

International Macadamia Symposium 2023



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Macadamias South Africa (NPC)
(SAMAC)



**Macadamia
genomics and
breeding
in South Africa**

Prof Zander Myburg

The Forest Molecular Genetics Programme



est. 2003



science & innovation

Department:
Science and Innovation
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A 21-year-old industry-government-academia partnership!






Macadamia Genomics



Macadamia in the Post-Genomics Era



The genomes of most Macadamia species and cultivars will soon be deciphered

We can now translate this information into practical tools for crop improvement



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Macadamia genomics

Basic numbers

- Number of chromosomes: 14 (typical)
- Genome size: 750 - 850 Mbp (medium size)
- Number of genes: 30,000 - 38,000 (typical)
- Commercial cultivars: 2 and 3-way hybrids

Genomes that others have sequenced

- HAES 741 - *M. integrifolia* (Nock et al. 2016; Nock et al. 2020)
- HAES 344 - *M. integrifolia* (Lin et al. 2022)
- GR1 - *M. integrifolia* (Xia et al. 2022)
- *M. tetraphylla* (Niu et al. 2022)
- *M. jansonii*, *M. integrifolia*, *M. tetraphylla* and *M. ternifolia* (Murigneux et al. 2020; Sharma et al. 2021a, Sharma et al. 2021b; Sharma et al. 2022)



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Macadamia Genome Sequencing at UP



Santa Anna
M. tetraphylla
(possible hybrid)

