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Training in organic breeding

Module 5 – Organic heterogeneous material (OHM) design and development

Unit 5.2: **Dynamic Mixtures: setting-up & selection**

Author: **Pedro Mendes Moreira (IPC)**

Co-funded by the European Union

Funded by the European Union, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI).

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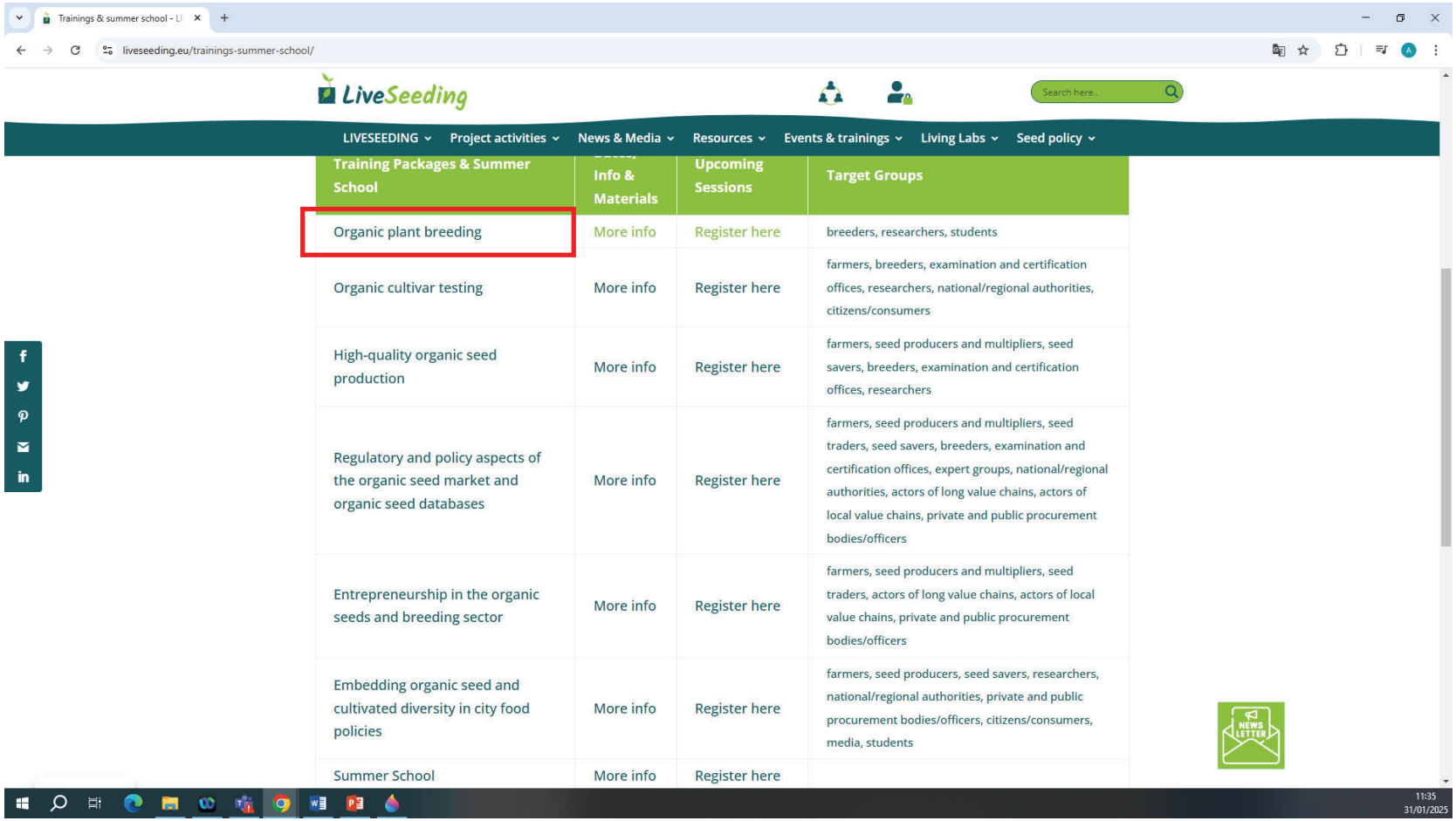
CONTEXT: Training in LIVESEEDING project

https://liveseeding.eu/trainings-summer-school/



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Training in organic breeding organized in 5 Modules

1. **Module 1** - Plant Genetic Resources (PGRs): collection, conservation and exchange to support the increase of agrobiodiversity in farming systems
2. **Module 2 - Phenomics: approaches and tools for genetic resources and breeding material characterisation - FEBRUARY 3rd 2025, 9:00 to 17:30 CET**
3. **Module 3** - Breeding methods fundamentals - FEBRUARY 13th 2025, 9:00 to 18:00 CET
4. **Module 4** - Development and application of molecular methods in organic breeding - MARCH 4th 2025, 9:00 to 18:00 CET
5. **Module 5 - Organic heterogeneous material (OHM) design and development - MARCH 7th 2025, 9:00 to 18:00 CET**

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Module 5 –
Organic heterogeneous material (OHM) design and development

MARCH 7th 2025 9:00 to 18:00 CET

Unit 5.1: Composite Cross Populations: setting-up & selection

9:00-11:00 Partner in charge: UPV (A. Rodríguez-Burruezo) and I. Goldringer (INRAe)

11:00-11:30 Break

Unit 5.2: Dynamic Mixtures: setting-up & selection

11:30-13:00 Partner in charge: IPC (P. Mendes Moreira)

13:00-14:30 Lunch Break

Unit 5.3: Fundamentals of populations genetics applied to OHM development and use

14:30-16:00 Partners in charge: UPV (A. Rodríguez-Burruezo) and I. Goldringer (INRAe)

16:00-16:30 Break

Unit 5.4: Using genomics to track the evolution of heterogeneous organic materials

16:30-18:00 Partner in charge: FiBL (M. Schneider)

