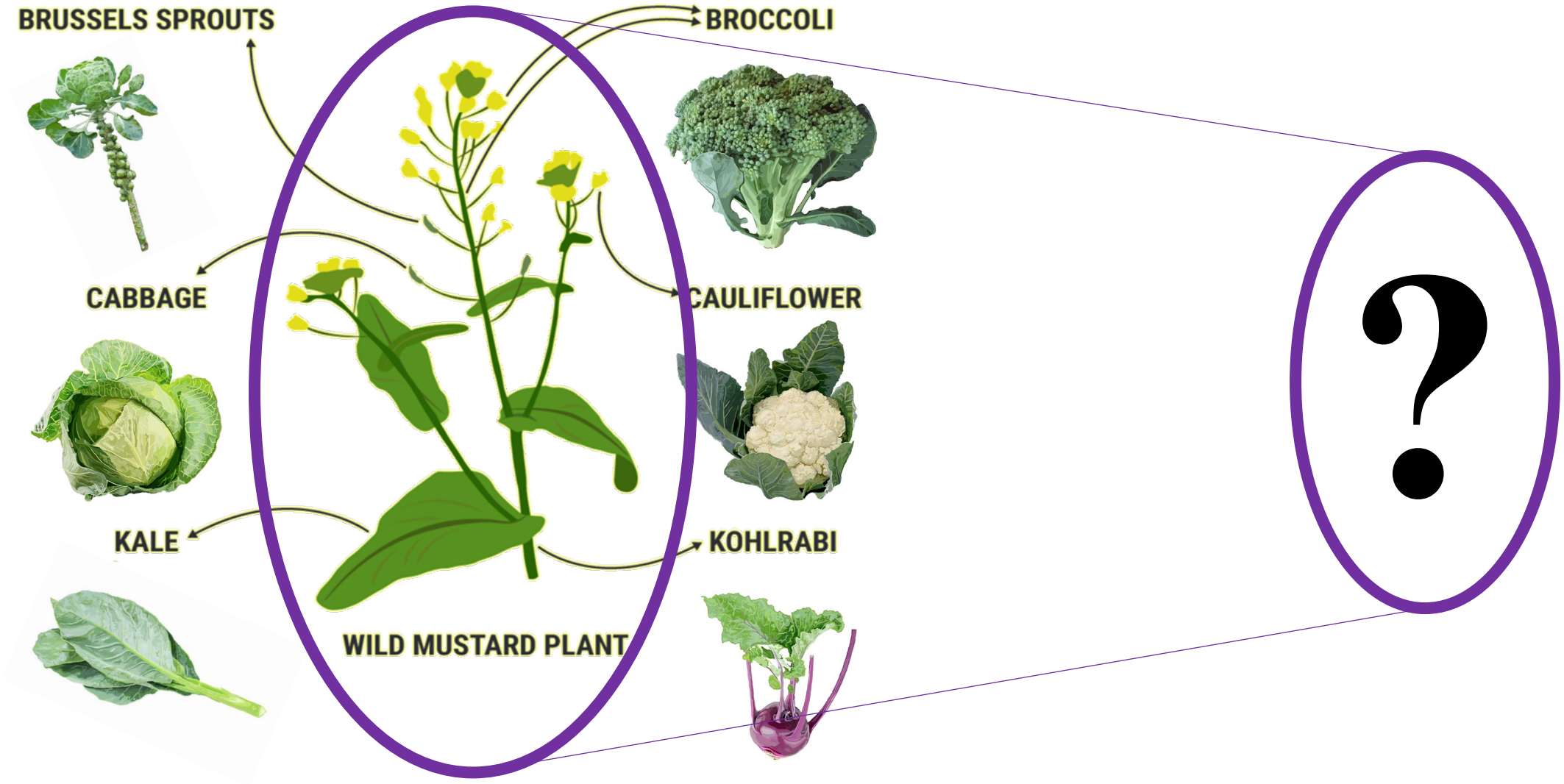




UNKNOWN WILD RELATIVE



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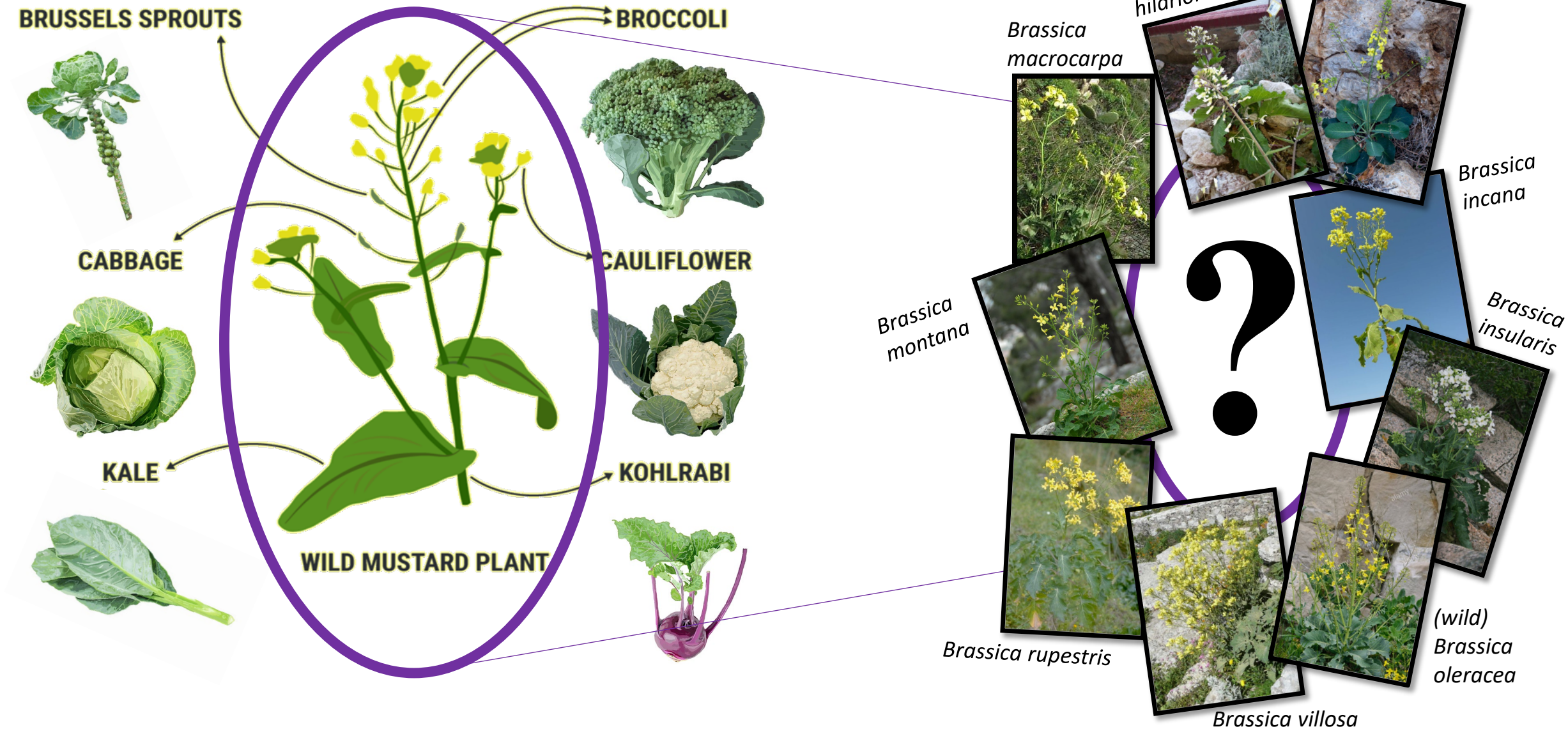

WILD BRASSICAS – *BRASSICA OLERACEA* RELATIVES

8 species with the CC genome

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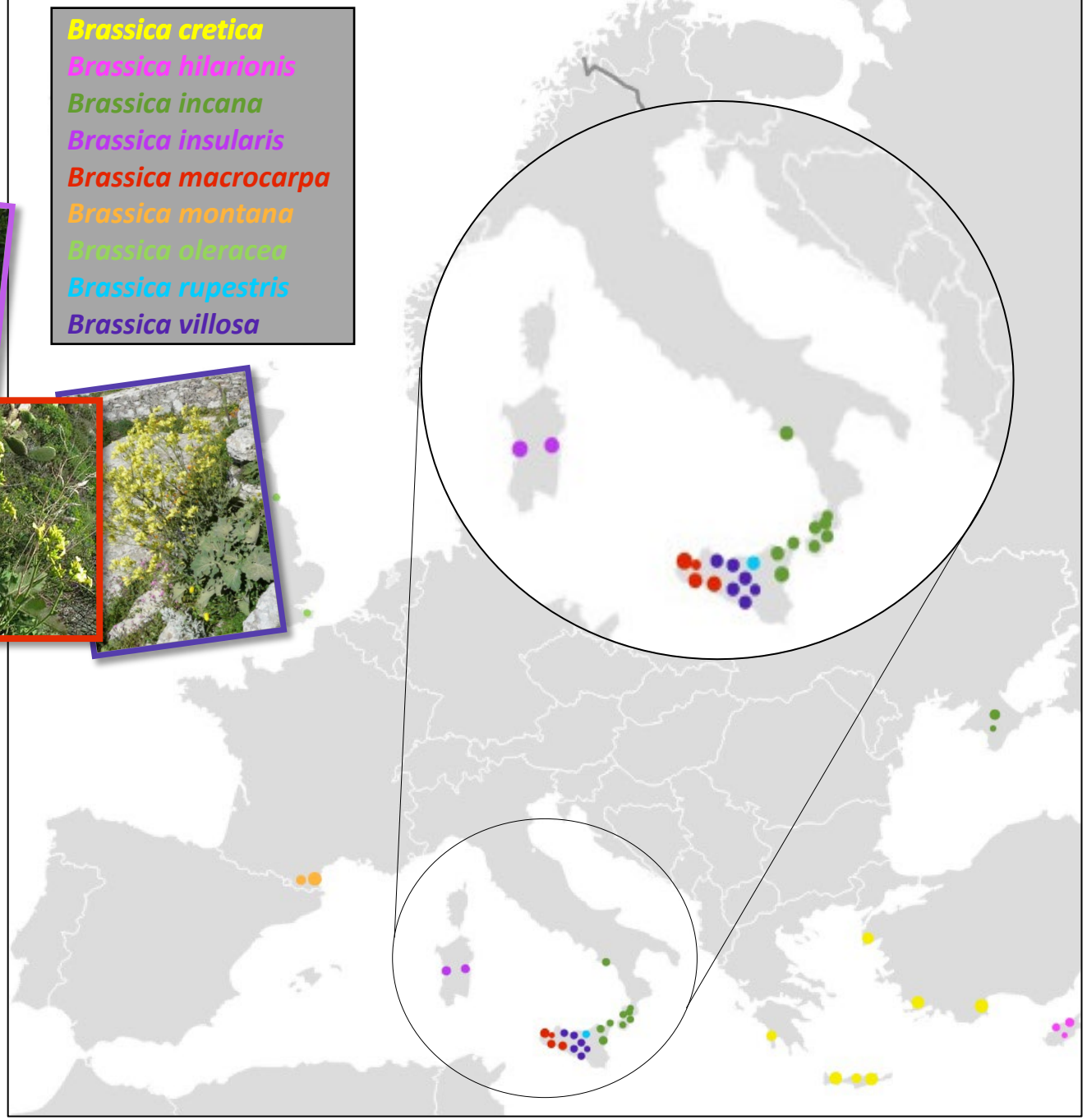
- ***Brassica villosa***

UNKNOWN DOMESTICATION ORIGIN

1. Italy/Sicily

-Center of diversity

(*B. macrocarpa*, *B. incana*, *B. rupestris*, *B. insularis*, *B. villosa*)



Vavilov 1951

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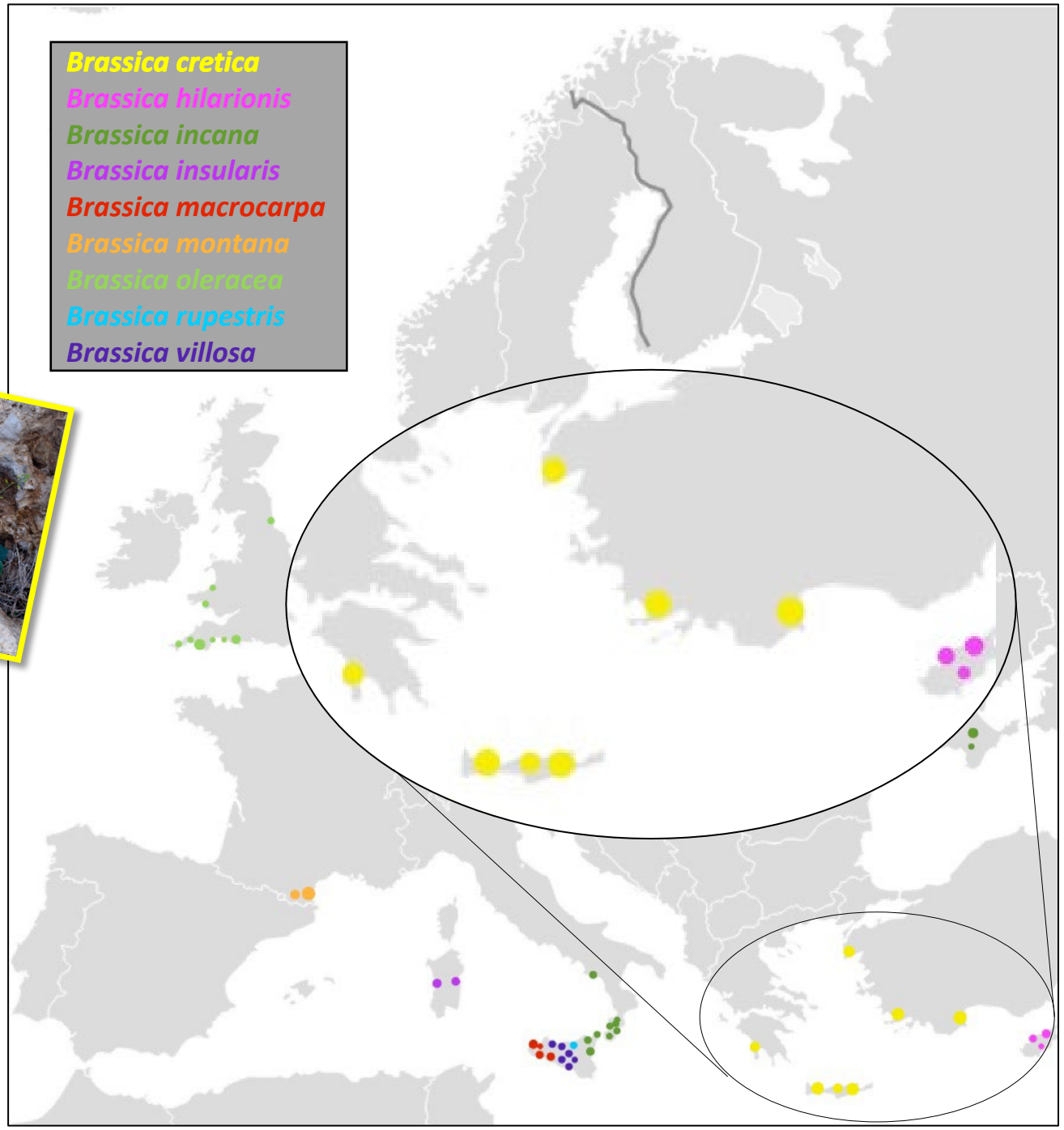
2. Eastern Mediterranean

-Linguistics and literary

(*B. cretica* and *B. hilarionis*)



Maggioni et al. 2018

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3. England

– Wild cabbage

(wild *B. oleracea*)

MAIN QUESTION

- Which wild relative is most closely related to *Brassica oleracea* and where is the center of domestication?