1.1 Gb assembly
98.0% complete
37 572 genes



695
M. integrifolia
x
M. tetraphylla

987 Mb assembly
98.4% complete
36 283 genes



791
M. integrifolia
x
M. tetraphylla
x
M. ternifolia

844 Mb assembly
99.0% complete
30 600 genes



Mary Ranketse

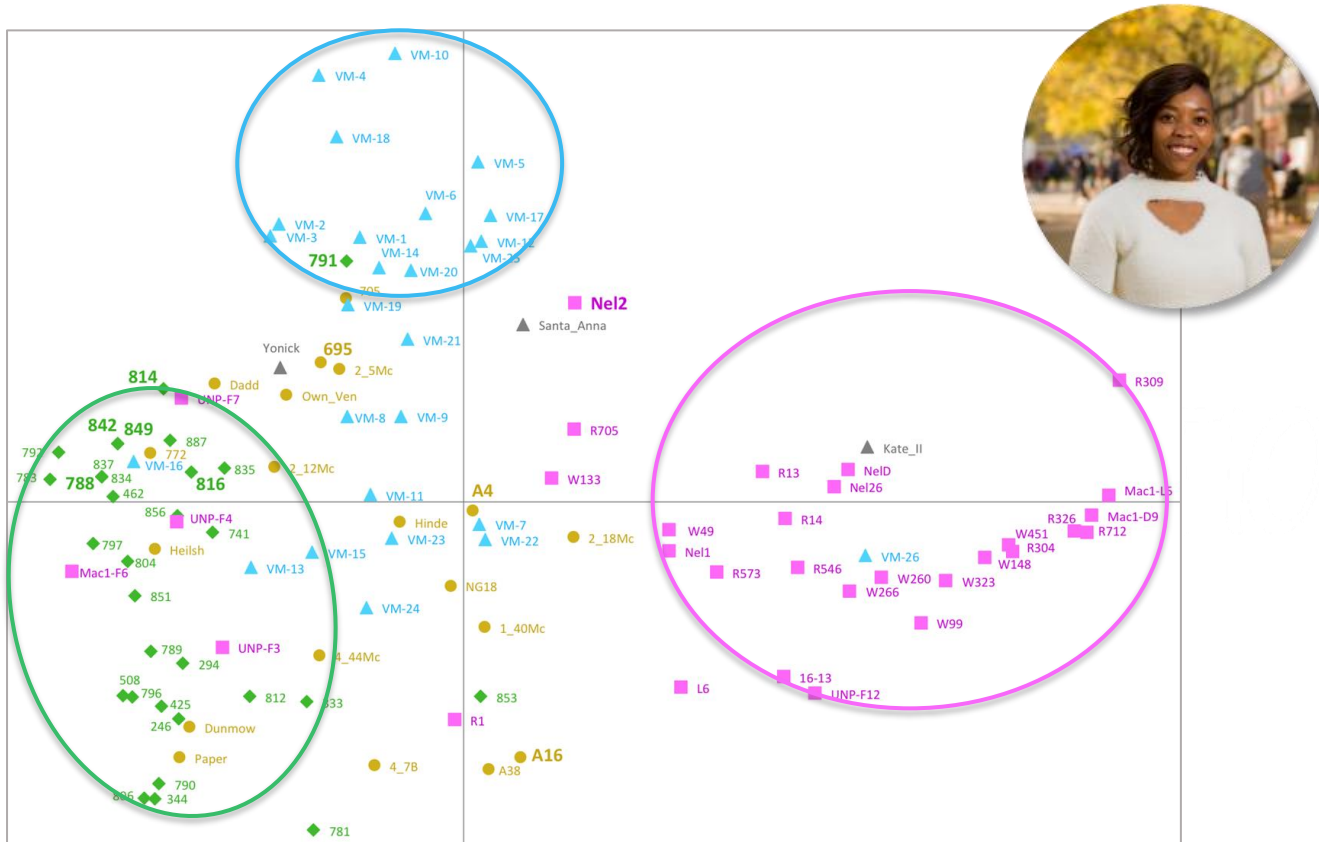


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How can genomics assist Macadamia growers?

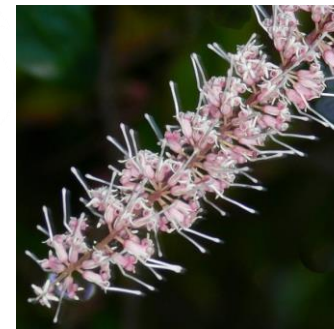


Genetic relationships of Macadamia cultivars (Ranketse et al 2022)

- Genetic resource management and propagation
- Optimal design and establishment of orchards
- Molecular (genome-assisted) breeding



Tree growth



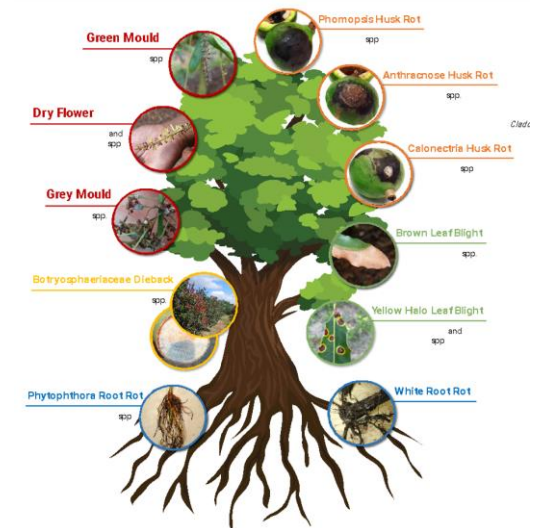
Flowering time



Yield



Oil production



Macadamia Protection Programme www.fabim.org.za <http://www.fabim.org.za> **FABI** SAMAC **UNIVERSITY OF PRETORIA** **UNIVERSITAT SA BUTHUNA**