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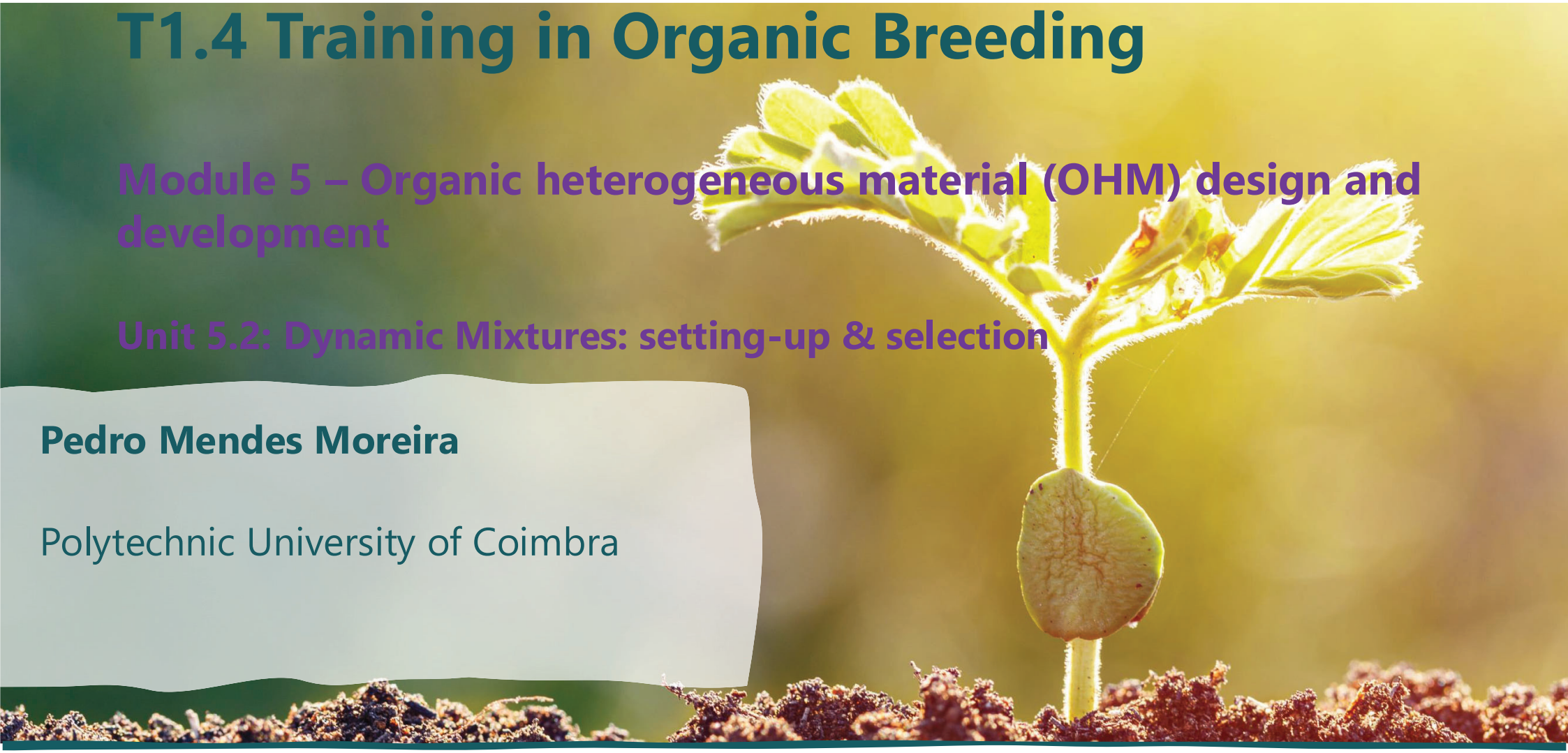
T1.4 Training in Organic Breeding

Module 5 – Organic heterogeneous material (OHM) design and development

Unit 5.2: Dynamic Mixtures: setting-up & selection

Pedro Mendes Moreira

Polytechnic University of Coimbra



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Module 5 – Organic heterogeneous material (OHM) design and development

Planned for today

DYNAMIC MIXTURE OF:

1. *Presentation about main topics on dynamic mixtures, why?,how and some examples (50 min)*
2. Fast quiz (about 10 min) ***
3. Debate, Wrap up & Proposed homework (about 10-15 min) ***
4. QUESTIONS: THROUGH THE CHAT (Anamarija Ćorić will manage)

*** = IMPORTANT for CERTIFICATES (ALL THE UNITS!!!!)

SEND TO BOTH: adrodbur@doctor.upv.es anamarija.coric@ips-konzalting.hr

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Why?

- Genetic Diversity
- Resilience to Climate Change
- Local adaptation
- Potential for Yield stability

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Types of maize populations

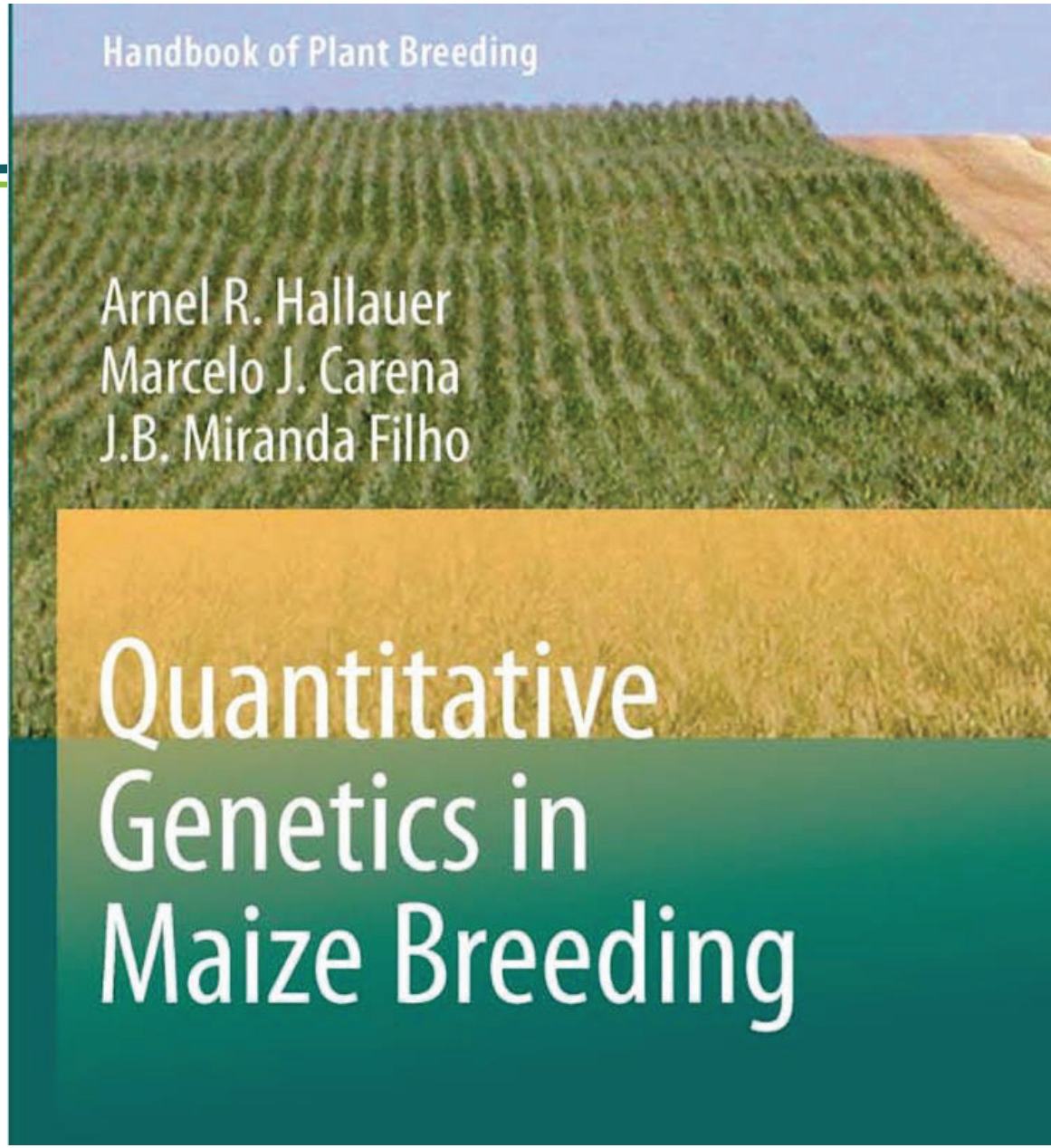
(1)F2 populations developed froma cross of two inbredlines;

(2)**Synthetic** developed from recombination of elite inbred lines(usually10–24lines);

(3)open-pollinated varieties;

(4)variety crosses produced by crossing either open-pollinated varieties or synthetic varieties;and

(5)**composites** developed by inter-mating material of diverse origin, such as open-pollinated and synthetic varieties, hybrids,and inbredlines



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BSSS

Iowa Stiff Stalk Synthetic (BSSS) creating the genetically broad-based synthetic variety, improving it by five cycles of half-sib recurrent selection with a tester, conducting several years of inbreeding and extensive hybrid testing, and producing seed increases for release and industry distribution.