DATA COLLECTION

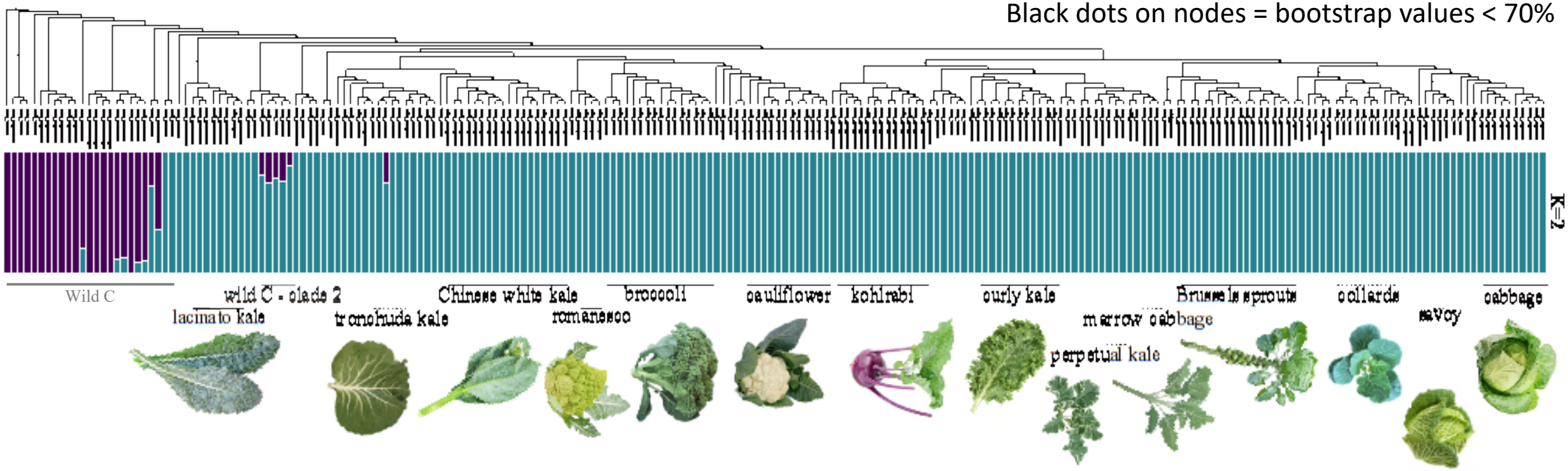
- Samples from USDA, IPK, UPM, and John Innes Center
- 225 samples across wild relatives and diversity of *B. oleracea* cultivars
  - Wild *B. oleracea* - 3
  - *B. cretica* - 3
  - *B. incana* - 5
  - *B. montana* - 2
  - *B. hilarionis* - 1
  - *B. insularis* - 5
  - *B. macrocarpa* - 4
  - *B. rupestris*- 7
  - *B. villosa* – 5
- Genomic data
  - RNA-seq data
- Phenotypic data
  - Leaf scans
  - Glucosinolates
  - Ionomics

Black dots on nodes = bootstrap values < 70%

- Many cultivars are recovered as monophyletic.
  - Some, such as Kales, are not.

Phylogenetic Tree generated using SNPhylo (Lee et al. 2014)

Black dots on nodes = bootstrap values < 70%



Example

25% Wild ancestry

75% Cultivar ancestry

Admixture analyses performed using fastSTRUCTURE (Raj et al. 2014)

Cultivar ancestry

Wild ancestry

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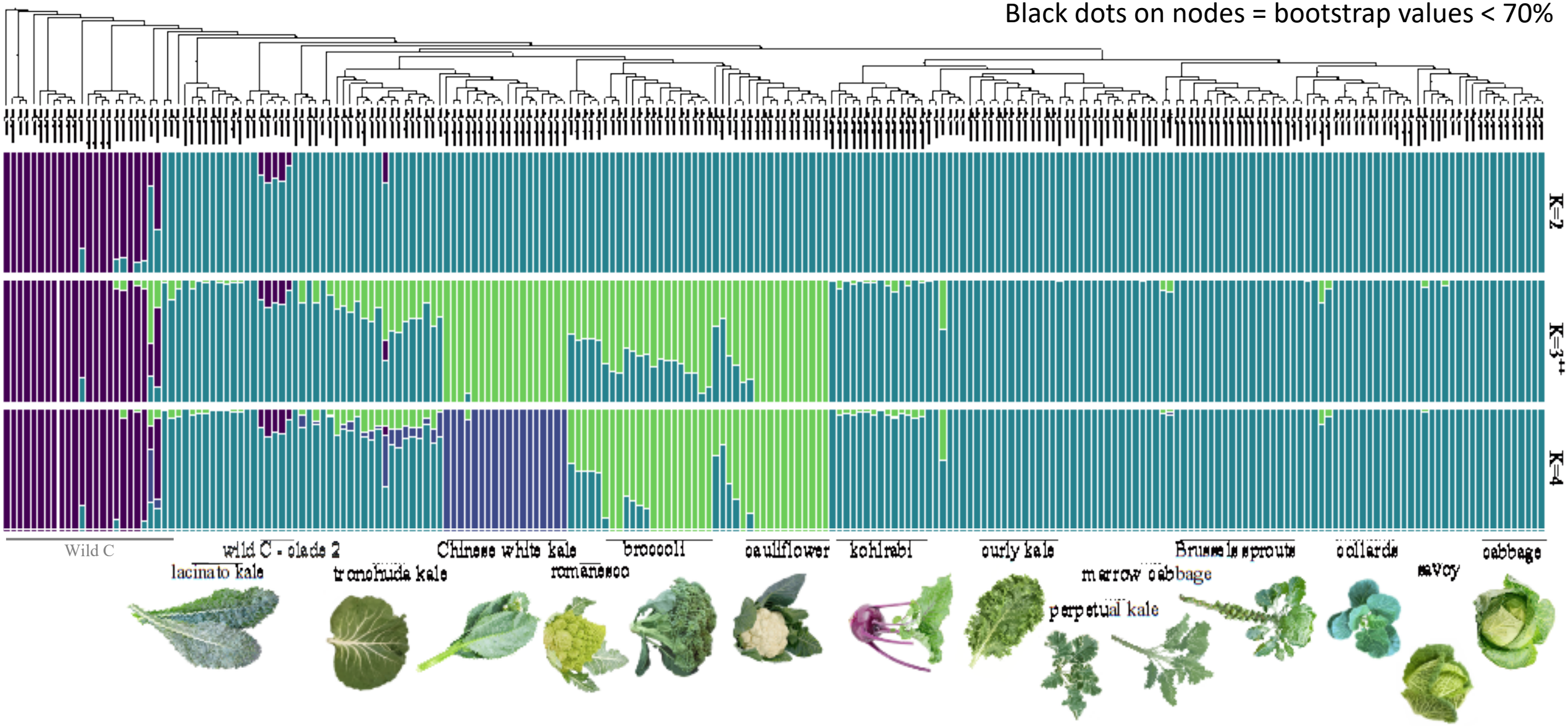

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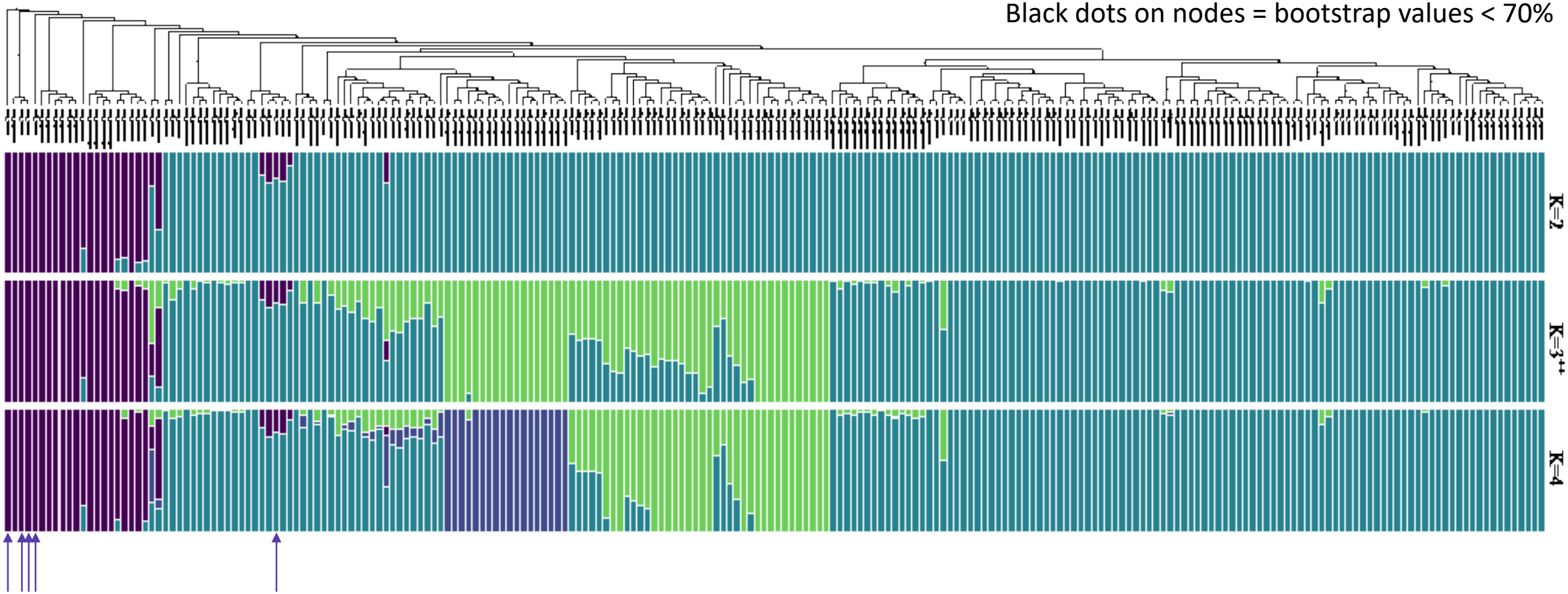

B. villosa

B. rupestris

B. montana

B. macrocarpa

B. insularis

B. hilarionis

B. incana

B. cretica

B. oleracea

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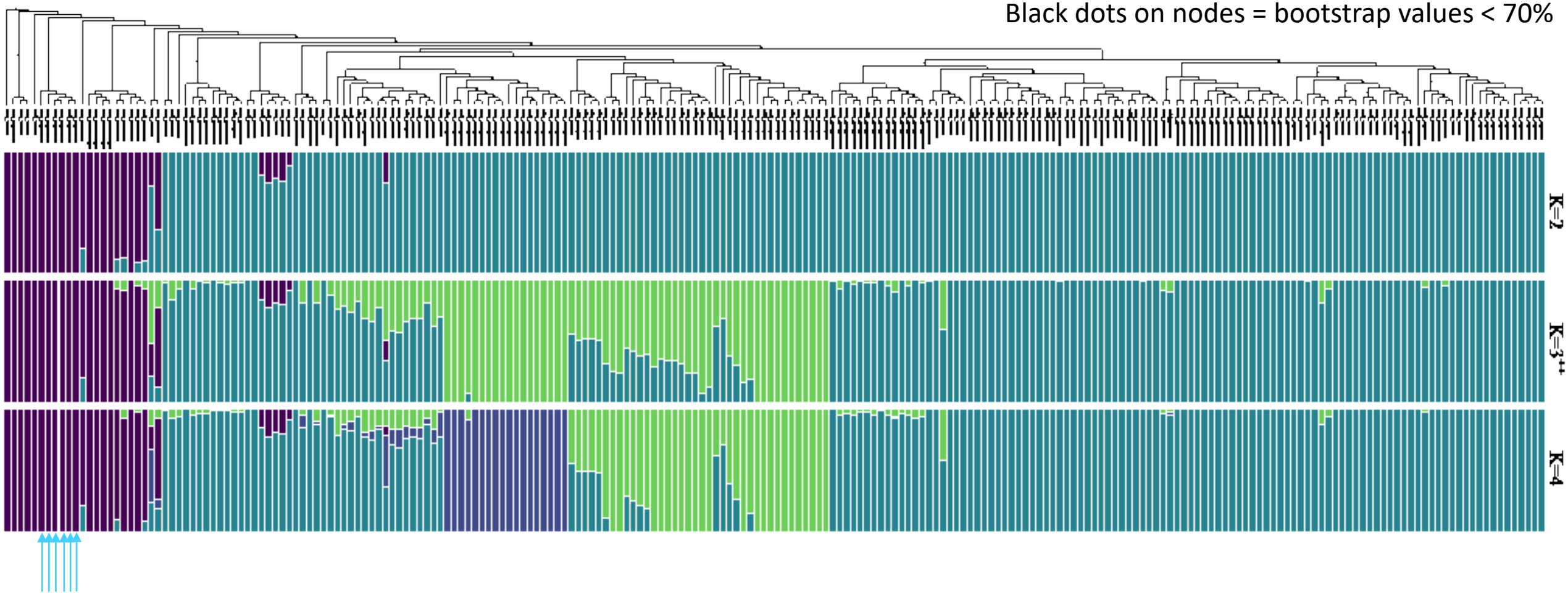

B. villosa | ***B. rupestris*** | *B. montana* | *B. macrocarpa* | *B. insularis* | *B. hilarionis* | *B. incana* | *B. cretica* | *B. oleracea*

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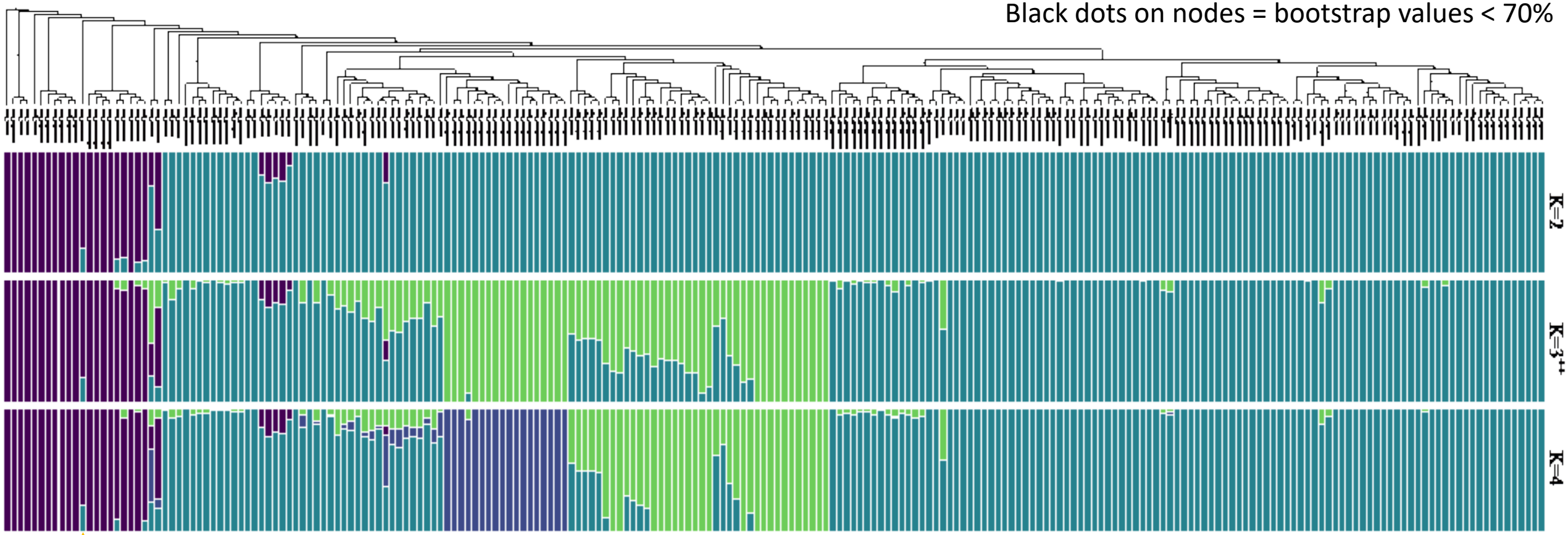