Disease resistance

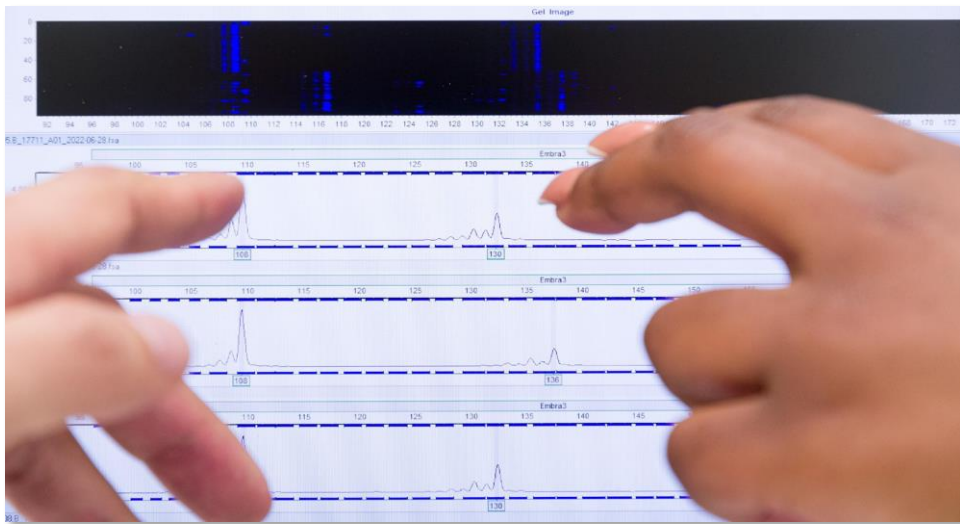




Genetic Resource Management

DNA Fingerprinting

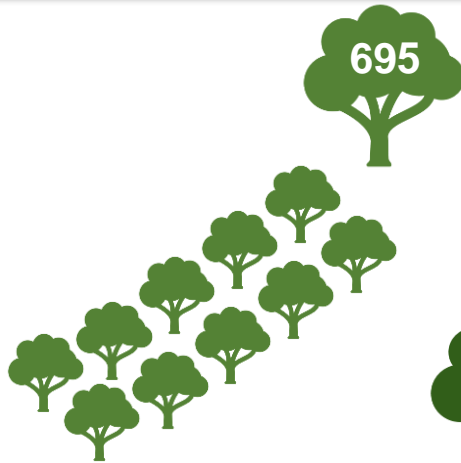
The Macadamia DNA Fingerprinting Service



13
Microsatellite
Markers



Cultivar analysis
Pedigree confirmation
Outcrossing, inbreeding



695

A4

A16

Nelmak2

791

Assess genetic integrity within a cultivar →
establish cultivar reference profiles

344

788

816

814

842



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Members
access a central
DNA reference
database

High-Throughput DNA Isolation Facility



576 samples/2 min



oktopure™ DNA extraction robot
768 samples in a morning



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Macadamia DNA Fingerprinting Service

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SAMAC
Macadamias South Africa NPC



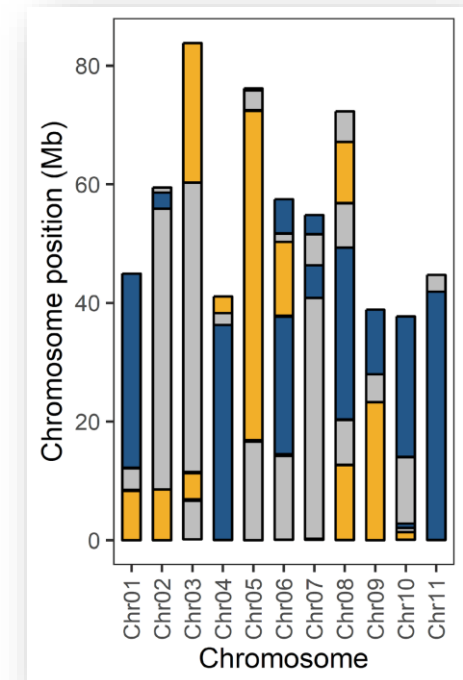
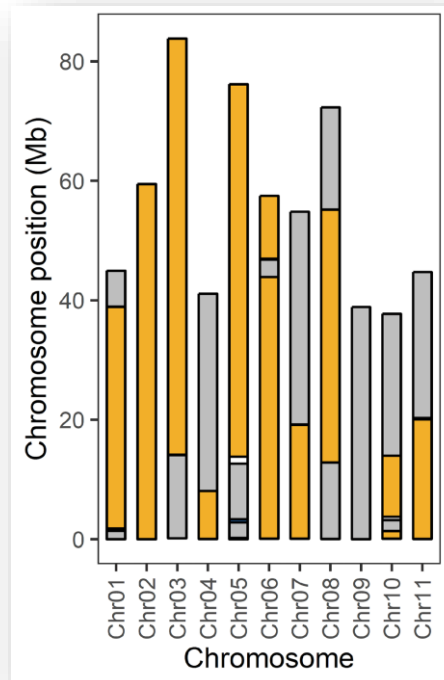
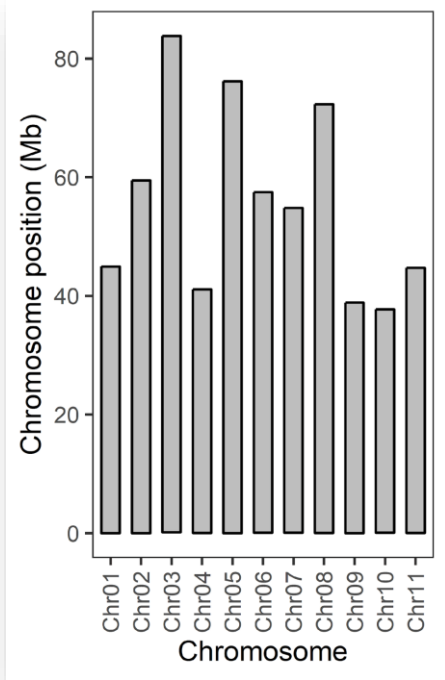