How?

Allogamic versus Autogamic

Autogamic – crosses? Or mixtures?

Allogamic

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Training in organic breeding

Module 5 – Organic heterogeneous material (OHM) design and development

Unit 5.2: **Dynamic Mixtures: setting-up & selection**

Author: **Pedro Mendes Moreira (IPC)**

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#78

Example 1 – Azorean CCP
Trial in Organic and Conventional

Rank Cal	Organic - Caldeirão		Rank V	Conventional - Vagem		Rank diferences
1	VA C0S0 19 - (Regadio Lousada	4313,74	19	VA C0S0 19 - (Regadio Lousada	6450,77	18
2	2501 - (11-2019 Caldeirão 2019	4252,3	21	2501 - (11-2019 Caldeirão 2019	6344,97	19
3	Bulk-Azores 2 - (110-2019 Cald	4248,98	11	Bulk-Azores 2 - (110-2019 Cald	7308,47	8
4	2516 - (23-2019 Caldeirão 2019	4235,95	30	2516 - (23-2019 Caldeirão 2019	5675,8	26
5	2527 - (Caldeirão 2018)	4195,12	35	2527 - (Caldeirão 2018)	5575,57	30
6	2499 - (9-2019 Caldeirão 2019)	4127,95	5	2499 - (9-2019 Caldeirão 2019)	7961,27	-1

Master degree of André Pereira and Duarte Pintado

BulkAzores1' and 'BulkAzores2' were obtained in 2018-19 through the crossing of 40 Azorean OPVs and subjected to mass selection at ESAC and on-farm in 2019.


SINPRE

‘SinPre’ CCP

Crossing of 12 maize populations (10 Portuguese landraces and two American populations) using a polycross method

frontiers in Microbiology | Microbe and Virus Interactions with Plants

Impact Factor 5.640 | CiteScore 7.3
More on impact ›

EDITED BY

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The editor and reviewers' affiliations are the latest provided on their Loop research profiles and may not reflect their situation at the time of review.

TABLE OF CONTENTS

ORIGINAL RESEARCH article

Front. Microbiol., 26 February 2021 | https://doi.org/10.3389/fmicb.2021.636009

Effect of Low-Input Organic and Conventional Farming Systems on Maize Rhizosphere in Two Portuguese Open-Pollinated Varieties (OPV), "Pigarro" (Improved Landrace) and "SinPre" (a Composite Cross Population)

Aitana Ares[1,2], Joana Costa[1,2*], Carolina Joaquim[3], Duarte Pintado[3], Daniela Santos[3], Monika M. Messmer[4] and Pedro M. Mendes-Moreira[5]

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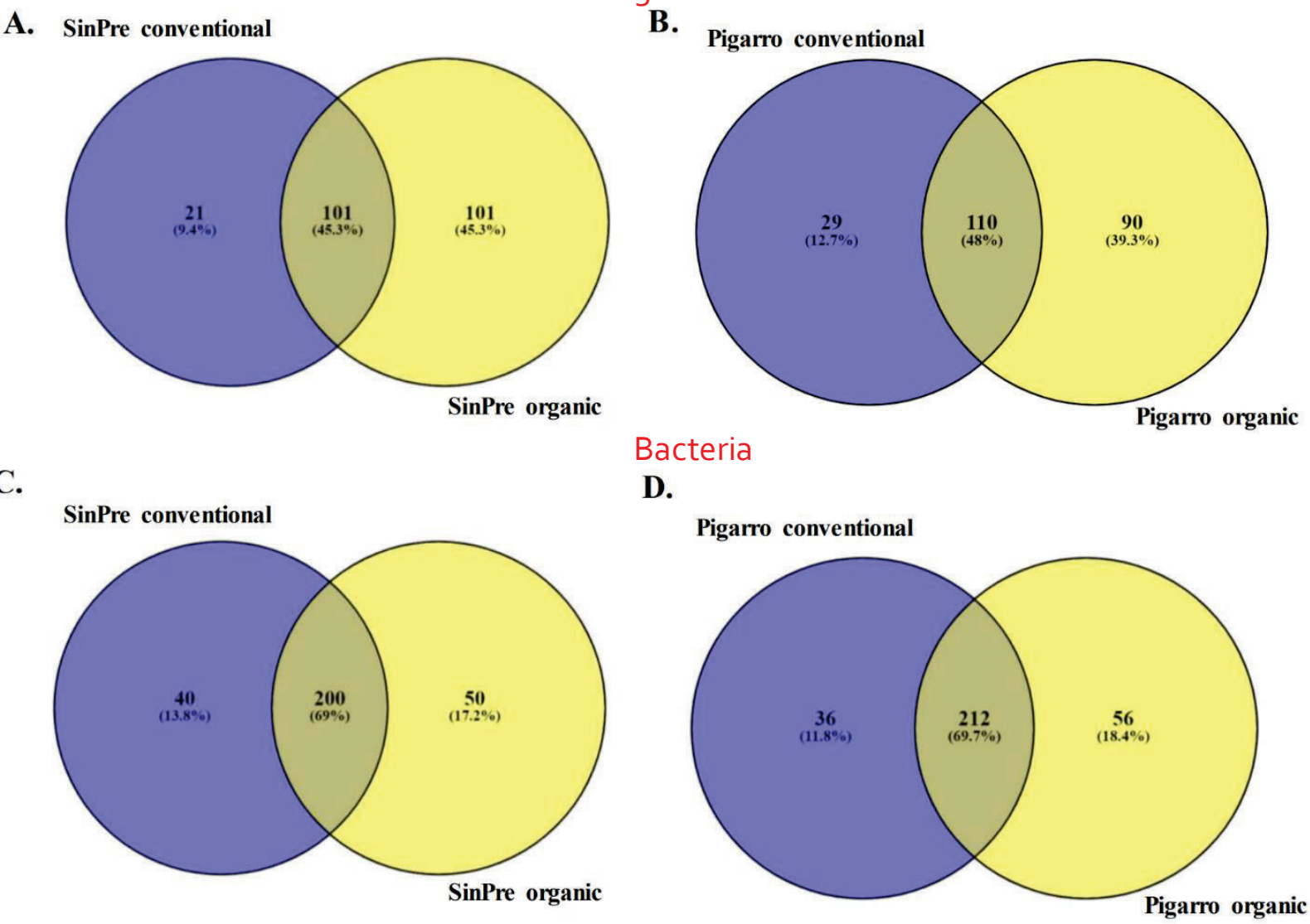
MICROBIOME IN MAIZE

Escola Superior
Agrária
Politécnico de Coimbra

Fungi



Bacteria

Genera of the rhizosphere of the maize populations

SinPre and Pigarro under conventional and organic farming system

Why?

