SUITABILITY FOR SEED FARMING AS PART OF A TRAITS-BASED SELECTION TOOL FOR PROMOTING NATIVE COVER CROPS IN MEDITERRANEAN AGROECOSYSTEMS:

A CASE STUDY FROM SPANISH OLIVE ORCHARDS.

Stephanie Frischie, Borja Jiménez-Alfaro, Cándido Gálvez
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2 Department of Earth and Environmental Sciences, University of Pavia, Italy
3 German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, Germany
SPECIES SELECTION TOOL: BEHIND THE SCENES

1 Background
   • Habitat
   • Restoration goals
2 Approach
3 Results from seed farming evaluation
4 Forthcoming selection tools
Native seed company in Spain recognizes an emerging market and unmet need for seeds of native herbaceous species to use as understory in woody crops.

PhD project to identify suitable native species for the application and how to commercially produce seeds.

DATA FROM THAT RESEARCH IS THE FOUNDATION FOR A FUTURE SELECTION TOOL USED BY FARMERS AND NATIVE SEED COMPANIES.
Native seed company in Spain recognizes an emerging market and unmet need for seeds of native herbaceous species to use as understory in woody crops. NASSTEC grant to develop native seed industry and research. PhD project to identify suitable native species for the application and how to commercially produce seeds. Data from that research is the foundation for a future selection tool used by farmers and native seed companies.
Background

Olive cultivation

- *Olea europaea subsp. europaea*
- Perennial woody crop
- Native to Mediterranean Basin
- Adapted to poor soils and drought
- Wind-pollinated flowers in April
- Fruit set during dry summer period, harvest Oct-Dec
- Fruits are perishable, mechanically removed from trees and taken to mill within hours
- Hundreds of varieties for microconditions of soil, climate, end use, plantation system
- Water availability and pests are main limits to production
Background

Olive production
Background

Olive production
Background

Agriculture and biodiversity in Spain

80% of global production from Spain (2x more than next producer, Italy)

80% of Spanish production from Andalusia
30% (2.6 m ha) of land area in Andalusia

Background

Agriculture and biodiversity in Spain
Low species abundance in the soil seedbank of an olive orchard under conventional herbicide management in Córdoba, Spain.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Number of germinated seedlings</th>
<th>Percent of total germinated seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Spergularia sp.</em></td>
<td>1279</td>
<td>51%</td>
</tr>
<tr>
<td><em>Pulicaria paludosa</em></td>
<td>535</td>
<td>21%</td>
</tr>
<tr>
<td><em>Conyza spp.</em></td>
<td>327</td>
<td>13%</td>
</tr>
<tr>
<td><em>Anagallis arvensis</em></td>
<td>105</td>
<td>4%</td>
</tr>
<tr>
<td><em>Galium aparine</em></td>
<td>144</td>
<td>6%</td>
</tr>
<tr>
<td>Apiaceae</td>
<td>83</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>47</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>2520</td>
<td>100%</td>
</tr>
</tbody>
</table>

85%
Background
Agriculture and biodiversity in Spain

BARE SOIL

↑ ecological simplification

↑ soil erosion

sustainability and long-term productivity
Background
Agriculture and biodiversity in Spain

COVER CROPS

- ecological simplification
- soil erosion

- sustainability and long-term productivity
Current species/varieties available to farmers are forage legumes, grasses and brassicas from temperate Eurasia.

excess biomass + phenology + water use =

Poor fit with Med climate and olive farming

high maintenance & cost (tillage, mowing, herbicide) =

Low acceptance rates
Need for cover crops species which:

– have short life cycle in winter, senesce at onset of summer dry season
– protect soil from erosion
– host beneficial insects
– are suitable to seed increase for sufficient seed supply
Background

Interest in native cover crops

Germination trials of annual autochthonous leguminous species of interest for planting as herbaceous cover in olive groves

Gema Siles*, Juan A. Torres, Luis Ruiz-Valenzuela, Antonio García-Fuentes

Departamento de Biología Animal, Biología Vegetal y Ecología, Área de Botánica, Facultad de Ciencias Experimentales, Universidad de Jaén, Paraje Las Lagunillas s/n., Jaén, Spain

Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
http://dx.doi.org/10.5424/sjar2014123-5255

Natural vegetation management to conserve biodiversity and soil water in olive orchards

Maria P. Simoes¹,², Anabela F. Belo¹,²*, Carla Pinto-Cruz¹,² and Anacleto C. Pinheiro¹,³

Agriculture, Ecosystems and Environment 217 (2016) 119-127
Background

The Mediterranean Basin biodiversity hotspot area is nearly the same as olive cultivation.