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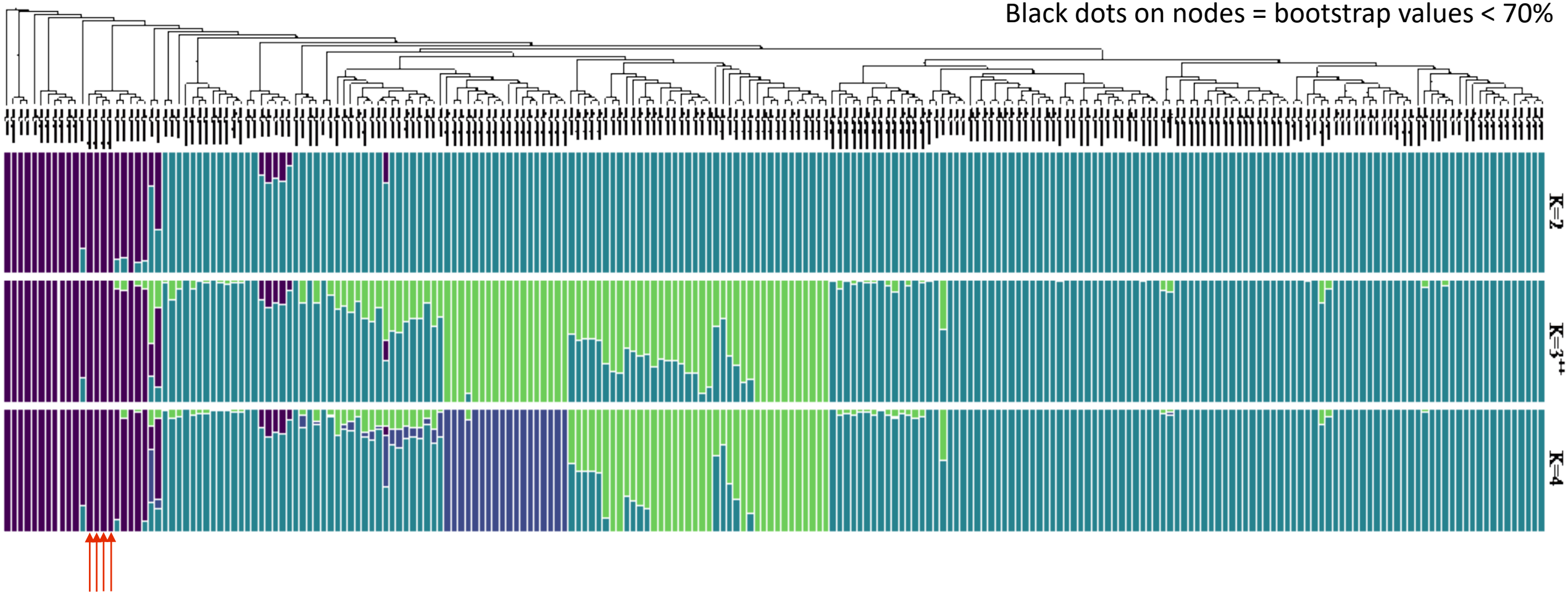

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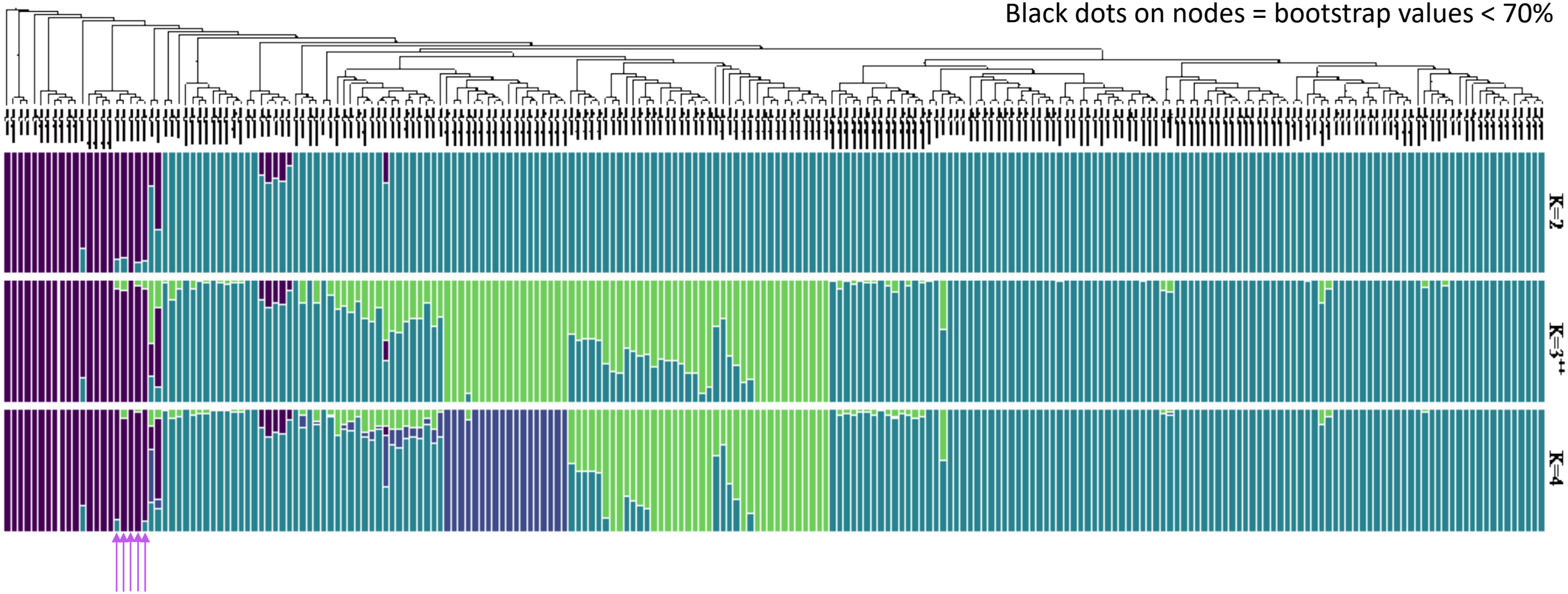

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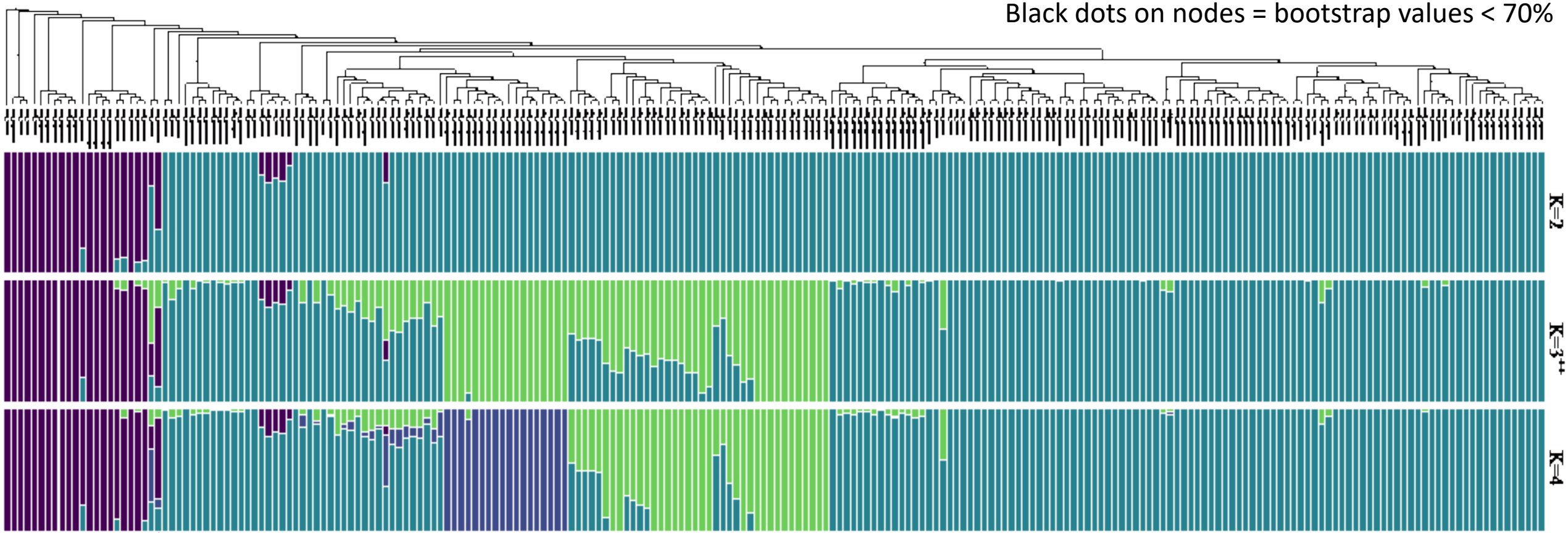

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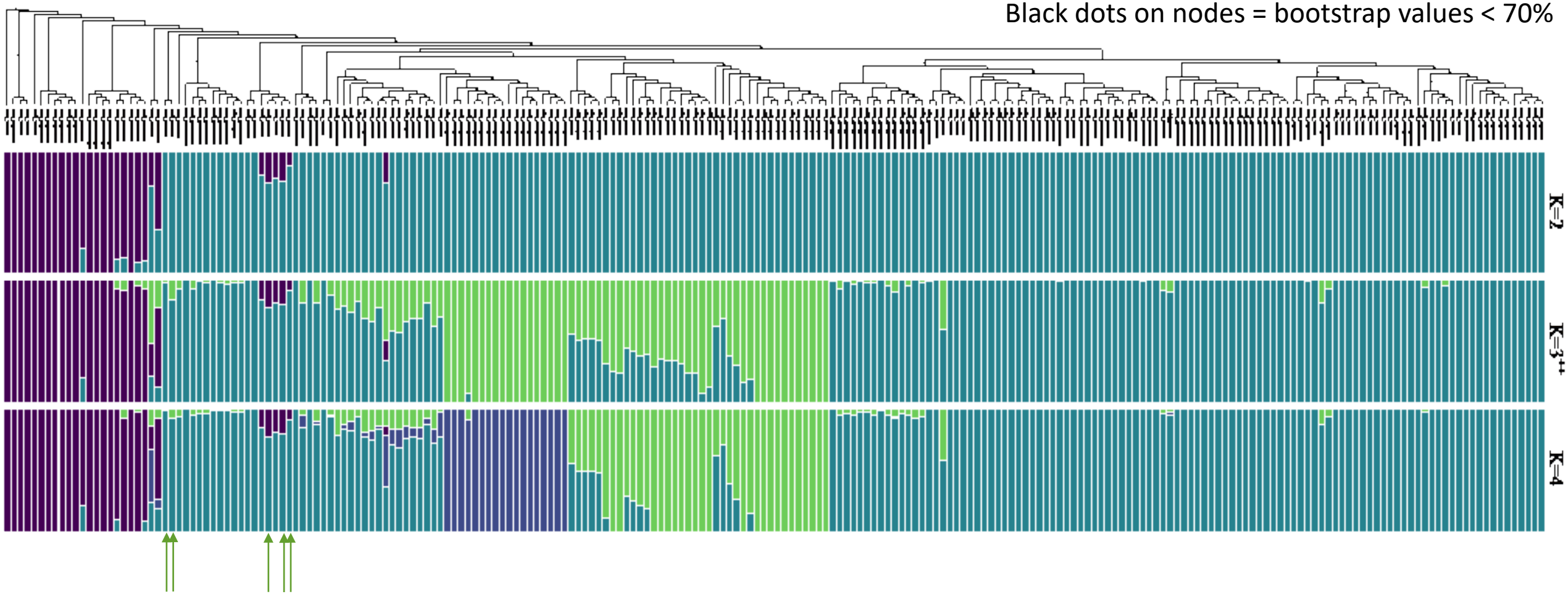

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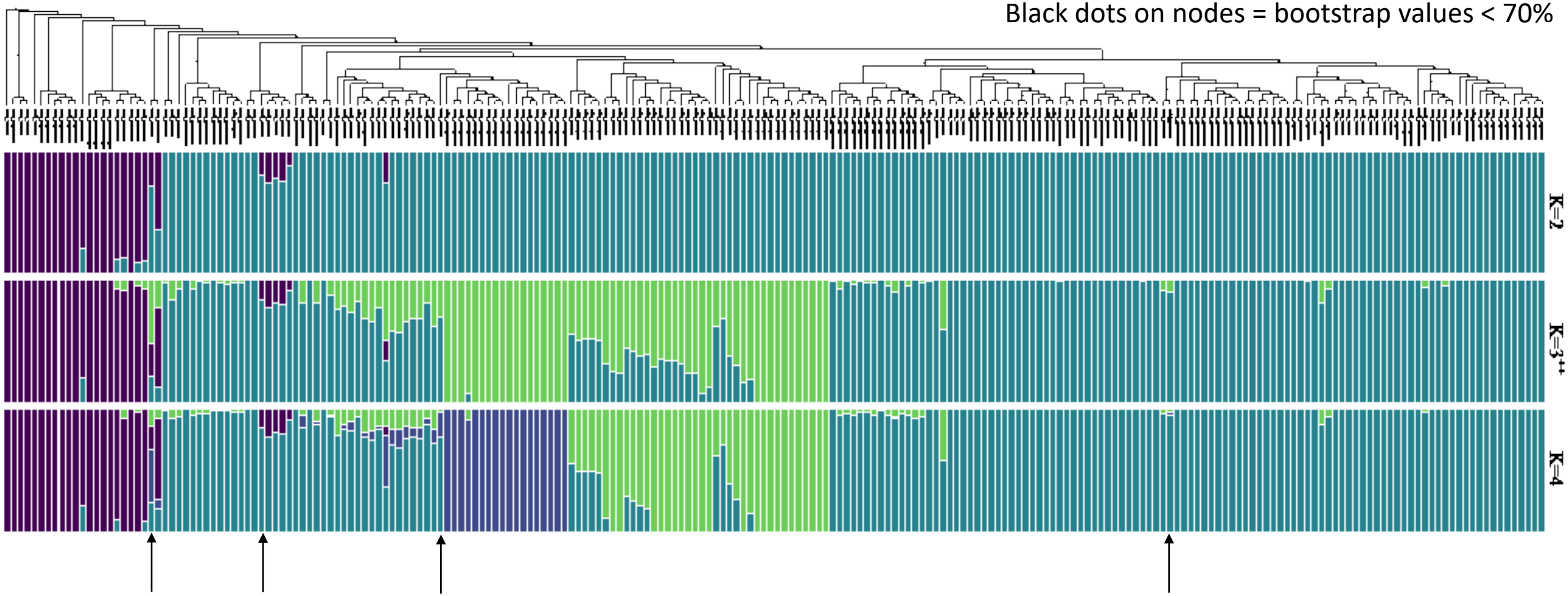