Maydica 54 (2009): 269-285

'FANDANGO': LONG TERM ADAPTATION OF EXOTIC GERMPLASM TO A PORTUGUESE ON-FARM-CONSERVATION AND BREEDING PROJECT

P.M.M. Mendes-Moreira[1,2,9,*], M.C. Vaz Patto[2,9], M. Mota[3], J. Mendes-Moreira[4,5], J.P.N. Santos[1], J.P.P. Santos[1], E. Andrade[6], A.R. Hallauer[7], S.E. Pego[8,9]

[1] *Escola Superior Agrária de Coimbra, Departamento de Fitotecnia, Sector de Protecção Vegetal, Portugal*
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[8] *Fundação Bomfim. Rua da Boavista, 152-154, 4700-416 Braga, Portugal*
[9] *Zea+, Portugal*

Received July 6, 2009

Mendes-Moreira, P. M. M., Patto, M. V., Mota, M., Moreira, J. P. C. L. M., Santos, J. P. N., Santos, J. P. P., ... & Pego, S. E. (2009). " Fandango": long term adaptation of exotic germplasm to a Portuguese on-farm-conservation and breeding project.

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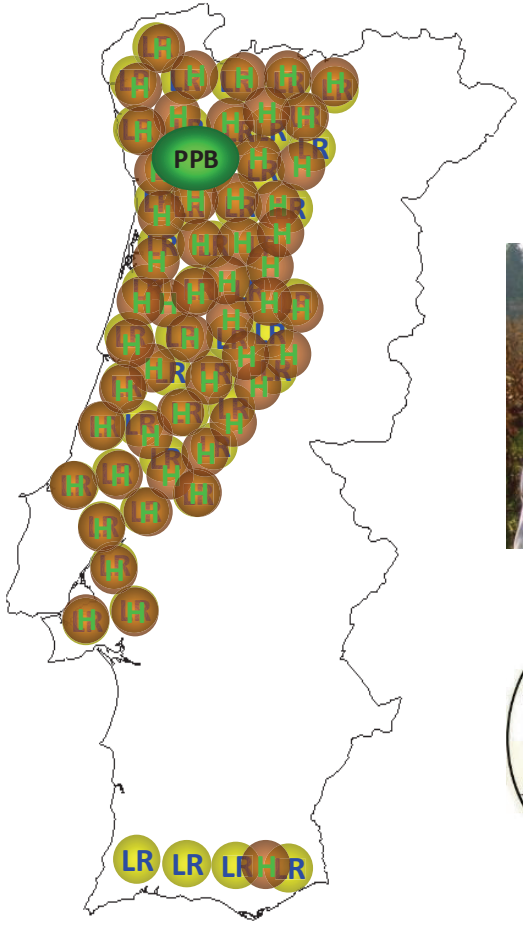
Hybrids Program

Early1940s

Genetic Resources

1975-76 First collection missions



Silas Pêgo

Participatory Plant Breeding since **1984**

NUMI
BRAGA
PORTUGAL
NÚCLEO DE MELHORAMENTO DE MILHO

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Fandango

Hybrid

Story of a synthetic population,

76 yellow elite inbred lines (dent and flint; 20% Portuguese and 80% North American

1	2		76
76	…	2	1

“NUTICA” – 1975-78

1983 - North Carolina Design 1 matting design (1 male crossed with 5 females)

‘Fandango’- on farm introduction and mass selection until today

And other Populations

Mendes-Moreira, P. M. M., Patto, M. V., Mota, M., Moreira, J. P. C. L. M., Santos, J. P. N., Santos, J. P. P., ... & Pego, S. E. (2009). " Fandango": long term adaptation of exotic germplasm to a Portuguese on-farm-conservation and breeding project.

‘Fandango genesis’

- **Step 1: ‘NUTICA’ Formation (1975)**
  - Created from 77 yellow elite inbred lines (20% Portuguese, 80% North American).
  - Intermated under natural isolation and subjected to selection cycles.

1	2		76
76	…	2	1

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‘Fandango genesis’

- **Step 2: ‘Fandango’ Synthesis**
  - Created using North Carolina Design 1 mating (1 male x 5 females).
  - Formed by mixing all resulting crosses in open pollination.

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Participatory Breeding in Sousa Valley (VASO Project)

- Initiated in 1985 by Silas Pego with CIMMYT support.
- Farmers engaged in breeding and selection to ensure adaptation to local conditions.
- Trials conducted in Portugal (3 locations, 3 years) and the USA (4 locations, 1 year).

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The ABC of phenotypic recurrent selection

Two parental control mass selection:

