Ecogeographical approaches to characterize CWR adaptive traits useful for crop adaptation

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Crop adaptation and climate change
Moving phenotypic optima and adaptive evolution

- Wild plants:
  - Migration
  - Adaptive evolution
Moving phenotypic optima and adaptive evolution

- Wild plants:
  - Adaptive evolution

Gomulkiewicz & Holt (1995)
Moving phenotypic optima and adaptive evolution

- Crops:
  - Artificial selection
  - Additive genetic variation: (CWR)

Gomulkiewicz & Holt (1995)
Need to optimize search for CWR germplasm accessions and populations

- The most representative collection with the least accessions
- Population/accessions most likely to have the genetic additive variance for the desired traits
Ecogeographical approach

Ecogeographical approach

Adaptive gene diversity is modulated by natural selection.
Limiting environmental conditions shape adaptive traits.

- **Genetic flux**
- **Mutation**
- **Drift**

- **Epistasis**
- **Dominance**

- **Natural Selection**

- **Additive genetic variance**

- **Genotype x Environment**

- **Genotype**

- **Environment**

- **Trait**
Ecogeographical approach

- Adaptive genetic diversity is modulated by natural selection
- Limiting environmental conditions shape adaptive traits

Environment -> Genotype x Environment -> Trait

Natural Selection -> Additive genetic variance

- Genetic flux
- Mutation
- Drift

- Epistasis
- Dominance
Ecogeographical approach

Environmental factors that characterize the adaptive landscape

Temperature, rainfall, bioclimatic indices, etc.

Slope, orientation, elevation, latitude/longitude, etc.

Soil type, pH, salinity, organic C, soil texture etc.

... over 100 variables available from different sources (WorldClim, FAO, NOAA, etc.)
Ecogeographical Land Characterization Maps

Generation of ecogeographical categories in a territory

Two step cluster analysis

BIC algorithm to determine automatic number of clusters

3 Climatic clusters
3 Soil clusters
3 Geophysical clusters

27 ecogeographical categories

Map of ecogeographical zones
Ecogeographical Land Characterization Maps

- To combine climatic, edaphic and geographic data to enable the prediction of patterns of adaptive genetic variation according to geographic origin (Peeters et al., 1990)

Ecogeographical Characterization of Germplasm Collections

- To obtain a complete ecogeographical characterization of each germplasm accession
- Over 100 ecogeographical variables associated to each accession with quality georeferencing data.
Ecogeographical Core Collections

- Ecogeographic core collections provide good representation of the genetic diversity of the original collection.
- Validation of ecogeographic core collections using phenotypic data
Phaseolus vulgaris seed collection

15 morphological variables

Ecogeographical Core Collections compared to Phenotypic Core Collections and phenotypically assessed

Ecogeographical Core Collections

- GIS extracting categories from ecogeographical map
- Phenotypic characterization data
- 2199 P. vulgaris georeferenced accessions

Grouping methods
- Categories from ecogeographical land characterization Map (CEM)
- Two Step Cluster (TSC)
- Ward MLNM (WM)
- UPGMA
- No grouping method (RANDOM)

Allocation strategies
- C,P,L
- C,P,L,D
- C,P,L,D
- C,P,L,D

Random selection of accessions

CORE COLLECTIONS 10% or 15% sampling intensities

Independent sampling (k=1000)
- MD, VD, CR, VR, XD, and SEP (synthetic evaluation parameter)

Representativeness criteria (Hu et al., 2000)

Ranking using SEP as reference
### Phaseolus vulgaris Core Collections

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Ecogeographical Core Collections

*Phaseolus vulgaris* Core Collections

This was assessed with landraces. Better results expected with CWRs.
- No characterization of CWR genetic diversity.
- Efficient representation of adaptive genetic diversity in CWRs
- Most representative collection with the fewest accessions
- Ecogeographical representativity to adequately represent genetic diversity useful to breeders

Identification of geographic gaps
Optimized collection of CWR germplasm

Identification of ecogeographic gaps

Low – null representation
Optimized collection of CWR germplasm

Predictive distribution map for *Lupinus* species

Ecogeographic gaps in high species richness areas

Prioritized locations for collecting *Lupinus* species in Spain

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Optimized collection of CWR germplasm

Prioritized locations for collecting *Lupinus* species in Spain
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[Map of Spain with locations marked]

[Graphs showing distribution of *Lupinus* species]

[Photos of *Lupinus* plants and collected seeds]

Focused Identification of Germplasm Strategies

- Select accessions/populations most likely to have desired genetic variation for a target trait
- Applied to traditional varieties. Even more appropriate for CWR.
- Using ecogeographical data for prediction of phenotypic traits before evaluation trials.
- FIGS subsets ≠ core collections
Focused Identification
Germplasm Strategies

*Beta* L., *Brassica* L. and *Lupinus* L.

Traits: Tolerance to drought and salinity

**ELC map for Brassica L.**

**Annual Precipitation map (Bioclim12)**

*Brassica* CWR populations

Selected *Brassica* CWR populations with De Martonne aridity index values < 10

Subset of first 100 *Brassica* CWR populations with the lowest De Martonne aridity index values
Wild populations of *L. angustifolius* L. from the Iberian Peninsula:

- Semiarid
- Subhumid
- Humid

**Year 2013**

Culture cycle for:
- Seed production
- Reducing maternal effects

**Year 2014**

Common garden
- Reciprocal sowing in native localities
- Evaluation under different water availability conditions
If we are able to map the different adaptive scenarios for the target species, we can:

- Carry out efficient germplasm collections
- Create ecogeographical core collections (ex situ or in situ)
- Complement genotypic/phenotypic characterization
- Determine optimal places to multiply/regenerate germplasm
- Identify populations/accessions most likely to have the desired traits
On-coming ecogeographic tools

- **CAPFITOGEN**: Workshops for strengthening the capacitation of national programs of plant genetic resources in Latin America – International Treaty PGRFA (http://www.planttreaty.org/es/capfitogen)
  - **ELC Mapas**: Ecogeographical Land Characterization Maps
  - **GEOQUAL**: Assessment of quality of georreferencing information
  - **Representa**: Analysis of ecogeographical representativeness
  - **ECOGEO**: Ecogeographic characterization of germplasm
  - **ColNucleo**: Generation of Ecogeographic Core Collections
  - **DIVmapas**: Maps of high ecogeographical, phenotypic, genetic diversity areas
  - **FIGS_R**: Selection of germplasm through the application of abiotic filters

- Available for analysis of whole European territory and 34 European countries
  - On demand: mauricio.parra@fao.org, capfitogen@fao.org
  - Shortly as tools in the “cloud” available through internet
Thank you!