Genetic Resource Management

Ancestry Mapping



Ancestry Mapping

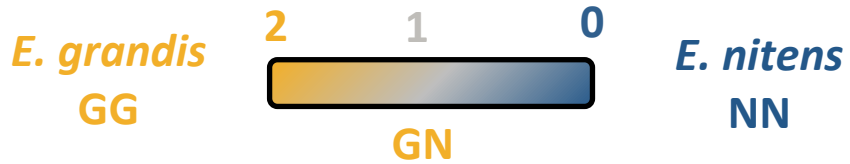


Pure species

F1 GN hybrid

F2 GN x G backcross

F2 GN x GN intercross



Ancestry Mapping

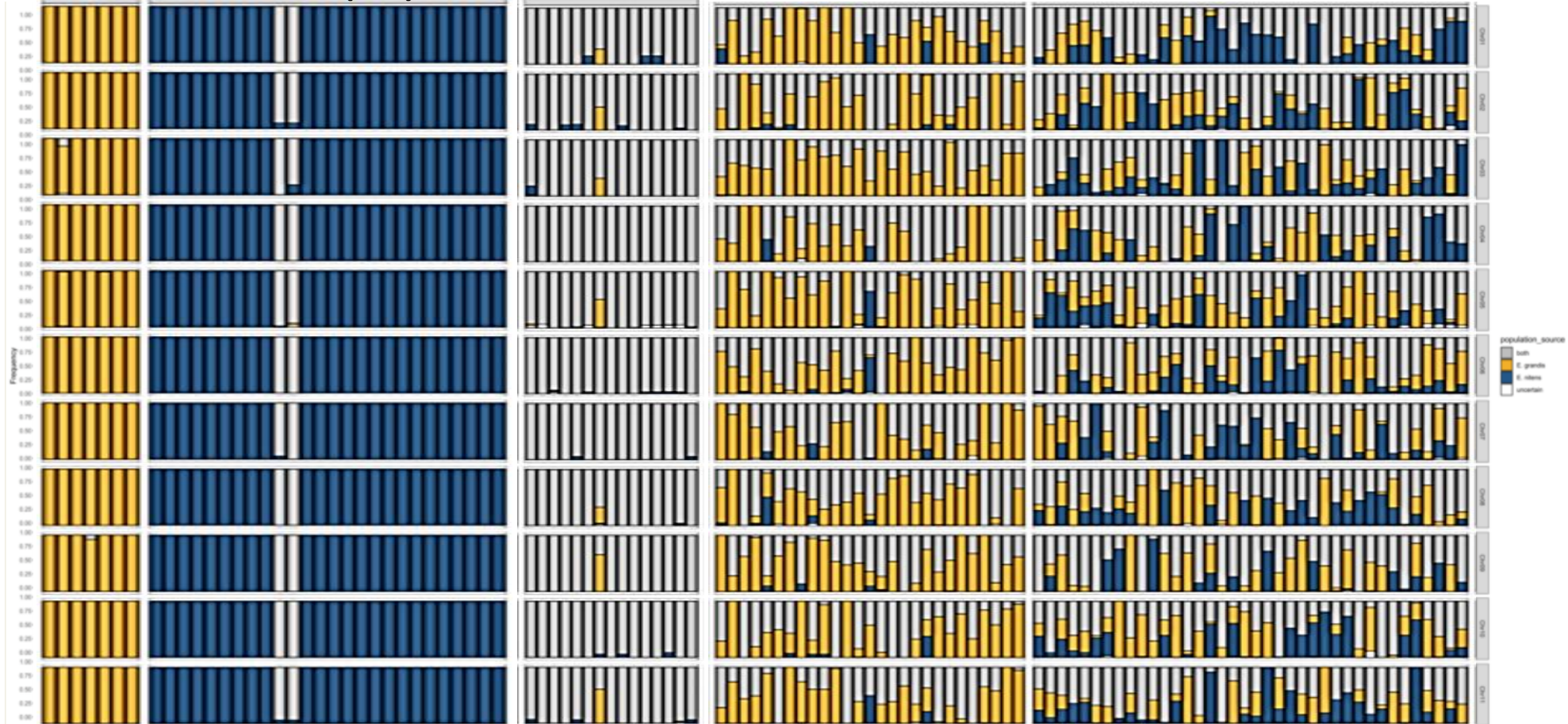
E. grandis (GG)