in the field

- before pollen shedding

- before harvesting

- at the storing facilities

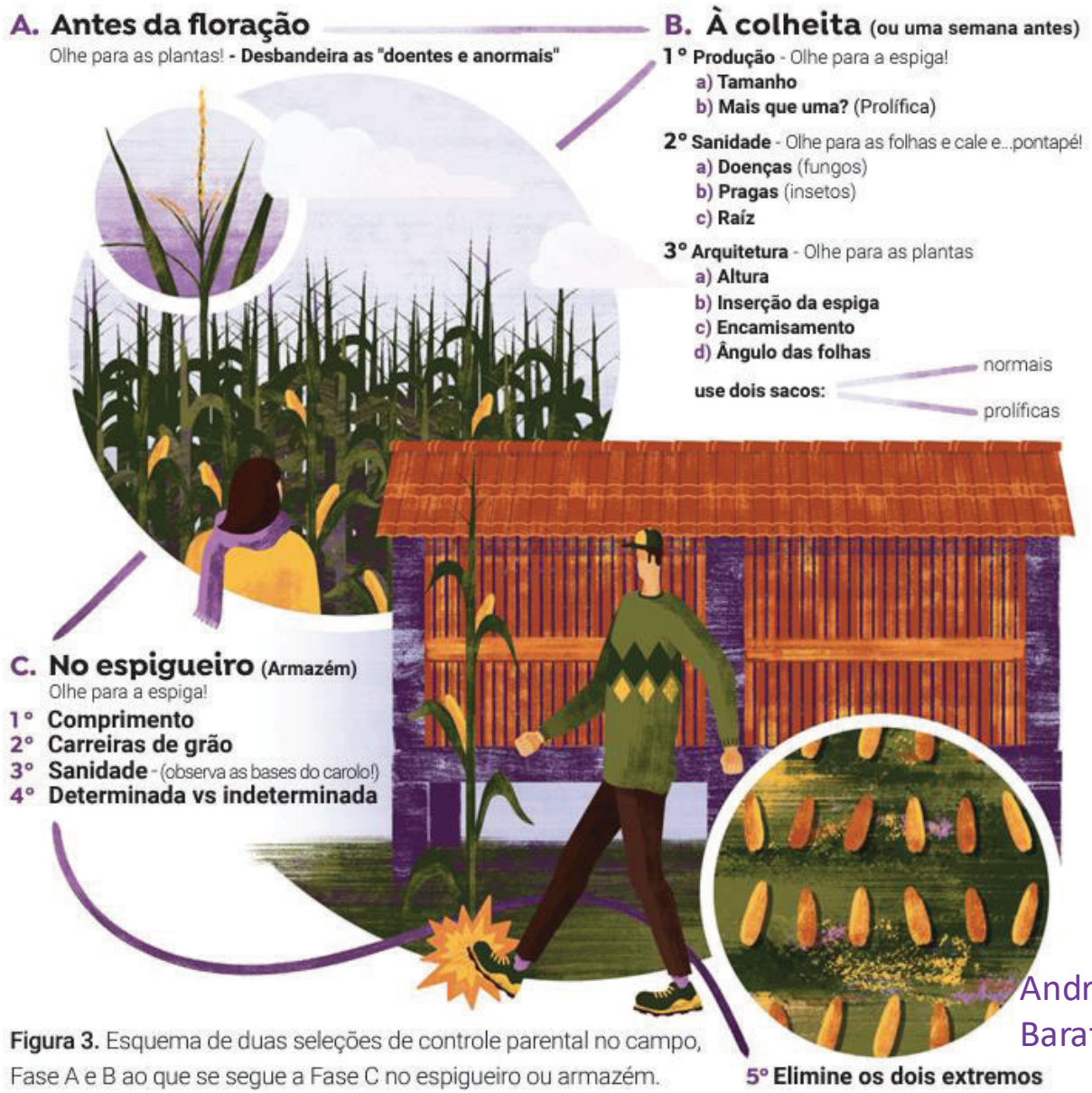

Figura 3. Esquema de duas seleções de controle parental no campo, Fase A e B ao que se segue a Fase C no espigueiro ou armazém.

André Barata

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Research Methods

- **Mass Selection Cycles:** Conducted over 22 years.
- **Field Trials:** Compared selection cycles across different environments.
- **Data Analysis:** ANOVA, regression models, and non-parametric methods (MARS).

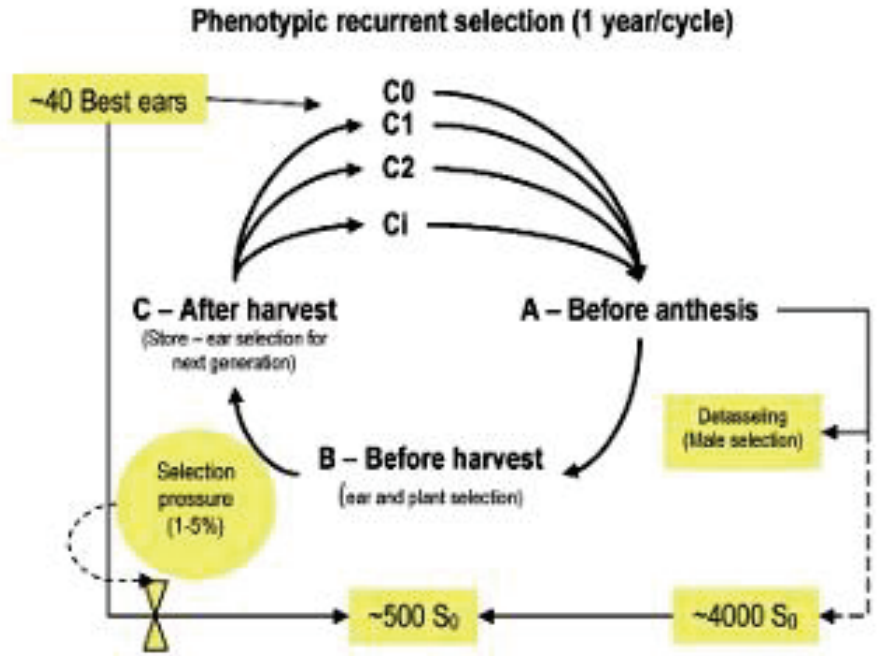
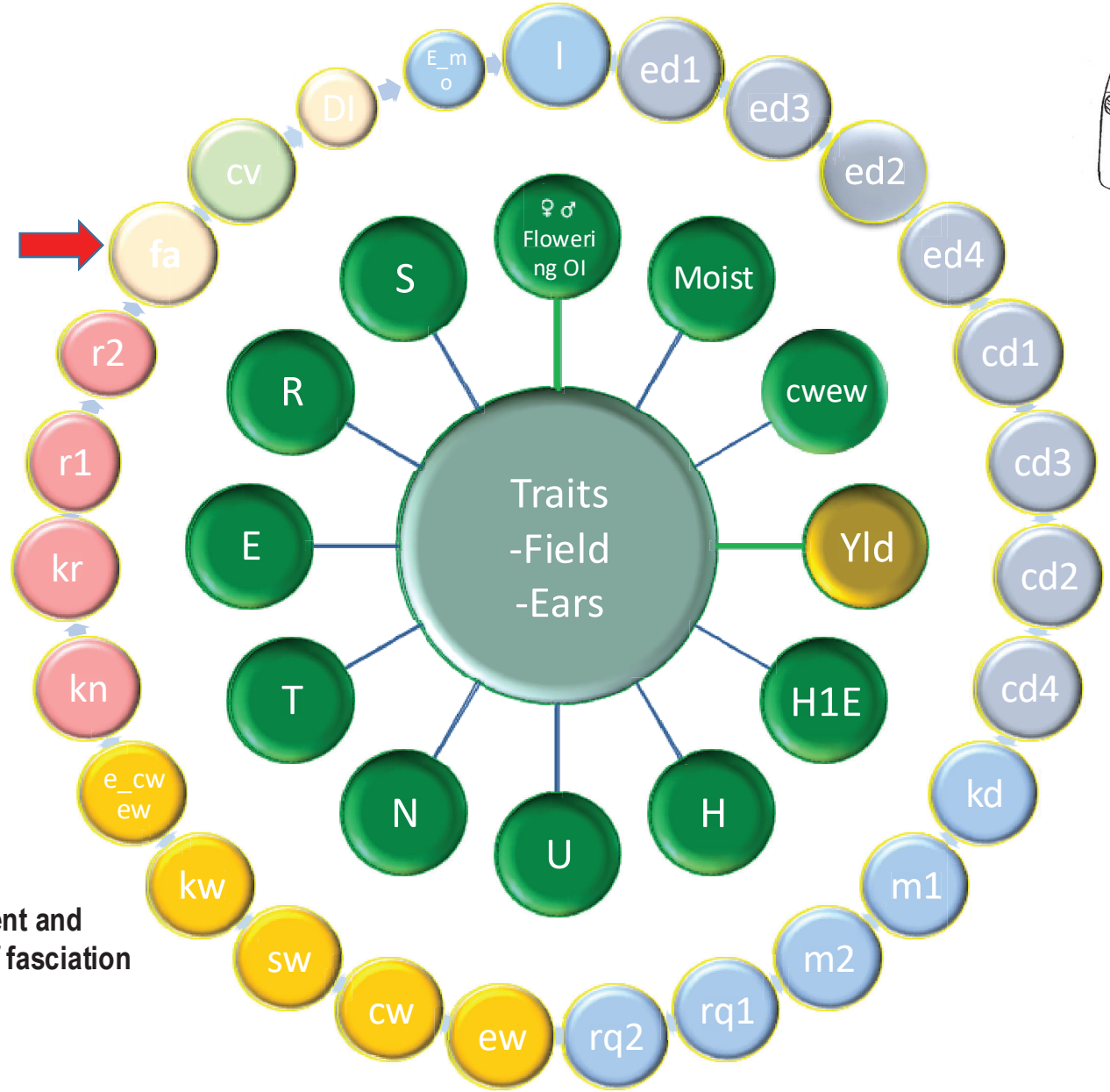


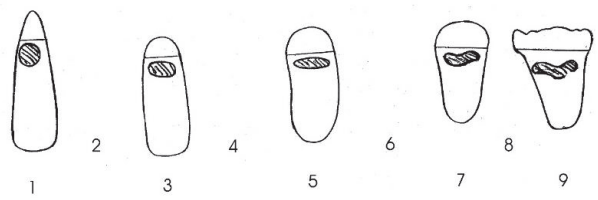
FIGURE 1 - Phenotypic recurrent selection methodology used in 'Fandango' by the breeder.