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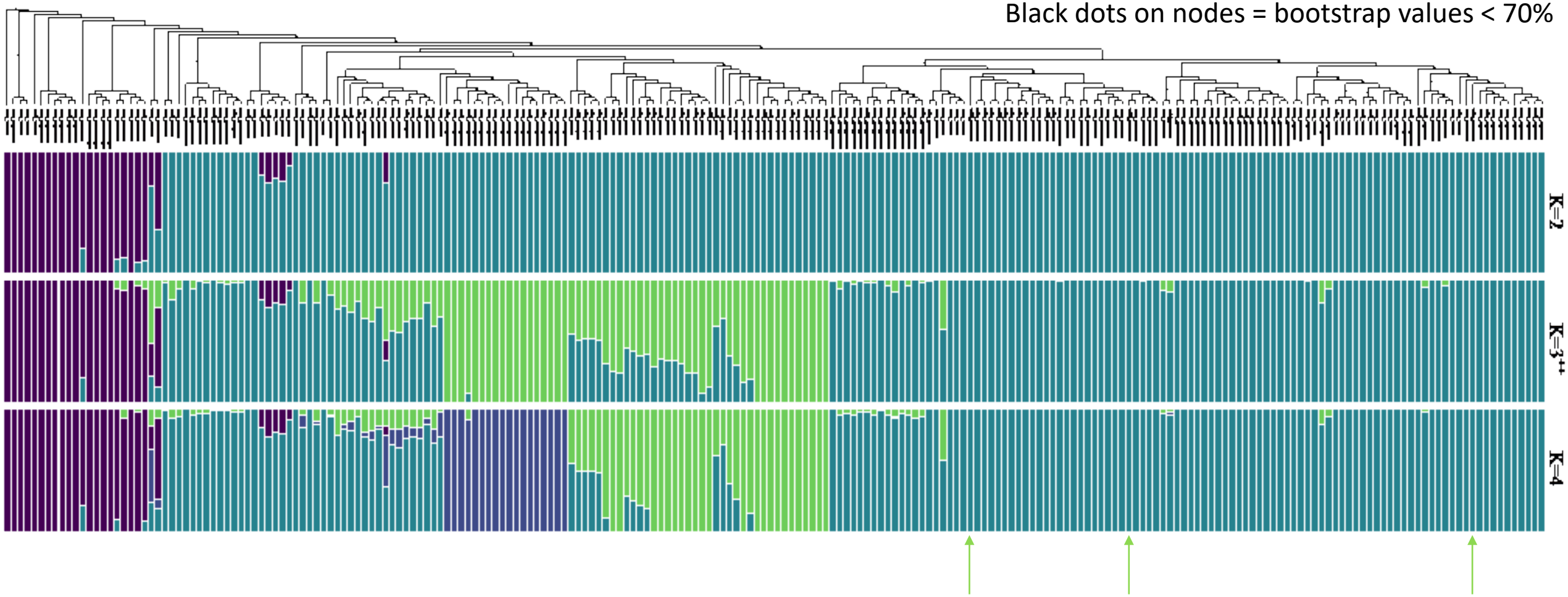

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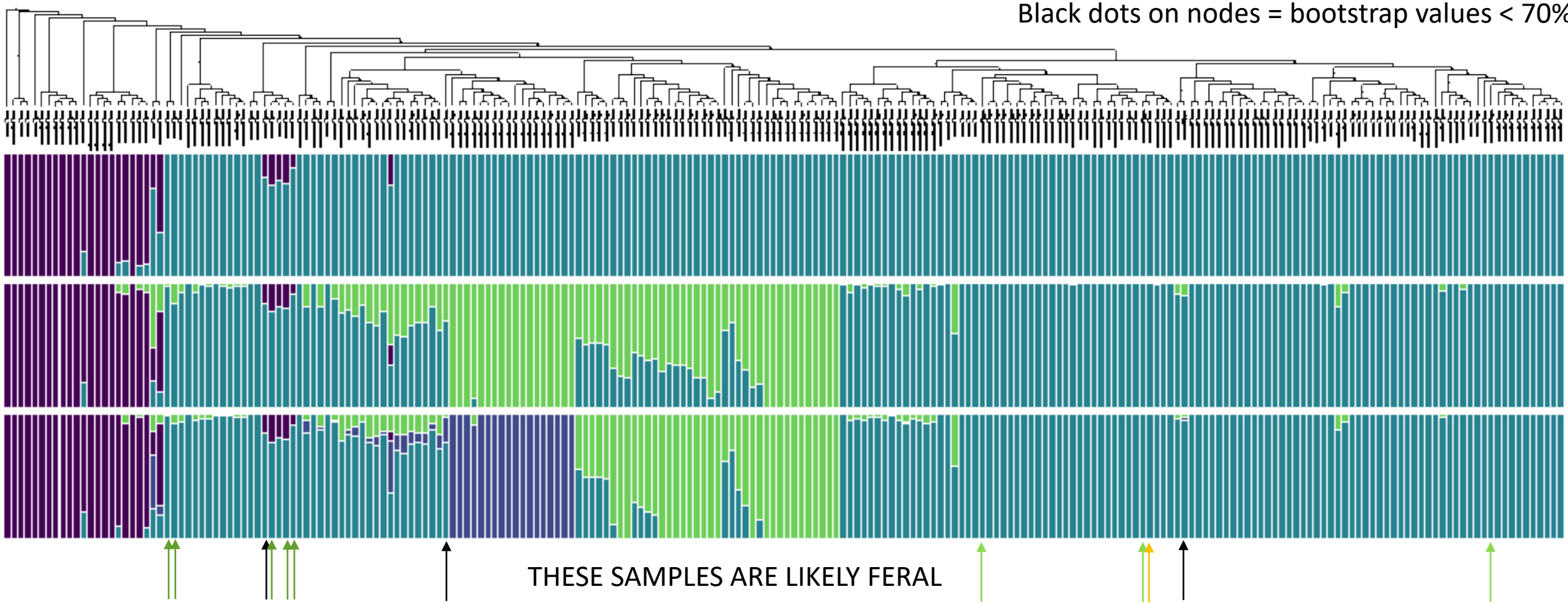

THESE SAMPLES ARE LIKELY FERAL


B. villosa


B. rupestris


B. montana


B. macrocarpa


B. insularis


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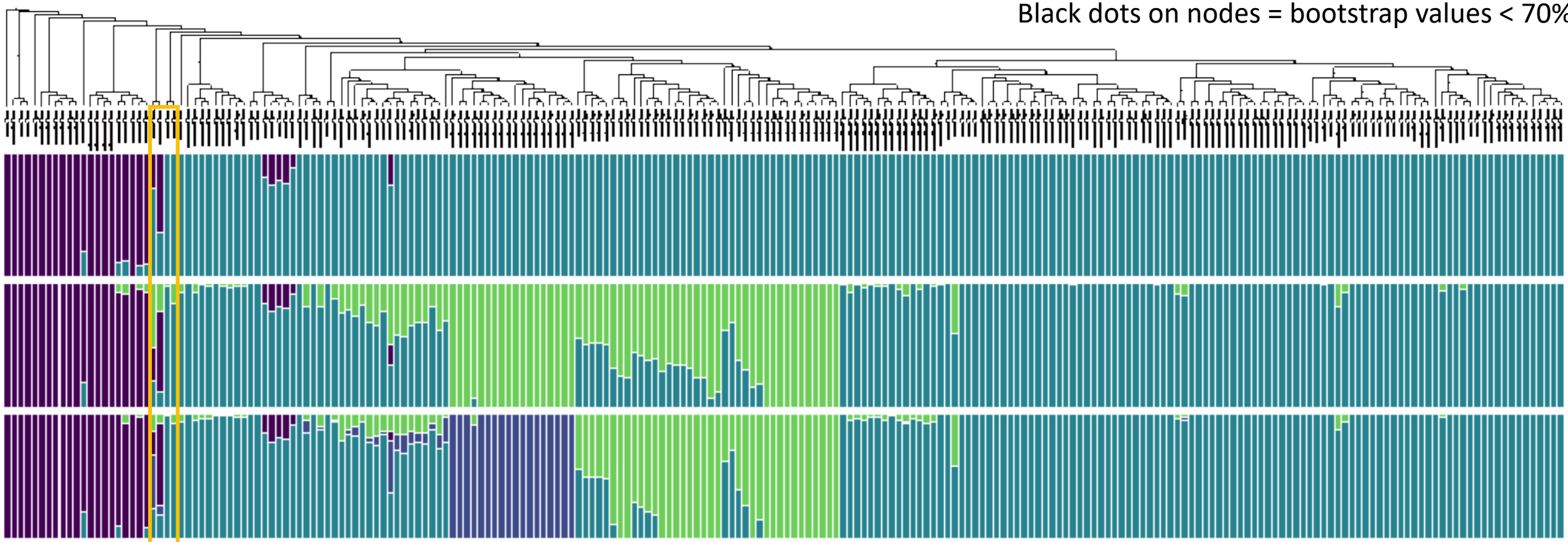
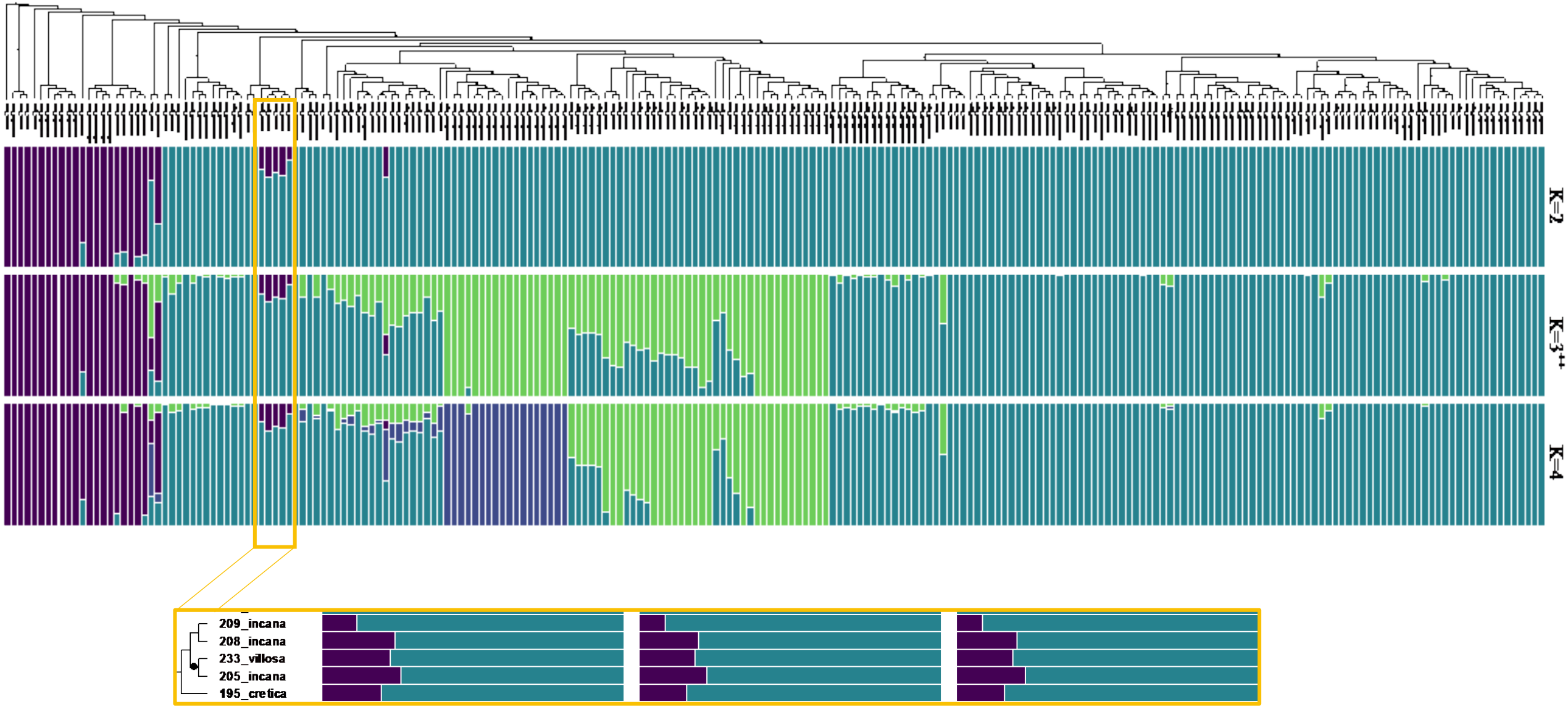


Closest living wild relatives… but….