E. nitens (NN)

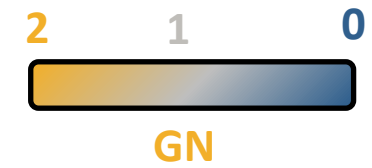
GN F1

GN x G backcross

GN x GN intercross



E. grandis
GG



E. nitens
NN



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Genomic Breeding





Considerations for molecular breeding

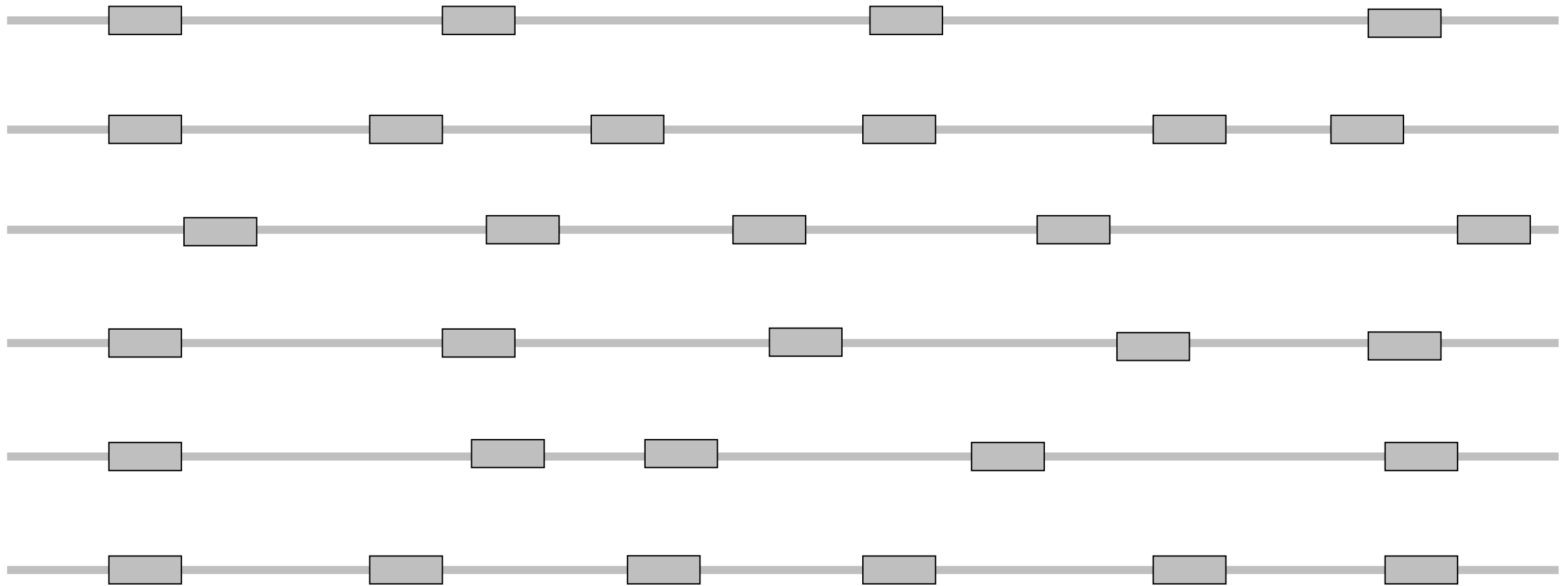
- Most traits of interest are affected by many genes (polygenic)
- Need genome-wide DNA markers (10,000s) to tag genetic variation at these genes
- Can identify DNA markers by sequencing genomes of a diverse set of Macadamia genotypes (Reference panel)
- Identify DNA markers and gene variants associated with traits of interest
- Need a training population ($n \sim 1000$) with measured trait values AND genome-wide marker genotypes
- Predict the genetic merit (breeding value) of plants at seedling level → **Genomic Selection (GS)**
- Can save 5-8 years on breeding cycle → **Accelerated breeding**