Material and Methods

- ‘**Fandango**’ - 5-7 entries
  - Mass. Selection Breeder:
  - C1—86, C3—88 (except 2007), C5—90
  - Mass. Selection Farmer:
  - C11—96, C15-00, C19-04, C22-07 (only 2008)

- 3 Replications
- Plots
  - Portugal **9.6 m²** (2 rows x 7.00 m lenght x 0.75 m between rows);
  - Iowa **8.31 m²** (2 rows 5.47 m lenght 0,76 m between rows)
  - Density ~50 000



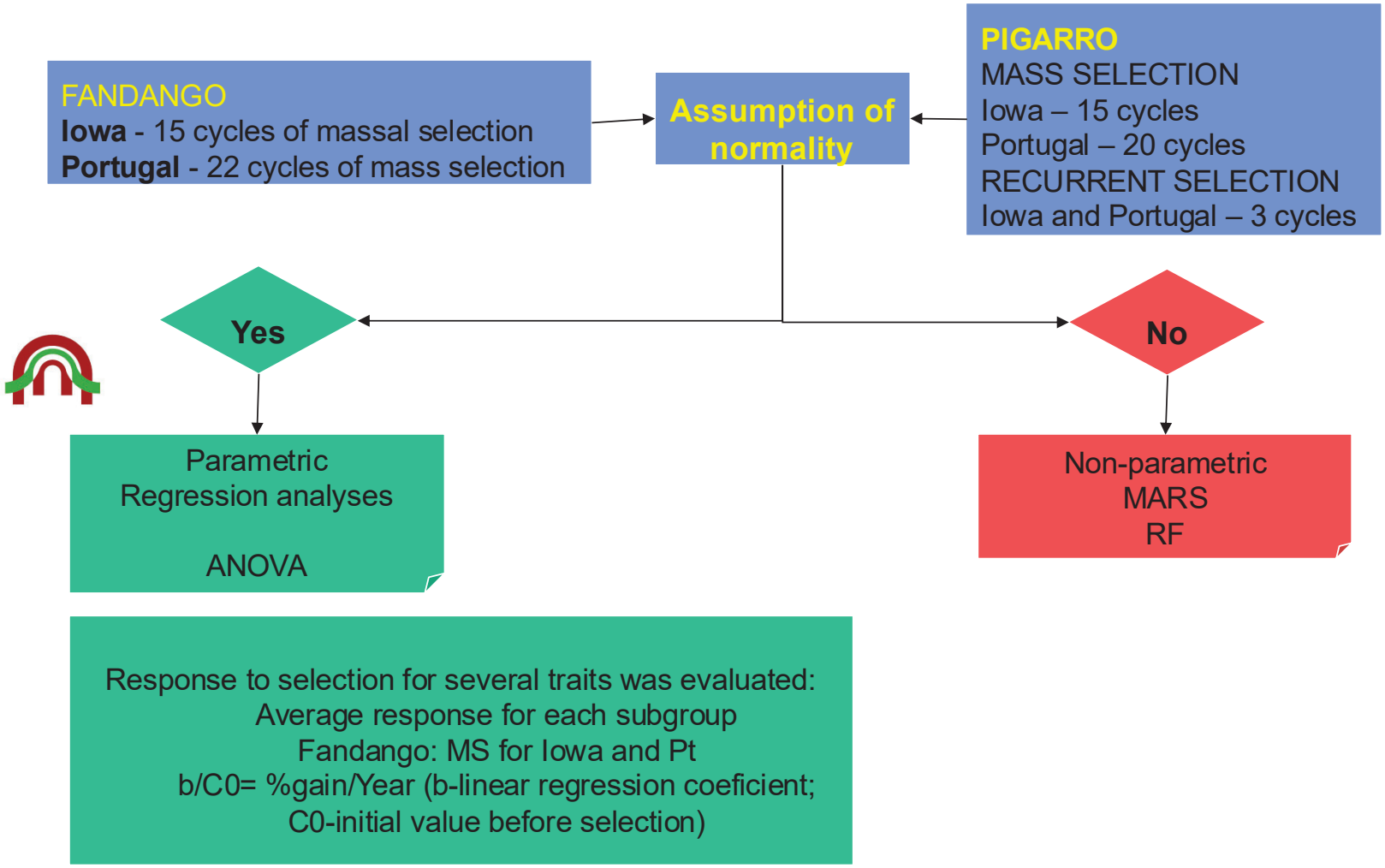


Overall assessment and decomposition of fasciation
Field traits 12
Ear traits 27

Statistical Analyses

ANOVA
Sheffé test
Response to selection
BS vs FS for Iowa and Pt

Material and Methods (Data analyses)