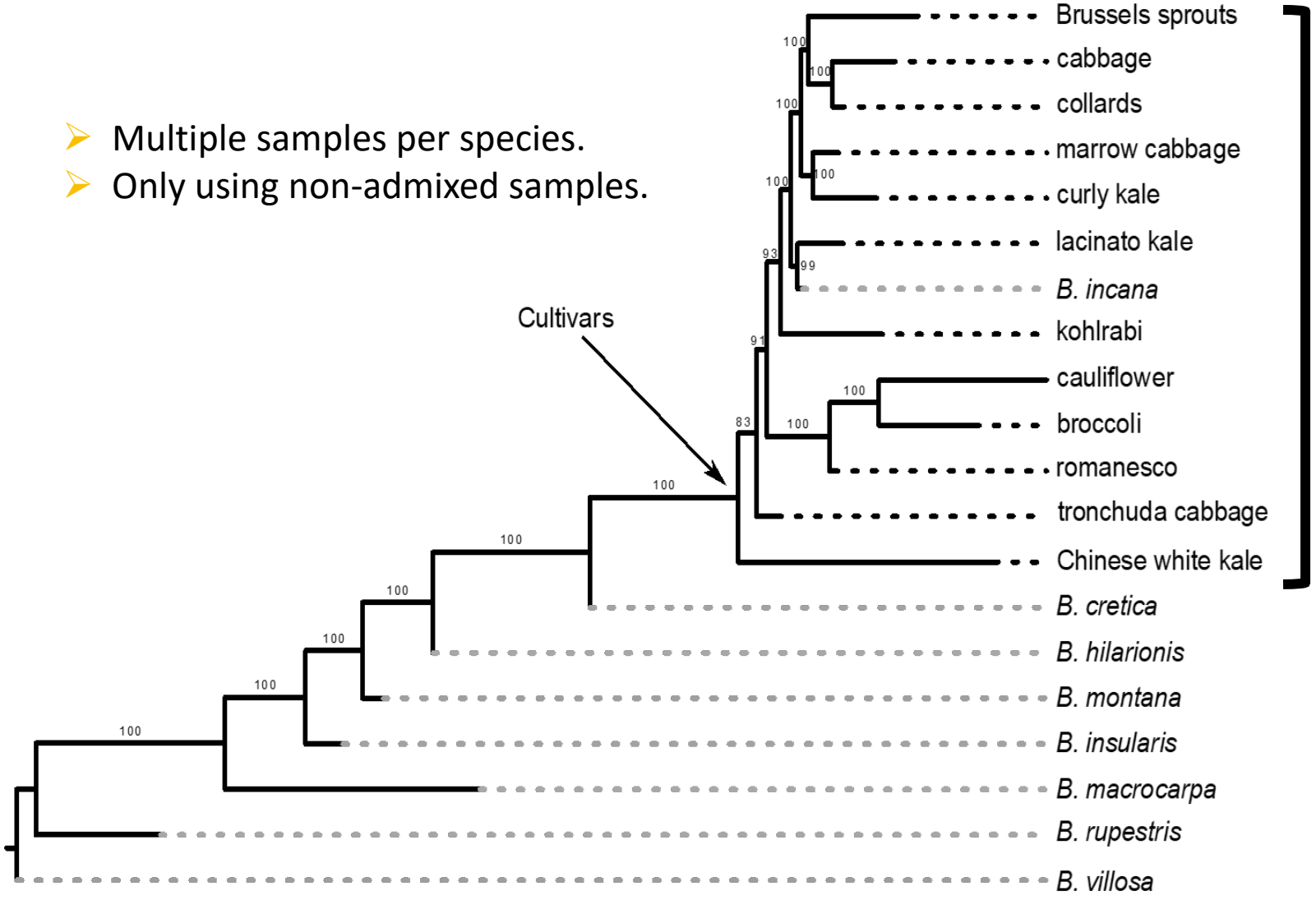
- *B. incana* 100% shared ancestry with cultivars
- *B. hilarionis* ~60% shared ancestry with cultivars **+ ancestry from all groups**
- *B. cretica* ~30% shared ancestry with cultivars + ancestry from all groups



- Wild C – clade 2 shares ancestry with cultivars and wild taxa

SPECIES PHYLOGENY INDICATES *BRASSICA CRETICA* AS CLOSEST LIVING WILD RELATIVE

- Multiple samples per species.
- Only using non-admixed samples.



IQ-Tree - Polymorphism-aware phylogenetic Models (PoMo; Schrempf et al. 2016)

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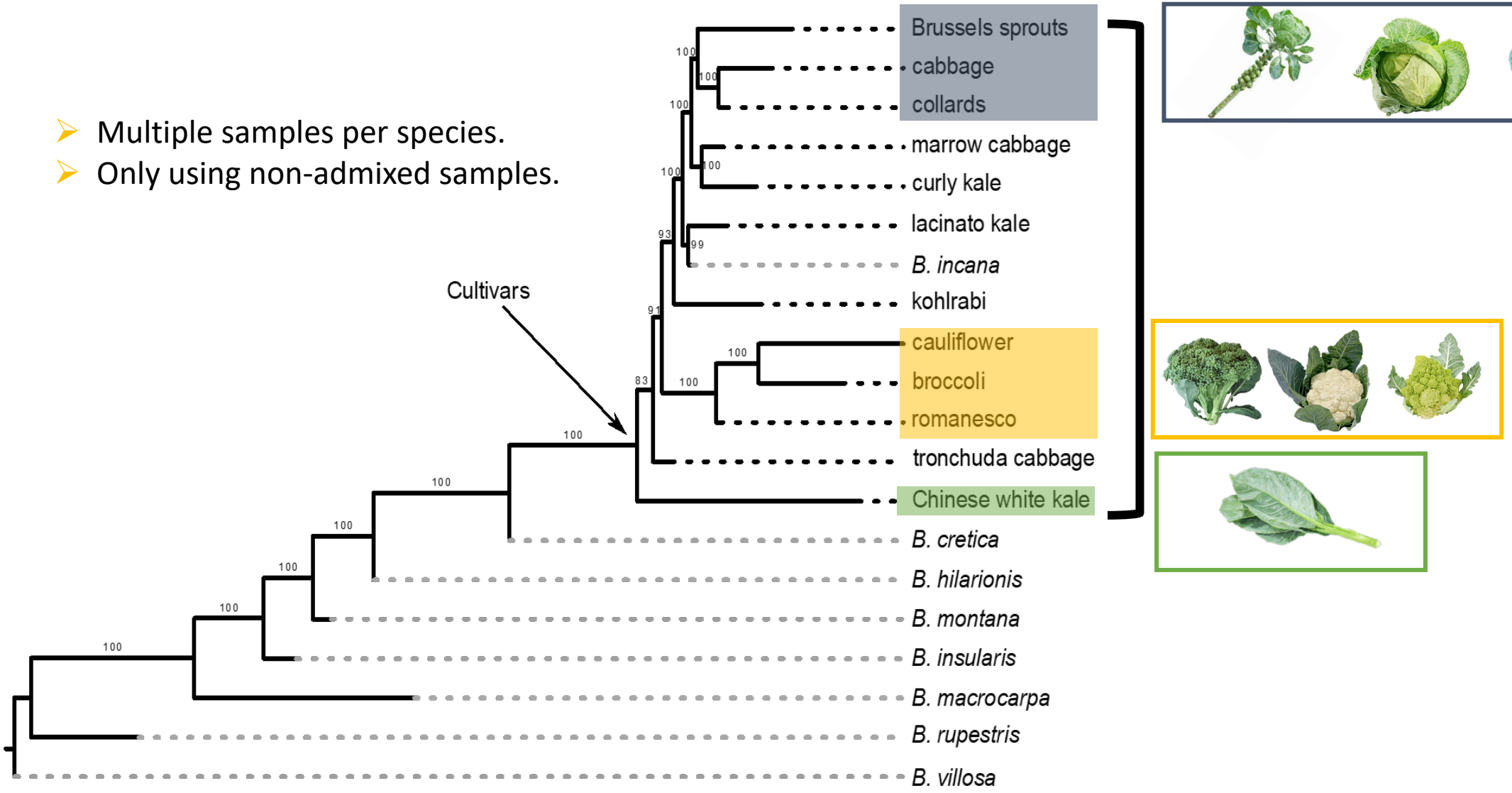

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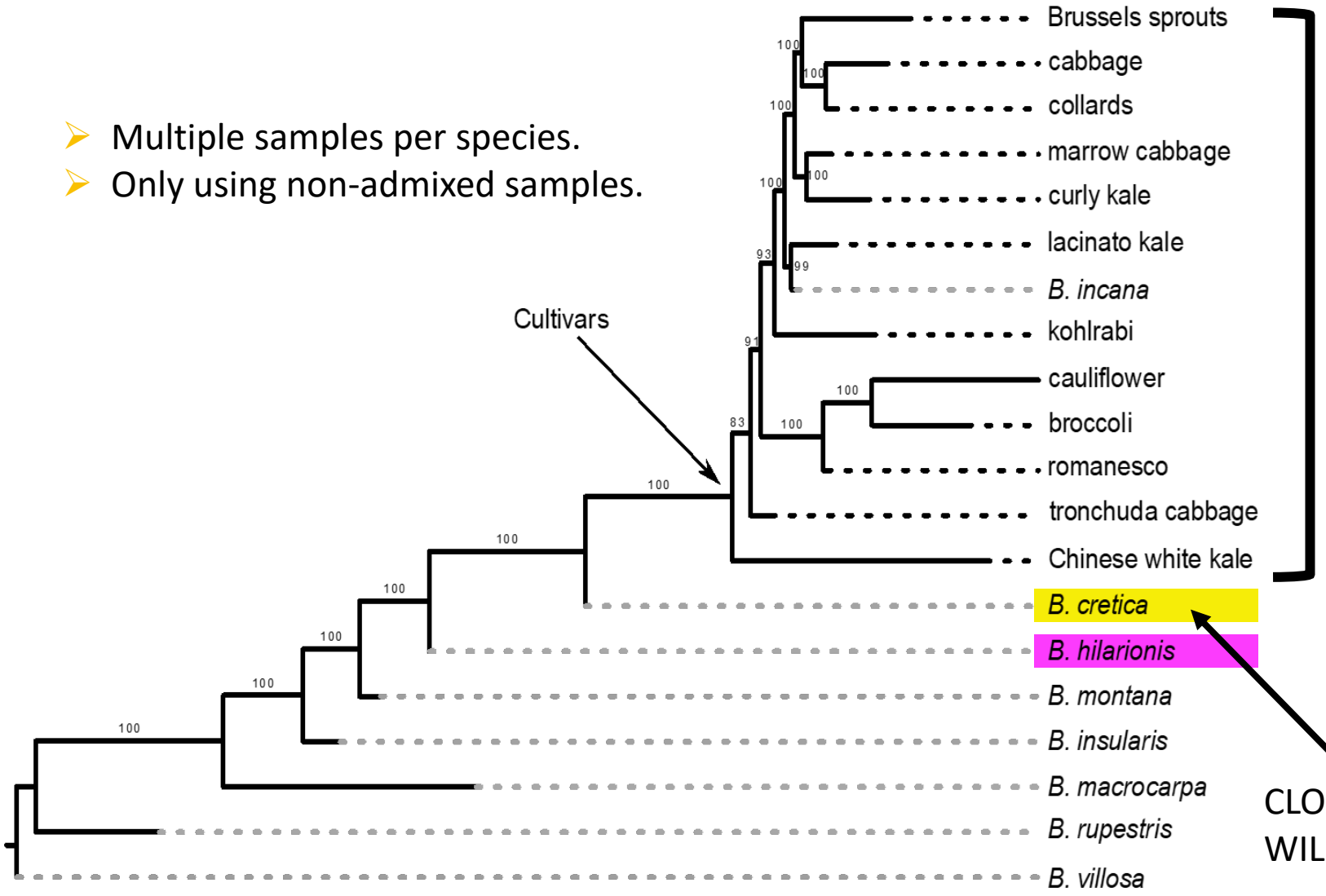
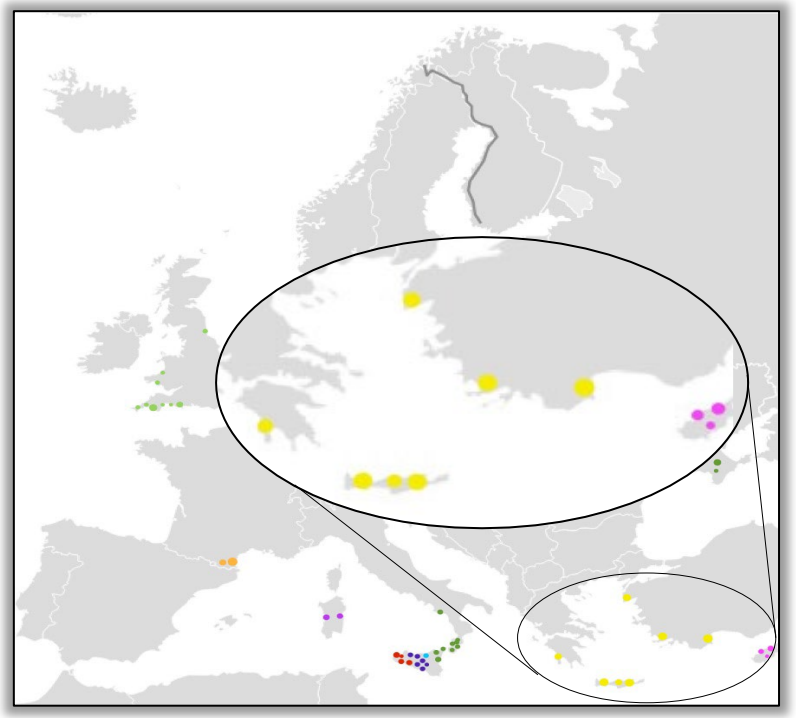