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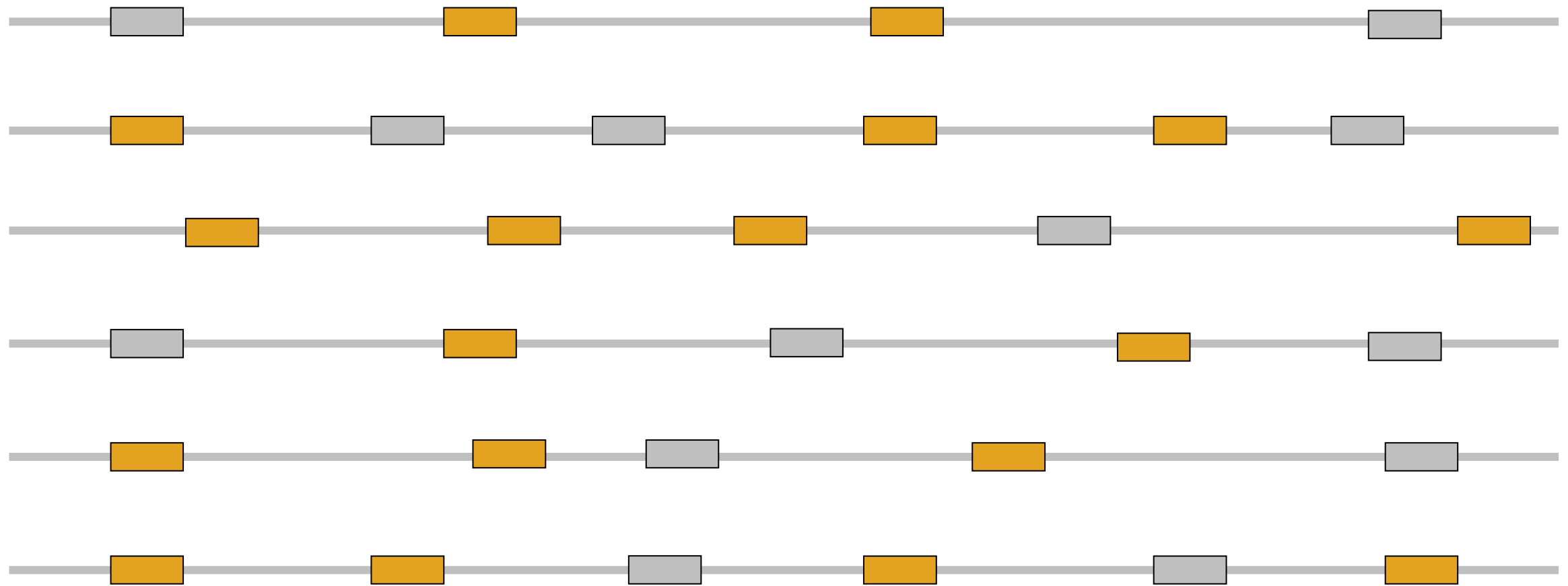