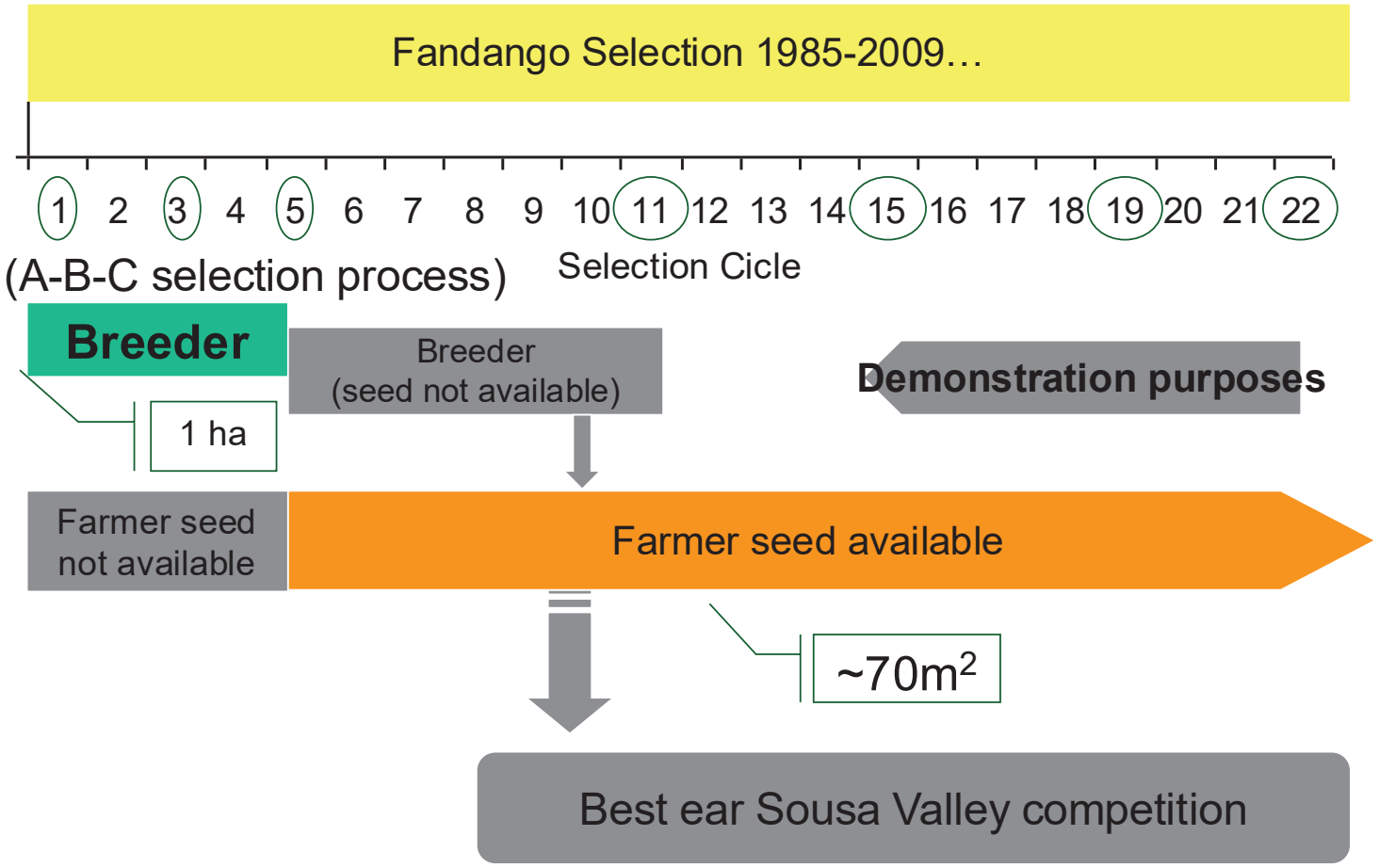


Material and Methods

- A second analysis was performed in order to get insights on the causes that explain the yield. We have used three methods for analysis:
  - MARS
  - Classification and Regression Trees (CART)
  - Random Forests (RF).

- The reason to use three methods instead of just one is to get advantage of their complementary characteristics in order to better understand what influences the yield in both populations

‘Fandango’ selection



Key Findings – Yield and Selection Response

- The selection process included 22 phenotypic mass selection cycles and occurred in two phases:
- 1) The breeder phase from cycle 1 to cycle 5, and
- 2) The farmer phase, after cycle 5.
- The aim of the breeder was the yield improvement of ‘Fandango’. To achieve this goal, stratified mass selection was done for both parents. For yield, no significant changes were observed during selection when all locations were considered (Fig. 8).
- Nevertheless for Lousada, and during the first 5 cycles, a higher tendency exists for yield increase (3.09% of gain per cycle per year) for breeder selection compared with farmer selection (0.63%, of gain per cycle per year) (Fig. 9).

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Key Findings – Yield and Selection Response

- Yield response differed between Portugal and Iowa.
- In Portugal: Increased plant height, ear height, kernel number, and ear diameter.
- In Iowa: Yield decreased under mass selection.
- Selection was more effective when controlled by breeders than farmers.

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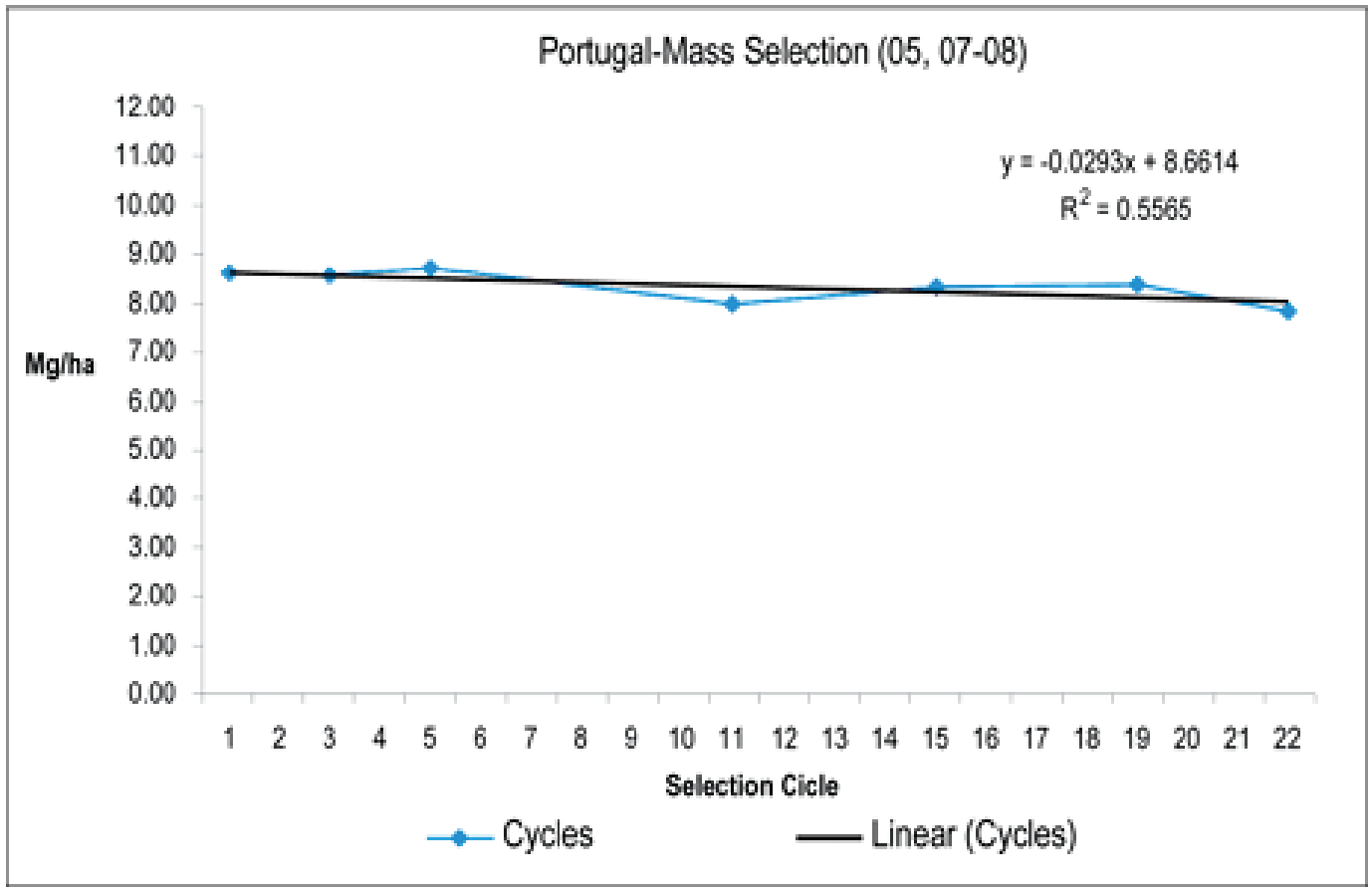

FIGURE 8 - Yield evolution during the 22 cycles of mass selection.