Myers et al. 2000; IUCN; Oteros 2014
A native seed company in Spain recognizes an emerging market and unmet need for seeds of native herbaceous species to use as understory in woody crops.

A PhD project to identify suitable native species for the application and how to commercially produce seeds.

Data from that research is the foundation for a future selection tool used by farmers and native seed companies.

NASSTEC grant to develop native seed industry and research.
PhD project
Developing a new use for native species/seeds

Cover crops in Mediterranean woody crops
Species selection methodology:
  criteria
data

Criteria of interest
Traits related to criteria
Evaluation of criteria
Future development tool(s)
PhD project
Developing a new use for native species/seeds

Criteria/traits of interest

Screening native species to sow as cover crops based on suitability to:

1. olive orchard environment
2. seed increase
3. biodiversity and sustainable agrosystems
Approach

- Industry in its infancy
- Low-hanging fruit
- Define traits of interest
- Species pool
- Compile database with traits from the literature and sort
- Collect data on additional traits in field and lab experiments from upper species in sorted list
- Combine traits data into a species selection index

Meli et al. 2014 Applied Vegetation Science 17
Graff and McIntyre 2014 Austral Ecology 39:8
Sacande and Berrahmouni 2016 Restoration Ecology 24:4
Approach
Species filter

Agroecosystem species pool:

Inventory of cultivated habitats in Cordoba Province
979 taxa

Pujadas 1984

Filtering based on general criteria:

- Angiosperms 977 taxa
- Native 894 taxa
- Annuals/therophytes 518 taxa
- Olive orchard habitat 304 taxa

• species/ecotypes are adapted to the sites

Working species pool 304 taxa
Approach
Selection Index

- Host of pathogens (Verticillium, Xylella)
- Plant height
- Winter annual
- Germination niche (temperature, storage and water stress)
- Associations with invertebrate functional groups
Data collection
Plant-Insect associations for biocontrol of olive fly pest
Insect associations with native forbs to provide bio-control and biodiversity in olive orchards.

Collaboration: Dr. Mercedes Campos Spanish High Council for Scientific Research. Granada, Spain

Status:
- Samples have been identified, counted and put into functional groups.
- Currently analyzing data to assign High, Medium or Low values to plant species for beneficial insects.
Approach
Selection Index

- Host of pathogens (Verticillium, Xylella)
- Plant height
- Winter annual
- Germination niche (temperature, storage and water stress)
- Associations with invertebrate functional groups
- Species Selection Index of suitability based on seed farming traits
  - Growth habit and cover
  - Fruit height at maturity
  - Dispersal window
  - Ease of seed cleaning
Native seed company in Spain recognizes an emerging market and unmet need for seeds of native herbaceous species to use as understory in woody crops.

NASSTEC grant to develop native seed industry and research.

PhD project to identify suitable native species for the application and how to commercially produce seeds.

Data from that research is the foundation for a future selection tool used by farmers and native seed companies.
Seed Farming Traits

Expected outcomes

• Commercially available seeds of native species to sow as cover crops.
• Protocols for seed production
• Selection Tools:
  – Flow chart or website for seed producer to use with farmer to tailor seed mixes to crop and site.
Seed Farming Traits

Questions

What are appropriate seeding rates?
What should the row spacing be?
How soon do seedlings emerge?
When is the flowering period?
How long is the window for seed harvest?
What considerations for weed management?
Can a combine be used to harvest the seeds?
### Experimental design

**Seed Farming Traits**

**Dec 2015 - June 2016**

- 30 species
- 3m x 3m plots replicated in 3 blocks
- Random assignment of plots

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOC A</td>
<td>BLOC B</td>
<td>BLOC C</td>
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<tr>
<td>SICO</td>
<td>MOMO</td>
<td>ANVU</td>
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<tr>
<td>TUGU</td>
<td>SICO</td>
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<td>SIGA</td>
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<td>CABU</td>
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<td>NIDA</td>
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<td>ECHPL</td>
<td>BIAU</td>
<td>TRST</td>
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<tr>
<td>CAAR</td>
<td>PADU</td>
<td>VAPY</td>
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<tr>
<td>CHSE</td>
<td>NIDA</td>
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<td>NIDA</td>
<td>SIGA</td>
<td>CRCA</td>
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<td>MEOR</td>
<td>ANVU</td>
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<td>34</td>
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<td>39</td>
</tr>
<tr>
<td>40</td>
<td>41</td>
<td>42</td>
</tr>
</tbody>
</table>
## Experimental Design