CLOSEST LIVING WILD RELATIVE

EASTERN MEDITERRANEAN CENTER OF DOMESTICATION



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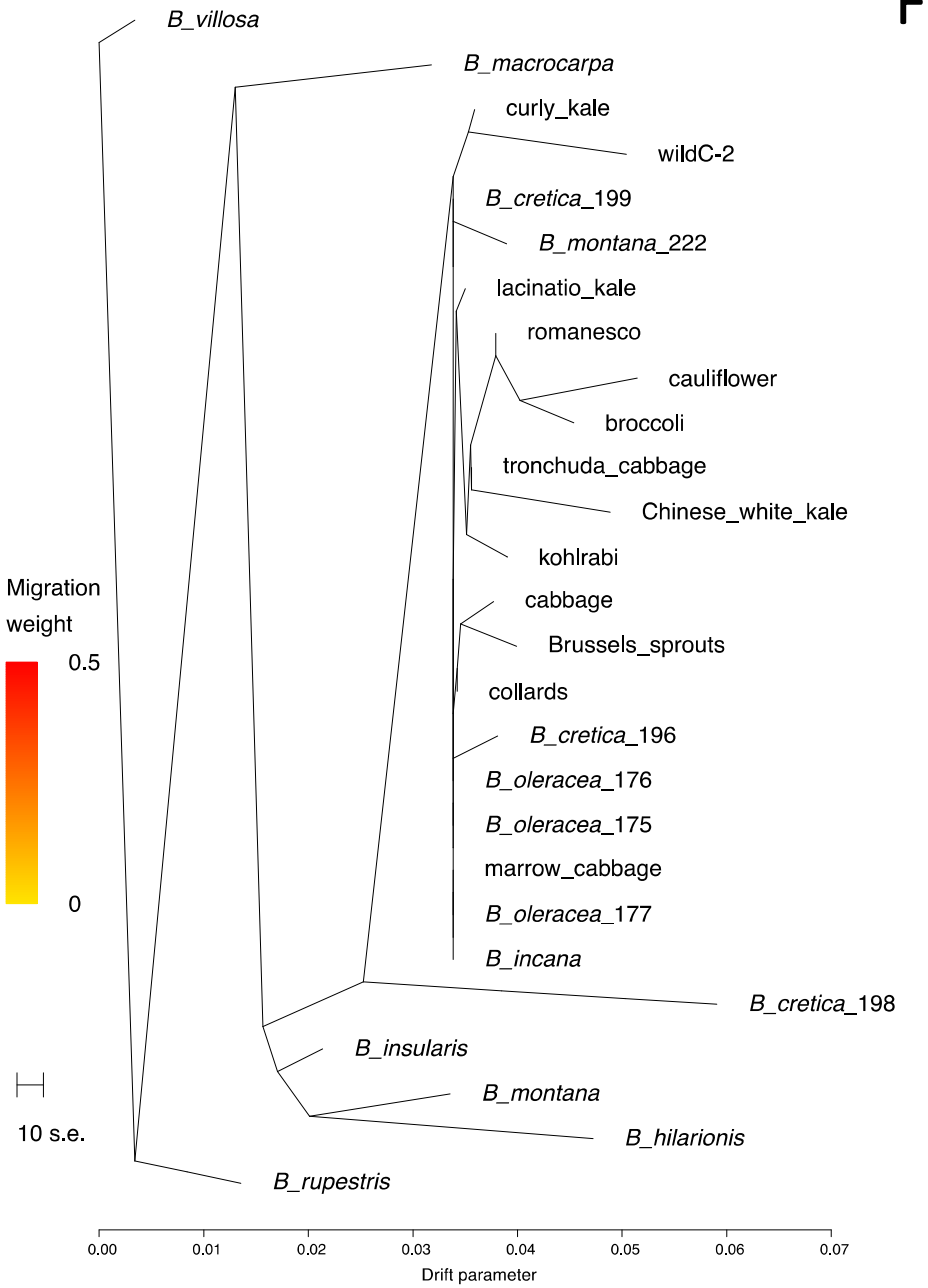
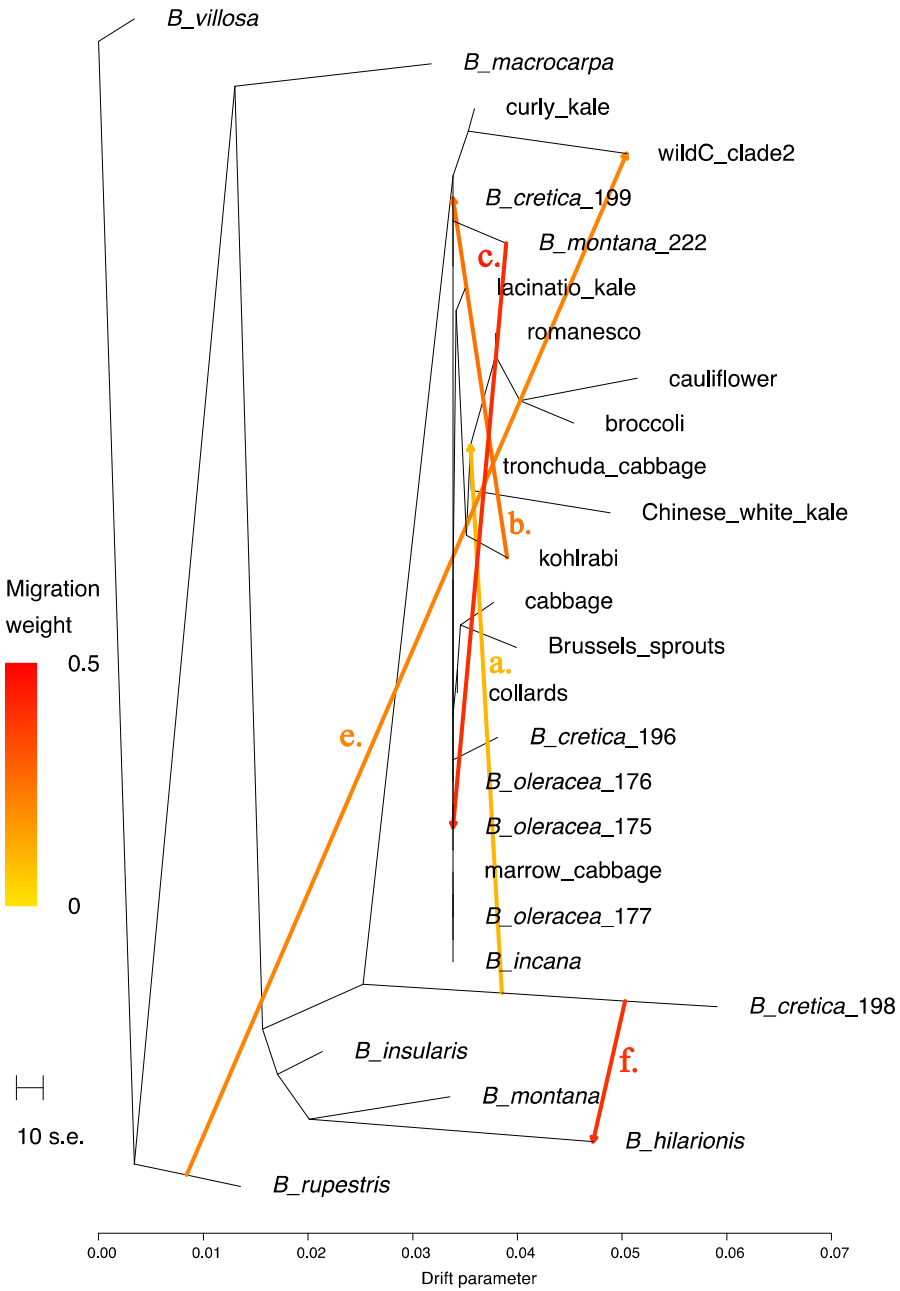
FERAL ORIGINS



- Without migration = 87.3% of the variance in the dataset

Treemix (Pickrell & Pritchard 2012)

FERAL ORIGINS



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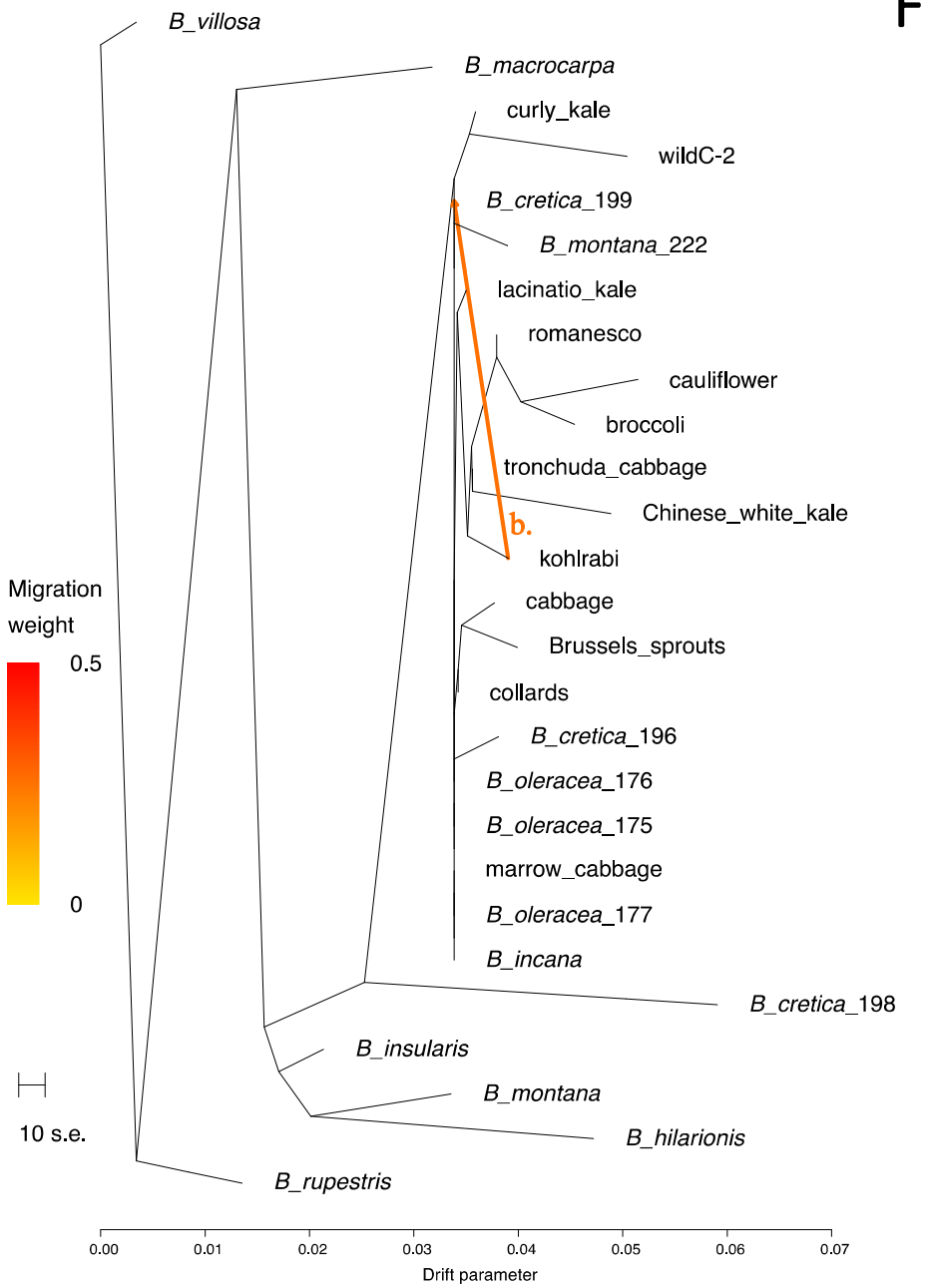
Treemix (Pickrell & Pritchard 2012)

FERAL ORIGINS



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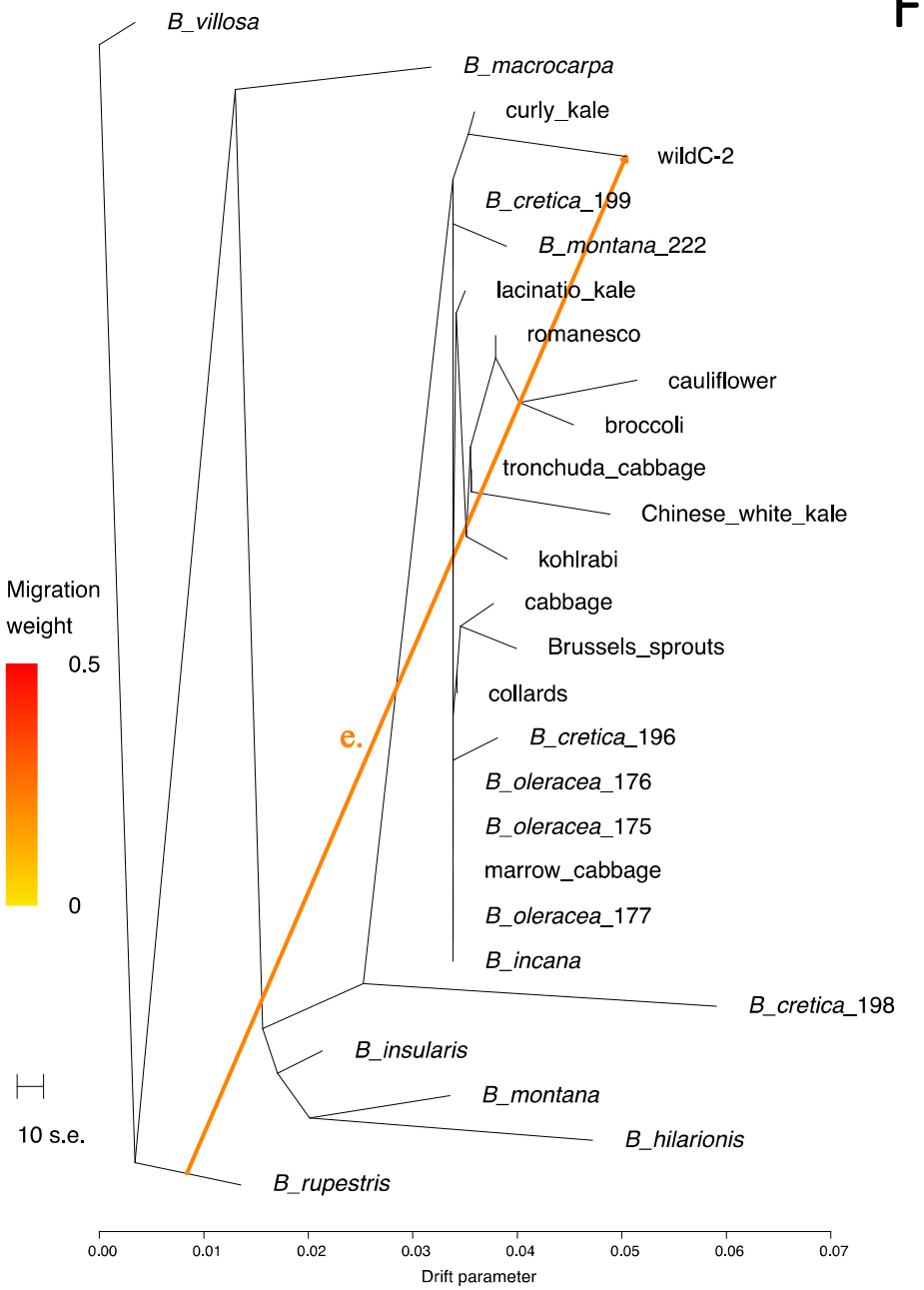

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- e. = migration from *B. rupestris* to wild C - clade 2
  - Explains admixture result
  - Perpetual kale (*B. oleracea var. ramosa*)

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ARCHAEOLOGICAL EVIDENCE FOR *B. OLERACEA* DOMESTICATION

- Oldest
  - ca. 3550-3350 BP Middle Bronze Age
    - 3 charred seeds on a hilltop settlement in southern alps (Schmidl and Oeggl 2005)

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- Other than seeds
  - Residues of Brassica leaves identified within pottery shards (Evershed et al. 1992)
    - Early Medieval (12th century)
    - England

CLASSICAL AND MEDIEVAL WRITTEN SOURCES FOR *B. OLERACEA* DOMESTICATION

- Earliest textual reference
  - 2500-2000 BP
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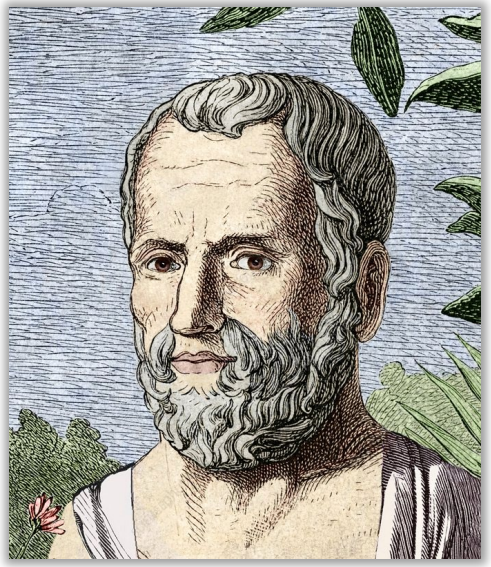

- 2330 - 2250 BP
  - Theophrastus
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- 3 varieties
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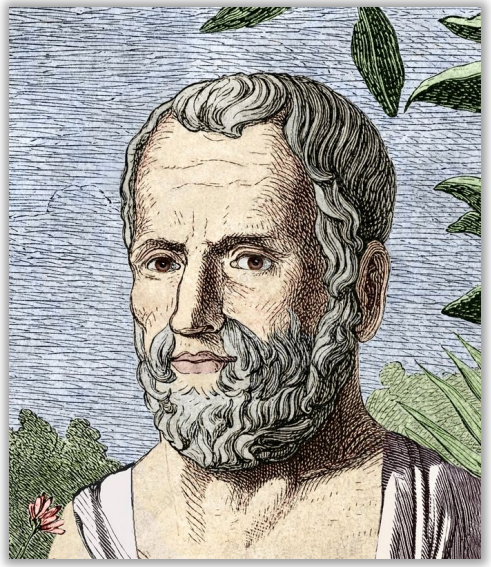

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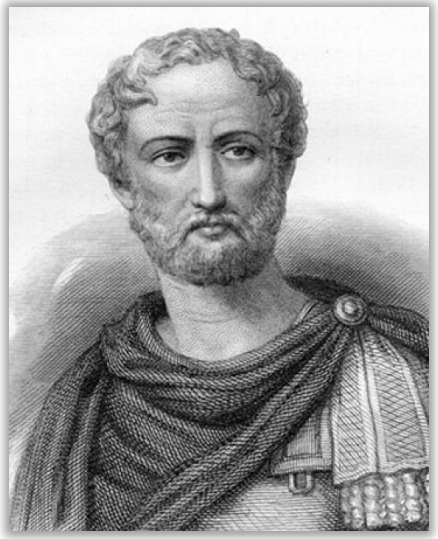