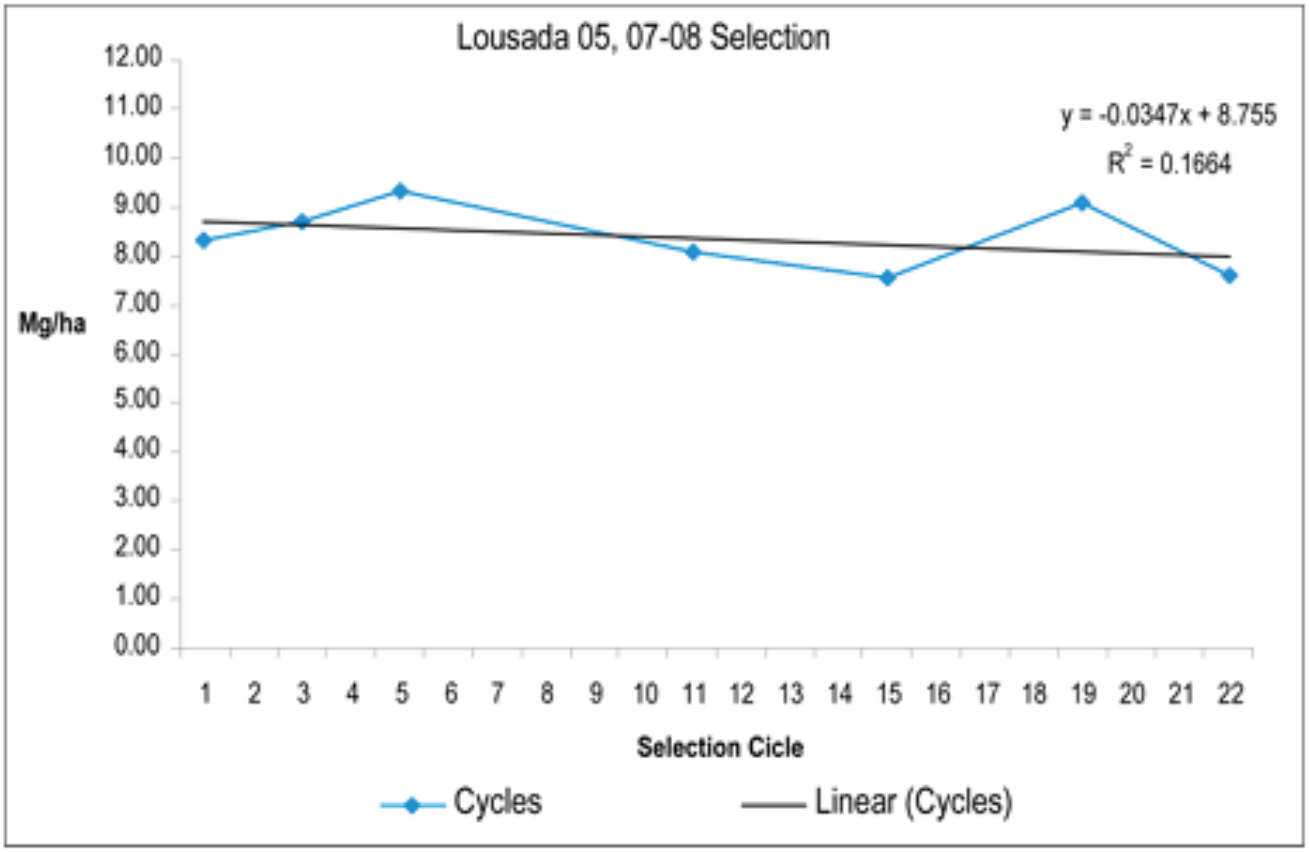

FIGURE 9 - Yield evolution during the 22 cycles of mass selection for Lousada. The first five cycles represent the breeder selection.

Key Findings – Yield and Selection Response

- The selection process included 22 phenotypic mass selection cycles and occurred in two phases:
- 1) The breeder phase from cycle 1 to cycle 5, and
- 2) The farmer phase, after cycle 5.
- The aim of the farmer selection was the **ear size maximization**. This selection procedure can be related to: a) hand versus mechanical harvesting. Generally farmers prefer lower densities and bigger ears if they harvest by hand; b) the "Best Ear of the Sousa Valley competition", was one of the main reasons that explains the popularity of 'Fandango'. Hence during farmer selection some decisions could prejudice hypothetical yield gain, such as the selection of higher moisture ears (for Lousada, R2 = 80.5; 0.62% of gain per cycle per year) comparing with breeder selection. Considering that maximum ear size is

Genetic Diversity and Selection Traits

- Kernel weight and ear weight were key factors influencing yield.
- Fasciation (mutation causing flattened stems/ears) increased with farmer selection.
- Increased ear row number and ear diameter under mass selection.
- Thousand kernel weight and ear length decreased over cycles.

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Importance of On-Farm Conservation

- Fandango won the “Best Ear of Sousa Valley” for 17 consecutive years.
- Farmer selection strategies prioritized large ears and high moisture content.
- Maintained genetic diversity while improving adaptation to local conditions.

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Unit 2.4: Methods for phenotyping and selection of agronomic traits of interest in organic farming

(EV formula) was defined as:

$$EV = \frac{0.6 \times KW + 0.2 \times L + 0.15 \times R + 0.05 \times KN}{4} \quad (1)$$

KW stands for kernel weight (grams) at 15% moisture, *L* for ear length (centimeters), *R* for kernel row number and *KN* for total number of kernels.

Not forgeting to feed local iniciatives that can help on PPB recognition

“Best Ear of Sousa Valley competition” can provide adequate measurements, indicate best traits for selection and prediction

$$EVA = \text{mlr.varsEV} = -7.030877 + 0.031605 \times KW + 0.387825 \times L + 0.337015 \times R12 - 0.008875 \times KN \quad (13 \text{ and } 14)$$

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M3 – U2 Common methods and strategies in organic breeding

QUIZ

Question 1: Should I follow the same methodology for producing CCPs using allogamic or autogamic plants

- *Yes/no*

Question 2: Can farmers produce CCPs?

- *Yes/no*

Question 3: Do synthetics and composites have the same genetic structure

- *Yes/no*

Question 4: What in meant by BSSS?

Send to :

pmm@esac.pt and anamarija.coric@ips-konzalting.hr

In 10 min

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M3 – U2 Common methods and strategies in organic breeding

DEBATE

- *Revise the quiz in common*
- *What I know about CCPs and Synthetics ?*
- *Own previous experiences*
- *Other questions and doubts*

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WRAP UP

- *What we have learned today?*
- *Select a crop the traits and methodology that you would choose to produce a CCP*

Send to :

adrodbur@doctor.upv.es *pmm@esac.pt* *and* *anamarija.coric@ips-konzalting.hr*

By 14th march

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Thanks for your attention!

VI_EUCARPIA CONFERENCE

on breeding to meet environmental & societal challenges

26 TO 28 MAY 2025
PORTUGAL

Instituto Politécnico de Coimbra - ESAC

Polytechnic University of Coimbra · LiveSeeding · EUCARPIA Section Organic & Low Input Agriculture

Additional available materials

1. Mendes-Moreira, P., Satovic, Z., Mendes-Moreira, J., Santos, J. P., Nina Santos, J. P., Pego, S., & Vaz Patto, M. C. (2017). Maize participatory breeding in Portugal: Comparison of farmer's and breeder's on-farm selection. *Plant breeding*, *136*(6), 861-871.
2. Vaz Patto, M. C., Moreira, P. M., Carvalho, V., & Pego, S. (2007). Collecting maize (Zea mays L. convar. mays) with potential technological ability for bread making in Portugal. Genetic Resources and Crop Evolution, 54, 1555-1563.