### Seed Farming Traits

<table>
<thead>
<tr>
<th>Anarrhinum bellidifolium (L.) Willd.</th>
<th>Plantaginaceae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthemis cotula L.</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Anthyllis vulneraria L.</td>
<td>Fabaceae</td>
</tr>
<tr>
<td>Biscutella auriculata L.</td>
<td>Brassicaceae</td>
</tr>
<tr>
<td>Calendula arvensis M.Bieb.</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Capsella bursa-pastoris (L.) Medik.</td>
<td>Brassicaceae</td>
</tr>
<tr>
<td>Cleonia lusitanica (L.) L.</td>
<td>Lamiaceae</td>
</tr>
<tr>
<td>Crepis capillaris (L.) Wallr.</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Echium plantagineum L.</td>
<td>Boraginaceae</td>
</tr>
<tr>
<td>Glebionis segetum (L.) Fourr.</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Helianthemum ledifolium (L.) Mill. Cistaceae</td>
<td></td>
</tr>
<tr>
<td>Medicago orbicularis (L.) Bartal.</td>
<td>Fabaceae</td>
</tr>
<tr>
<td>Medicago polymorpha L.</td>
<td>Fabaceae</td>
</tr>
<tr>
<td>Misopates orontium (L.) Raf.</td>
<td>Plantaginaceae</td>
</tr>
<tr>
<td>Moricandia moricandioides (Boiss.) Heywood</td>
<td>Brassicaceae</td>
</tr>
<tr>
<td>Nigella damascena L.</td>
<td>Ranunculaceae</td>
</tr>
<tr>
<td>Papaver dubium L.</td>
<td>Papaveraceae</td>
</tr>
<tr>
<td>Salvia verbenaca L.</td>
<td>Lamiaceae</td>
</tr>
</tbody>
</table>
| Scabiosa atropurpurea L.             | Caprifoliaceae-
| Silene colorata Poir.                | Dipsacaceae    |
| Silene gallica L.                    | Caryophyllaceae|
| Stachys arvensis (L.) L.             | Lamiaceae      |
| Tolpis barbata (L.) Gaertn.          | Asteraceae     |
| Tordylium maximum L.                 | Apiaceae       |
| Trifolium angustifolium L.           | Fabaceae       |
| Trifolium hirtum All.                | Fabaceae       |
| Trifolium lappaceum L.               | Fabaceae       |
| Trifolium stellatum L.               | Fabaceae       |
| Tuberaria guttata (L.) Fourr.        | Cistaceae      |
| Vaccaria hispanica (Mill.) Rauschert | Caryophyllaceae|

Grasses evaluated in parallel PhD project
Experimental Design
Seed Farming Traits

3m x 3m plot
7 rows per plot
50 cm spacing between rows
Seeding rate target of 400 seeds/m2
Seed Farming Traits
Data for 30 spp

- Sowing rate
- Row spacing
- Establishment density
- Site prep and weeds
- Growth form
- Phenology
- Fruit height at maturity
- Seed quality for 2 harvest dates
- Seed yield / area
Initial Results: Suitability to seed farming
Cultural practices –
Density score (0-5), cover class, growth habit

2 = light
uneven incomplete
upright

3 = ideal
uneven incomplete
rosette

3 = ideal
uneven complete
creeping

3 = ideal
uneven complete
bushy

4 = thick
rows
upright

5 = too dense
complete
bushy
Initial Results: Suitability to seed farming
Cultural practices –
Distribution of Density scores across species

Species

Density score

TUGU   HELE   ANBE   CABU   PADU   MIOR   STAR   TODA   TRAN   TRIH   TRILA   SAVE   CLLU   SCAT   CRCA   ECPL   MEOR   SIGA   TOMA   ANVU   MOMO   NIDA   TRST   ANCO   CHSE   MEPO   SCO   BIAU   VAPY   CAAR
Initial Results: Suitability to seed farming
Phenology under cultivation
Dispersal and harvest window