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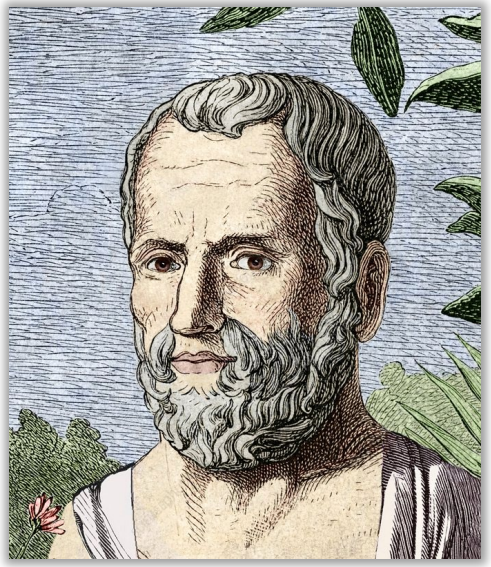
- Modern-day distribution of *B. cretica* includes south-east Greece and the Aegean Islands
- *B. incana* and *B. oleracea* are not known from Greece
- Therefore, these earliest types may belong to *B. cretica* which is incredibly diverse itself



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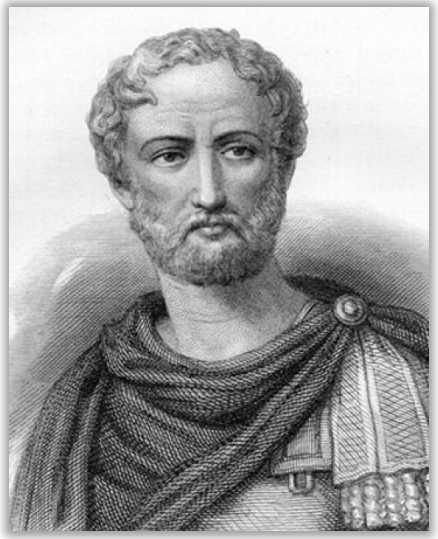

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THE ROLE OF CWRs IN DOMESTICATION

1 – Brassica oleracea

2 – Brassica rapa

Brassica napus

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BRASSICA RAPA DOMESTICATION: UNTANGLING WILD AND FERAL FORMS AND CONVERGENCE OF CROP MORPHOTYPES

Molecular Biology and Evolution, Volume 38, Issue 8, August 2021, Pages 3358–3372


Alex McAlvay


Aaron Ragsdale


Makenzie Mabry


Xinshuai Qi


Kevin Bird


Pablo Velasco


Hong An


J. Chris Pires


Eve Emshwiller

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MAIN QUESTIONS

- Is weedy *B. rapa* wild or feral?
- What is the center of domestication of *B. rapa?*

DATA COLLECTION – GENOTYPING BY SEQUENCING (68,468 SNPs)

slide courtesy of Alex McAlvay

DATA COLLECTION – GENOTYPING BY SEQUENCING (68,468 SNPs)

384 crop samples

Grelos

Rapini

Pak choi

Komatsuna

Choy sum

Turnips

Mizuna

Napa cabbage

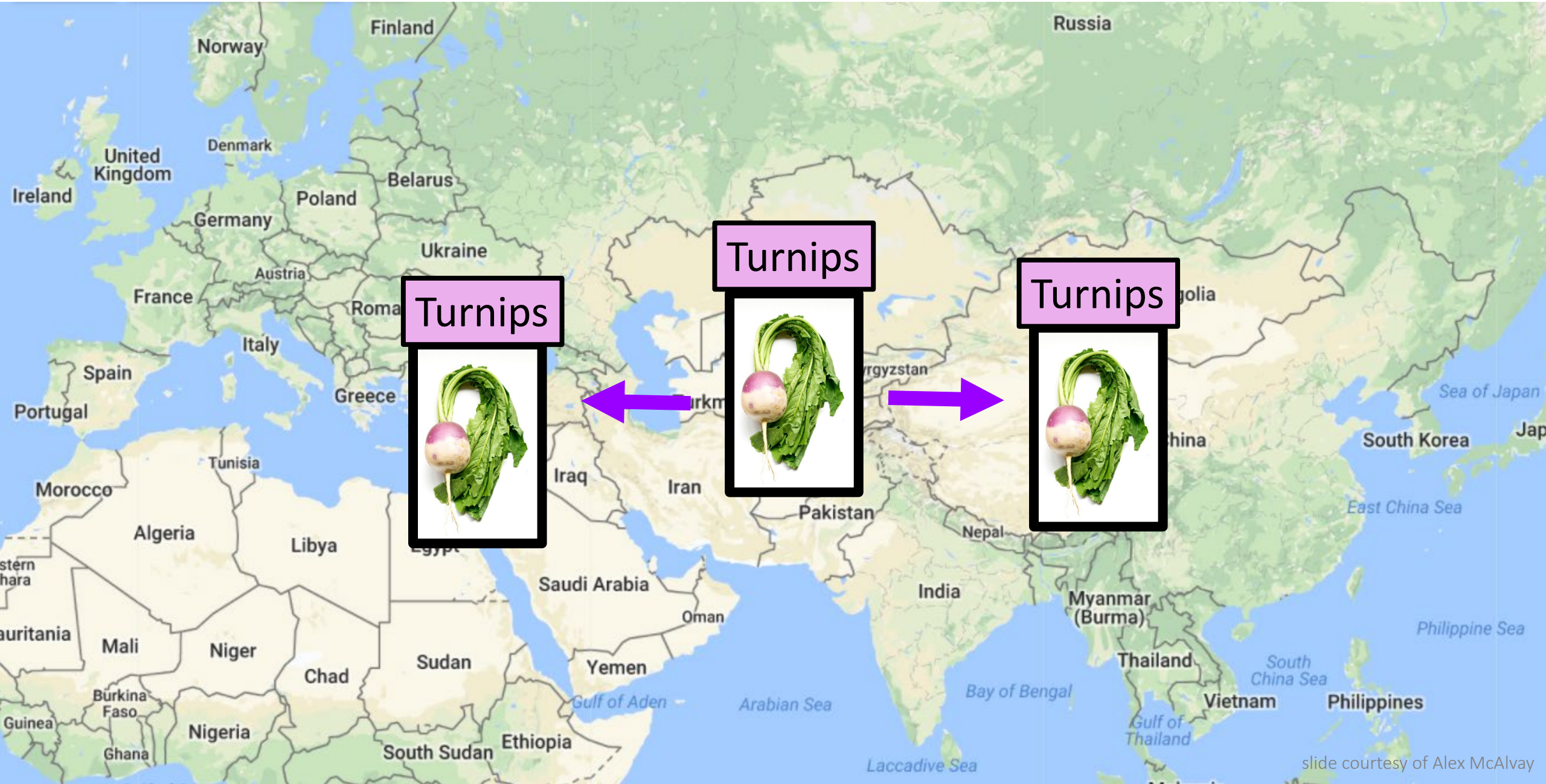
Wutacai

Brown sarson

Yellow sarson

slide courtesy of Alex McAlvay

INDEPENDENT SELECTION FOR LEAFY TYPES FROM TURNIPS



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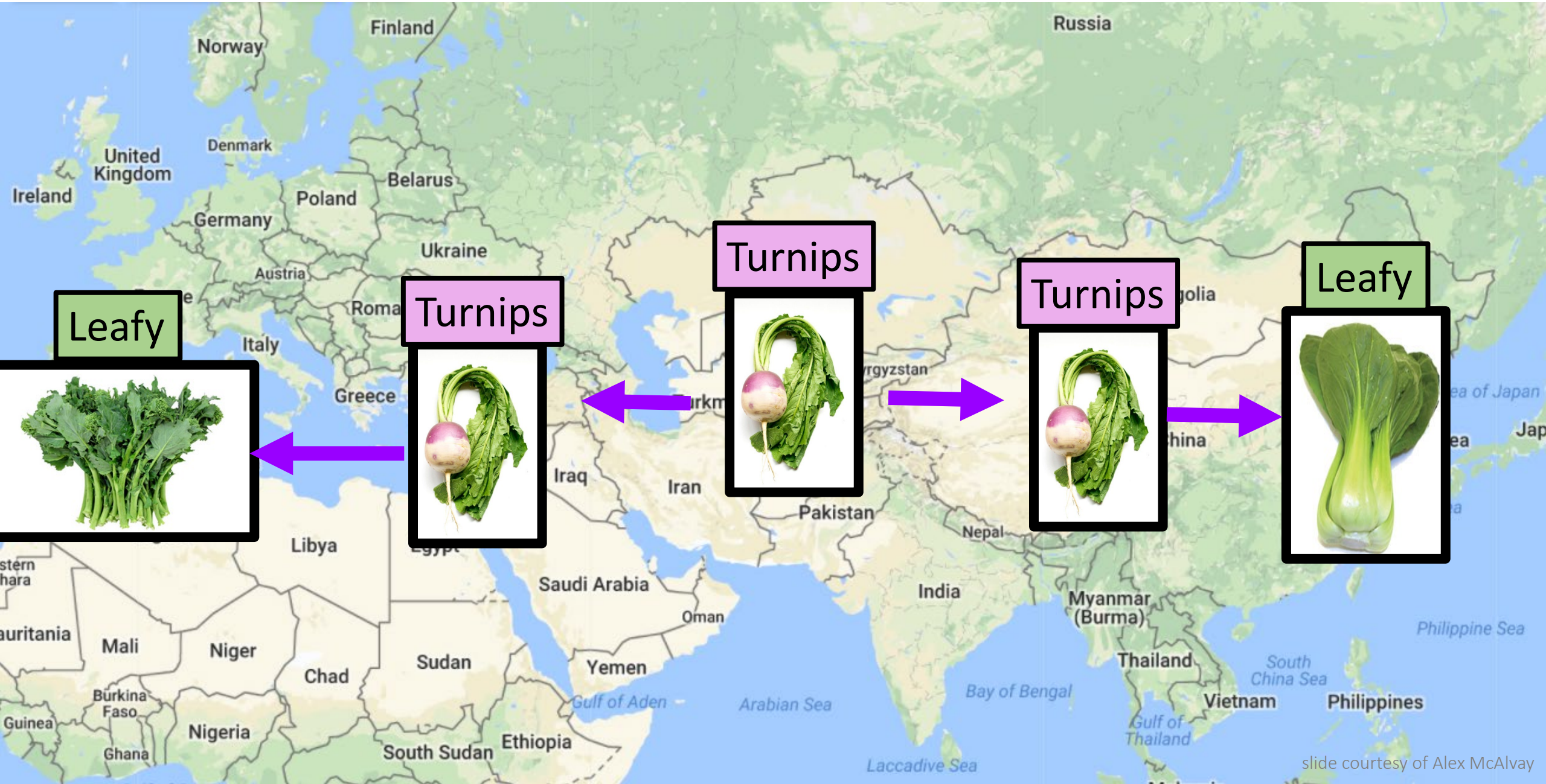

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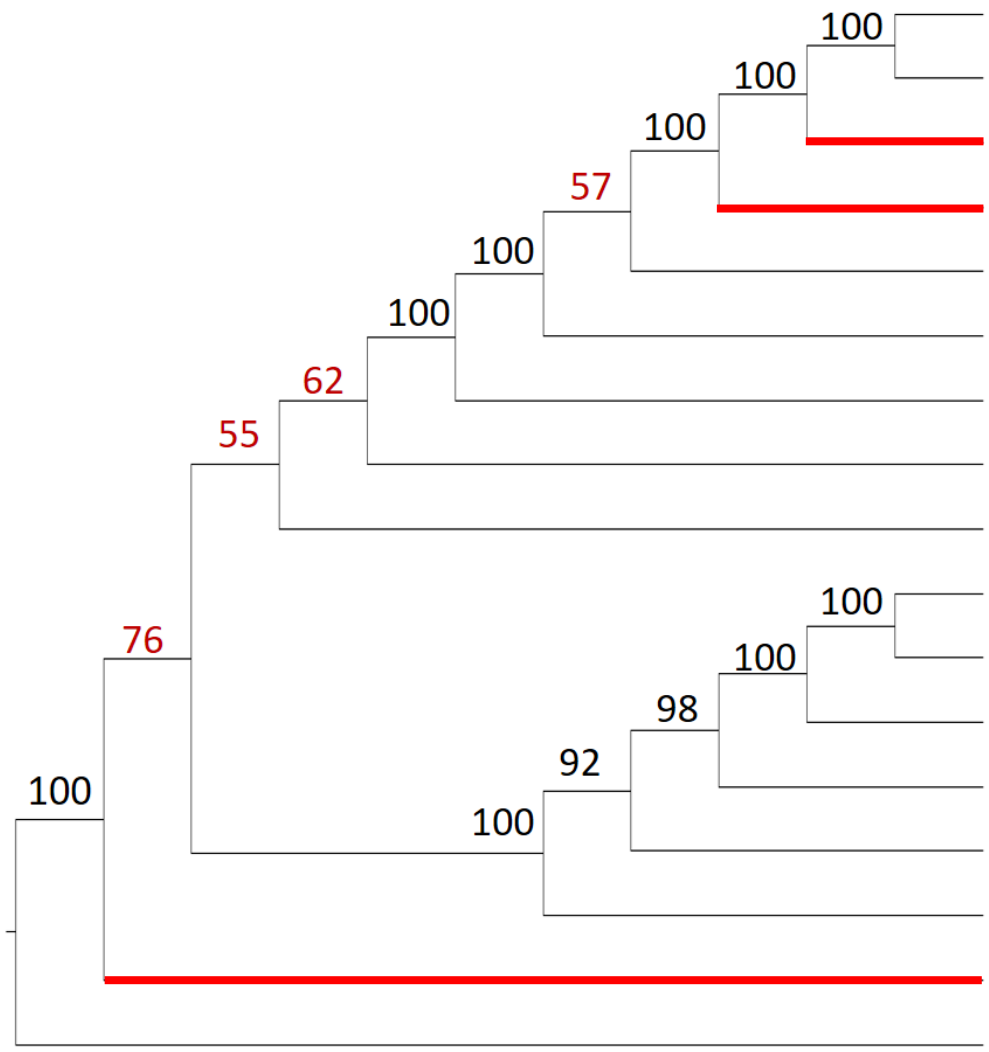
MULTIPLE ORIGINS OF WEEDINESS /FERALS

Originated from different crops



European crops

Weedy Americas
Weedy Europe

European crops

East and South Asian crops

Weedy Caucasus
Outgroup (*B. oleracea*)