Tracking gene variants in the Macadamia genome



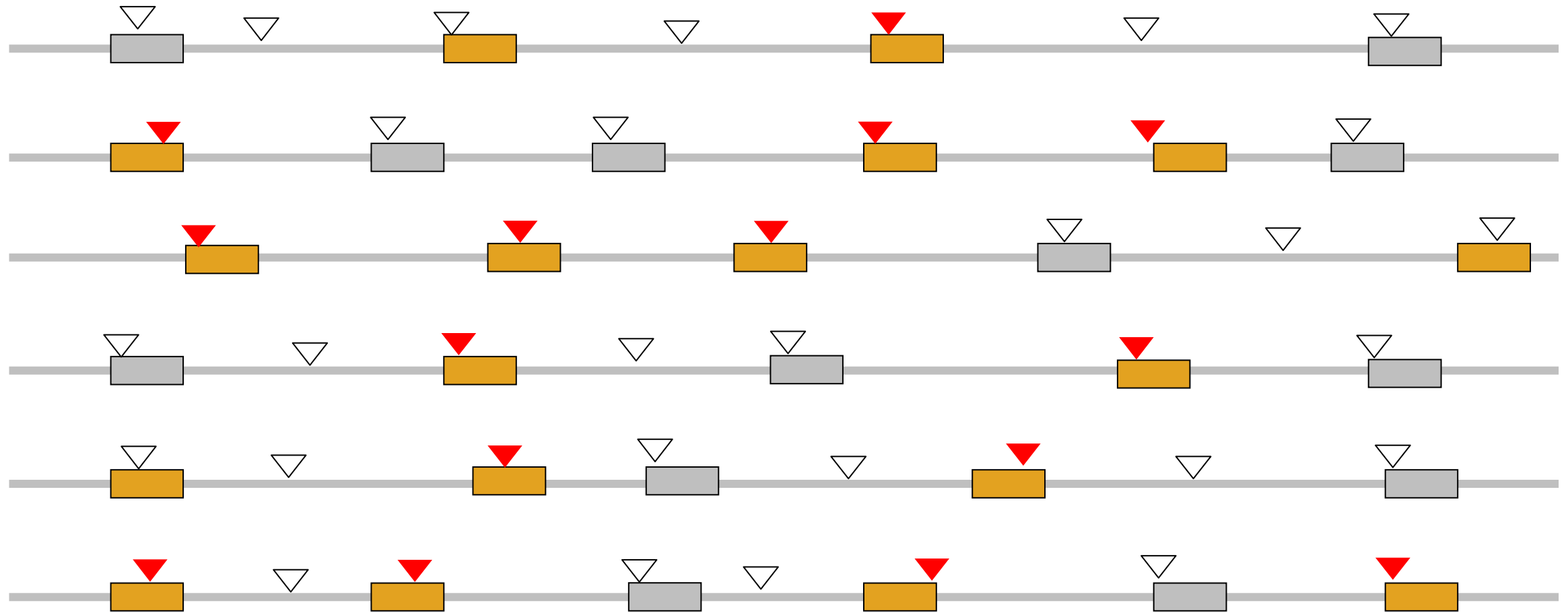
— Macadamia genome Genes

Tracking gene variants in the Macadamia genome



— Macadamia genome Genes NOT affecting the trait Genes affecting the trait

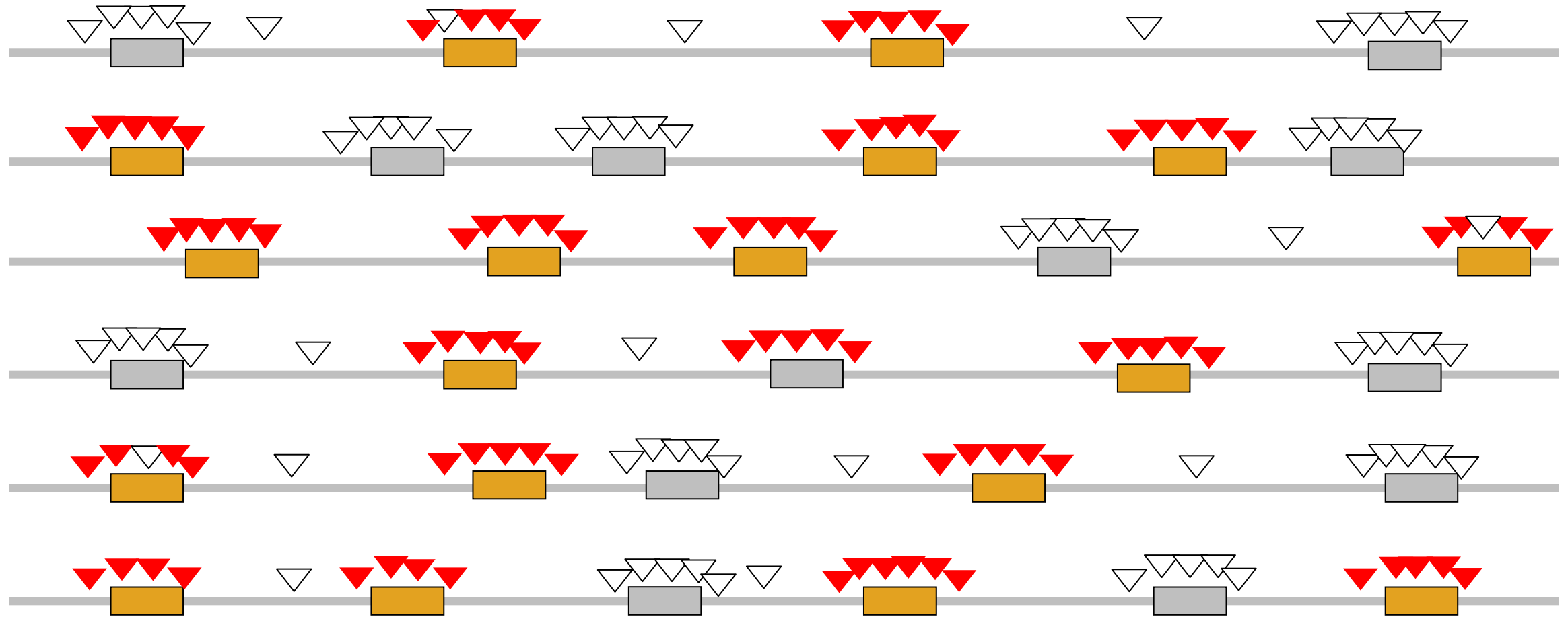
Tracking gene variants in the Macadamia genome



— Macadamia genome ▼ DNA Marker ("tag") PREDICTIVE of trait ▼ DNA Marker ("tag") NOT predictive

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Tracking gene variants in the Macadamia genome



— Macadamia genome ▼ DNA Marker ("tag") PREDICTIVE of trait ▼ DNA Marker ("tag") NOT predictive

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Summary and Future Work

- Three genomes sequenced (695, 791, Santa Anna)
- DNA Fingerprinting service for Macadamia industry
- Ongoing: Genetic linkage mapping (695 x 791 cross)
- Planning: Ancestry mapping to resolve hybrid nature of Macadamia cultivars
- Planning: Sequence a panel of 24 cultivars of relevance to South African breeding
- Offer a genome-wide genotyping service for Macadamia
- Develop a Genome-Assisted Breeding Platform for Macadamia



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Macadamia Genomics





QUESTIONS ?