<table>
<thead>
<tr>
<th>Phenology stage</th>
<th>Weeks since sowing</th>
<th>Calendula arvensis</th>
<th>Echium plantagineum</th>
<th>Anthyllis vulneraria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
<td>D D</td>
<td>D D D D D D D S</td>
<td>D D D D D D S S</td>
</tr>
<tr>
<td>2</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>3</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
<td>S</td>
<td>S</td>
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</tr>
<tr>
<td>4</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
<td>D D D S S S S S S S</td>
<td>D D D S S S S S S</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
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<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
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<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
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<td>10</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>
Results: suitability to seed farming
Average max and average min height of mature fruits + growth habit

Species

Mature fruit height (cm)

- round
- upright
- upright+r
- rosette
- prostrate
Additional Seed increase suitability traits to be included:

- Seed yield / area
- Mechanized harvest
- Ease of seed cleaning
Categories, indexes, classes, MCDA....
Speed Control

Type: 4111.10.00.2  Serialnumber: 29104
Year of construction: 2010  Weight: 33 Kg
Noise level:
Voltage: 230 Volt - 1 Phase + 0 + Ground - 50 Hz
Installed capacity: KVA  Power: A

Read the manual before switching on
Native seed company in Spain recognizes an emerging market and unmet need for seeds of native herbaceous species to use as understory in woody crops.

My PhD to identify suitable native species for the application and how to commercially produce seeds.

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Status
Seed Increase
Traits

OUTPUTS

• Selection methodology and Index of suitability (multi-criteria decision analysis)
  -> scientific publication
• Cultural and processing practices
  -> native seed producer manual
Example selection tool

Midwest Cover Crops Council - Cover Crop Decision Tool
Wisconsin: Eau Claire County Seeding Dates

NEW UPDATE!
Hover over cover crop; click to review the information sheet.

Location Information | Cash Crop Information | Soil Information | Attribute Information
--- | --- | --- | ---
**Location Information** Wisconsin [ ] Eau Claire [ ]
**Cash Crop** Corn - Silage [ ] Plant Date: 05/03/2017 | Harvest Date: 10/18/2017
**Soil Information** Somewhat Poorly Drained [ ] Tile: No [ ] Flooding: No [ ]
**Attribute Information** Goal #1: Erosion Fighter [ ] Goal #2: Lasting Residue [ ] Goal #3: Soil Builder [ ]

Attribute Ratings: 0-Poor, 1-Fair, 2-Good, 3-Very Good, 4-Excellent

<table>
<thead>
<tr>
<th>Reliable Establishment</th>
<th>Freeze Risk to Establishment</th>
<th>Frost Seeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash Crop Growing Period: Requires Aerial Seeding or Interseeding of Cover Crop</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soil Builder
Lasting Residue
Erosion Fighter

**NONLEGUMES**

<table>
<thead>
<tr>
<th>Nonlegumes</th>
<th>Mar 15</th>
<th>Apr 1</th>
<th>May 1</th>
<th>Jun 1</th>
<th>Jul 1</th>
<th>Aug 1</th>
<th>Sep 1</th>
<th>Oct 1</th>
<th>Nov 1</th>
<th>Dec 15</th>
<th>Jan 15</th>
<th>Feb 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley, Spring</td>
<td>3 4 3</td>
<td>June 1</td>
<td>June 1</td>
<td>June 1</td>
<td>June 1</td>
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<td>June 1</td>
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<td>June 1</td>
<td>June 1</td>
</tr>
<tr>
<td>Barley, Winter</td>
<td>4 4 3</td>
<td>June 1</td>
<td>June 1</td>
<td>June 1</td>
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</tr>
<tr>
<td>Buckwheat</td>
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<td>June 1</td>
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<tr>
<td>Chicory (part of a mix)</td>
<td>2 1 2</td>
<td>June 1</td>
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<tr>
<td>Millet, Japanese</td>
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<tr>
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<td>June 1</td>
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<td>June 1</td>
<td>June 1</td>
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<tr>
<td>Rye, Winter Cereal</td>
<td>4 4 4</td>
<td>June 1</td>
<td>June 1</td>
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<td>Ryegrass, Annual</td>
<td>3 2 3</td>
<td>June 1</td>
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<tr>
<td>Sorghum-sudangrass</td>
<td>3 4 4</td>
<td>June 1</td>
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<tr>
<td>Sugarcane</td>
<td>3 4 4</td>
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<tr>
<td>Sunflower (part of a mix)</td>
<td>2 3 2</td>
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</table>
Decision support tool for Europe: The RE-SPROUT Database

- Marxan- open source prioritization software
- Expected 2018
- Open-source, public web platform
- Connecting conservation, ecology, restoration, and seed producers

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