SVDquartets coalescent model (Chifman & Kubatko 2014)

slide courtesy of Alex McAlvay

IDENTIFIED SEVERAL FERAL *B.RAPA* AND TRULY WILD *B.RAPA*

slide courtesy of Alex McAlvay

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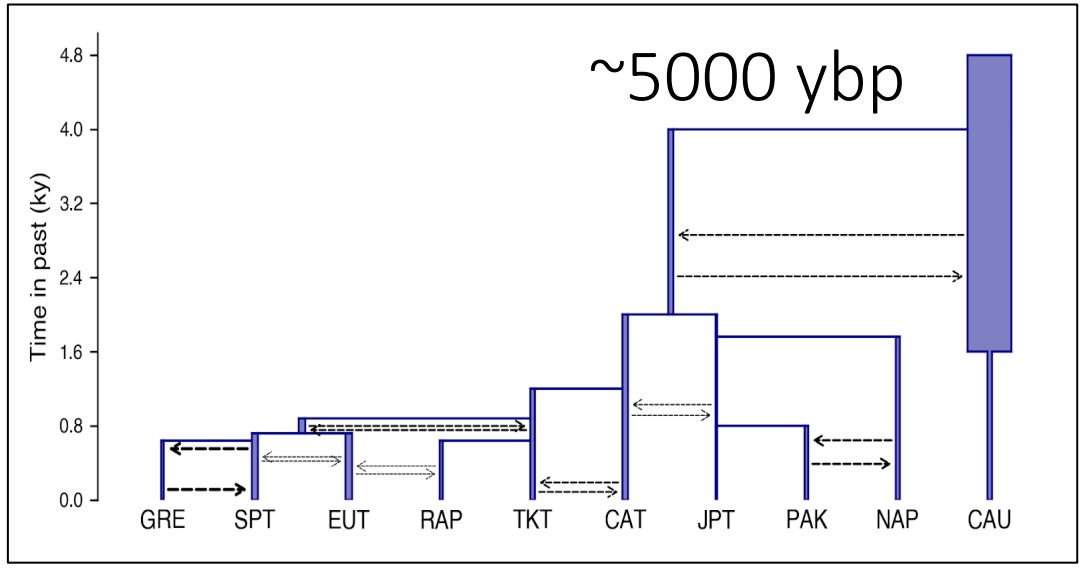
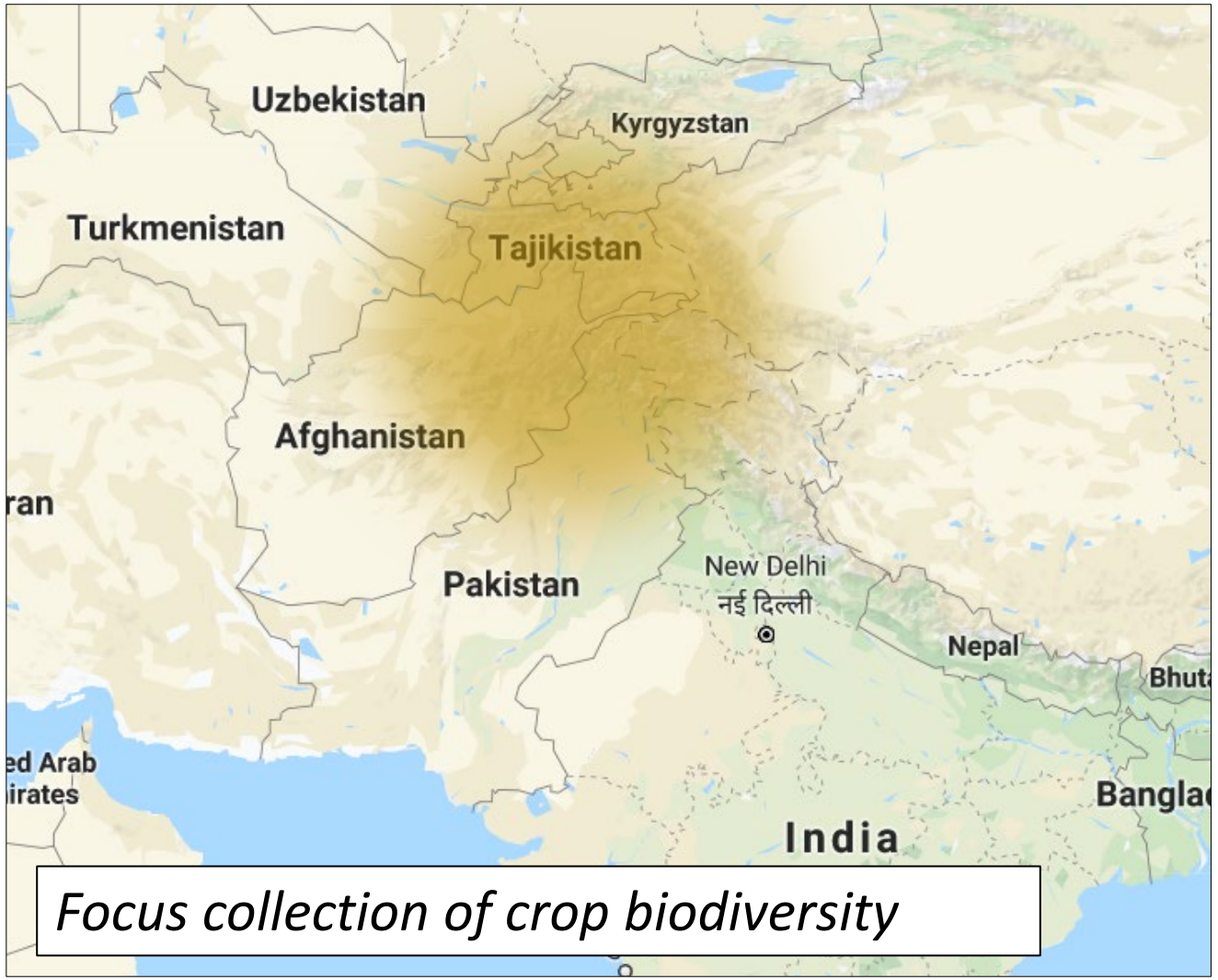
DEMOGRAPHIC MODEL SUPPORTS CENTRAL ASIAN ORIGIN





Demographic models – Moments (Jouganous et al. 2017)

slide courtesy of Alex McAlvay

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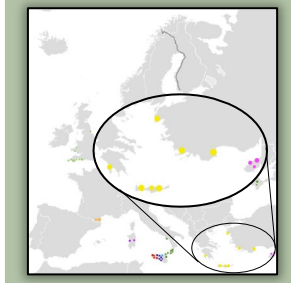

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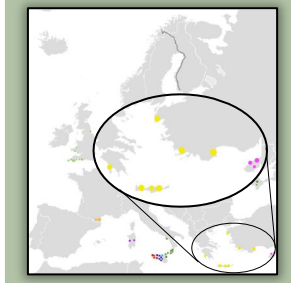

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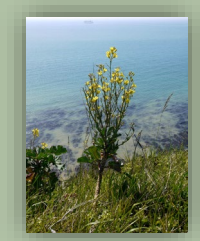

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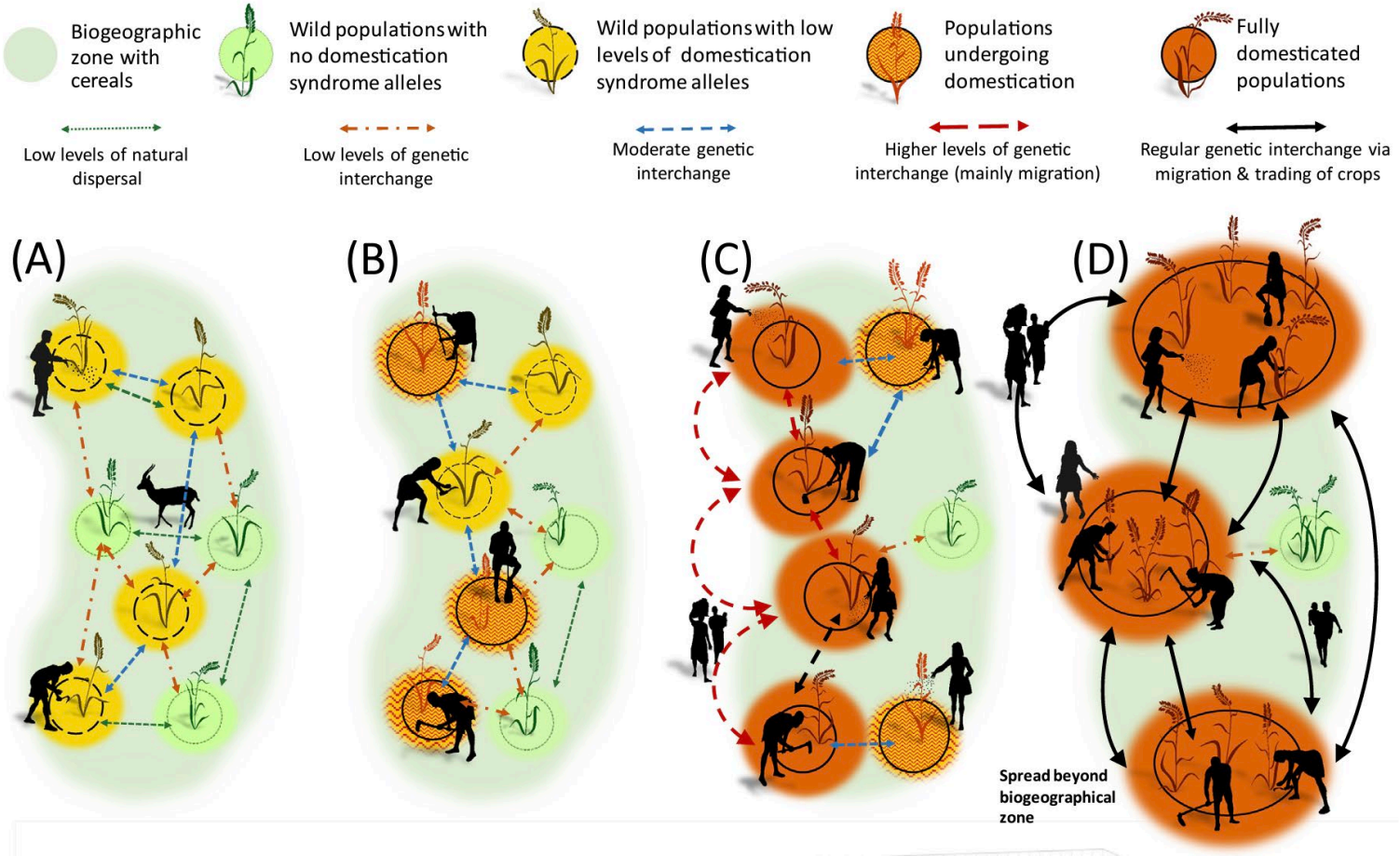
Brassica napus

- What could the role of these CWRs be for *B. napus*?
- Recent work highlights that there is a single origin, but lots of admixture (An et al. 2019, Wang et al. 2023).
- Knowledge of *B. oleracea* and *B. rapa* domestication histories (including the role of feral populations) will help inform our basic and applied understanding of *B. napus.*

A FERAL FUTURE

Allaby et al. 2022 – Emerging evidence of plant domestication as a landscape-level process



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Feral plants?

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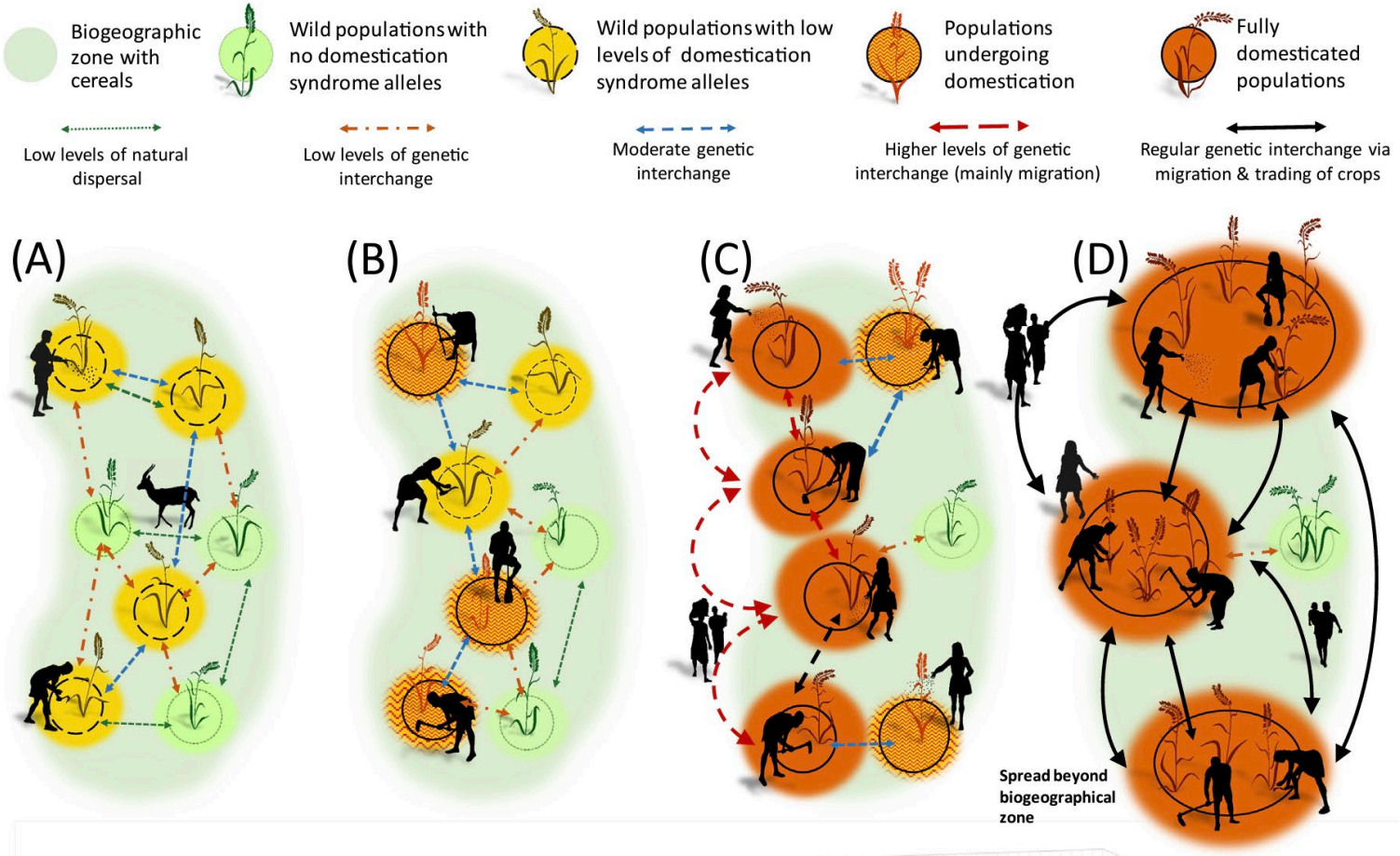

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Feral plants?

- But we know so little about them!
  - Mabry et al. (2023). Building a feral future: Open questions in crop ferality. *Plants, People, Planet*.

Scan to access the paper

A FERAL FUTURE

- *Can we harness the genetic diversity found in feral plants to develop crops that are better adapted to withstand harsher environments?*

Feral *Brassica oleracea*

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Feral *Brassica oleracea*

Alex McAlvay

Pam and Doug Soltis

- Current USDA postdoc fellowship to investigating feral *B. rapa* and *B. oleracea.*

- Let us know if you know of any populations we should include!

USDA

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University of Missouri

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WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

- Staff of UW-Madison Biotechnology Center and Bioinformatics Resource
- Staff at the Walnut Street Greenhouse at UW-Madison

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QUESTIONS?