Results of the research projects funded by the ARIMNet 2011 joint call

Dominique Fournier, Fabrice Gouriveau, Ali Rhouma, Sanaa Zebakh, Florence Jacquet

Coordination of Agricultural Research in the Mediterranean Area

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Dominique Fournier (INRA-UMARI), Fabrice Gouriveau (INRA-Moisa), Ali Rhouma (IRESA), Sanaa Zebakh (IAV Hassan II), Florence Jacquet (INRA-Moisa)

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1 Introduction

The ARIMNet Project (Coordination of Agricultural Research in the Mediterranean Area) funded by the European Union Seventh Framework for technological development and demonstration (FP7), ran between 2008 to 2013, involving 13 partners and 5 associated partners/institutions from 12 Mediterranean countries (Algeria, Cyprus, Egypt, France, Greece, Portugal, Israel, Italy, Morocco, Spain, Tunisia, and Turkey). It aimed at joining agricultural research forces to address in a coordinated way the challenges that the Mediterranean agriculture is facing.

In 2011, ARIMNet Partners launched a Joint Transnational Call for research proposals (hereafter referred to as "2011 Call"), and together, they committed around 7 million euros in the form of a common pot. Only Portugal was unable to commit funds at that time, but it then participated to all three calls launched in 2015, 2016 and 2017 under ARIMNet2, another ERA-Net (FP7; 2014-2017) coordinated by INRA building upon ARIMNet, and involving 24 partners from 15 Mediterranean countries. The 2011 Call was the first of this kind, considering that it engaged funding agencies from the north, east and south of the Mediterranean Sea, around shared topics and objectives. For many of the South Mediterranean partners (ministries and research funding agencies), this was their first Joint Call, an experience that they would further strengthen through ARIMNet2 Calls and other initiatives.

The 2011 Call was prepared over several months by ARIMNet Partners, who jointly agreed upon common eligibility criteria related to the call mechanism/procedure and the composition of the research consortia (e.g. a minimum of three countries, including at least one from the north and one from the south or east of the Mediterranean Sea). The call followed a single-step procedure: the pre-announcement was made in May 2011, the full text published in June 2011, and the deadline for project submission set to September 2011.

The Call strived to mobilise the Euro-Mediterranean R&I community around shared agriculture challenges, highlighting the research stakes and advances needed on the topics identified. Beyond that, it encouraged the development of multi/transdisciplinary and applied projects as a way to enhance research impacts in the medium to long term. It proposed to fund research on three key topics addressing the agriculture-food-environment-society nexus: 1. Production systems and their components: developing sustainable agricultural production in a context of increasing ecological and climatic stresses; 2. Food chain from production to distribution: enhancing the advantages of Mediterranean agriculture in developing products with high added value; and 3. Landscape and resources uses for agricultural and environmental purposes: sustainable management of land and natural resources.

As a result, 86 research proposals were submitted and 79 were deemed eligible and were evaluated by renowned researchers. The evaluation and ranking took place between December 2011 and March 2012. Ten projects were finally selected for funding, which started in 2012 and lasted for three to four years (they ended between May 2015 and December 2016) (Annex 1).

The projects funded through this call were monitored by ARIMNet partners to assess their progress and outputs, through a commonly established monitoring framework including specific reporting tools/indicators and regular meetings. A standard report was to be filled by project coordinators at mid-term (covering the period Month 1 - Month 18) and at the end of their projects (covering the period Month 1 – Month 36), which contains productivity/impact indicators including among others scientific publications and/or patents, capacity-building activities, mobility (staff exchange), dissemination actions, etc. Mid-term reports covering technical and financial aspects were assessed both by Funding Agencies and by external scientific evaluators to assess project progress compared to initial plans, and to propose corrective measures to address possible deviations.

Final reports were assessed by funding agencies to control the fulfilment of the project objectives and their correct implementation from a scientific and financial point of view. Project coordinators met with the Funding Agencies at mid-term (around Month 18) and at the end of their projects (after Month 36) to expose their results/progress, and discuss issues affecting project implementation.

The ten projects funded produced a range of academic (e.g. scientific publications) and non-academic (handbooks, new plant varieties, trainings, education, etc.) results, during their implementation and after, which are described in the projects' final reports and dissemination materials.

This document provides an overview of the diversity of these results and relevance for the Mediterranean agriculture and societies. It is based on an analysis carried out during the first semester of 2018, i.e. about two years after the end of the projects. Using the usual terminology in Research Impact Analysis (see box below), as part of the results, we consider in this analysis both projects' outputs (short term) and possible outcomes (medium-term), but could not realistically look at the project's impacts (long-term).

BOX 1. Impact terminology

Adapted from:

P-B. Joly, A. Gaunand, L. Colinet, P. Larédo, S. Lemarié, M. Matt (July 2015). ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. Research Evaluation, 24(4), 440-453. doi: 10.1093/reseval/rvv015

Blundo Canto G., Barret D., Faure G., Hainzelin E., Monier C., Triomphe B., Vall E. (illus.), 2018. ImpresS ex ante. An approach for building ex ante impact pathways. Montpellier, France, CIRAD, 64 p. ISBN: 978-2-87614-738-6 . https://doi.org/10.19182/agritrop/00013

Outputs: Products generated by the research project, during or immediately after it (short-term), for example scientific or non-scientific knowledge (publication, report, database, method, etc.), professional or academic training, expertise, technology, network, etc.

Outcomes: It is the appropriation, after some time (medium-term), of the research/intervention outputs by the actors interacting directly or indirectly with the research community, and leading to new practices (agricultural or managerial), new organizations, or new rules, etc.

Impacts: Long-term effects, positive or negative, intended or unintended, direct or indirect, induced by the project. They cannot be looked at during the life cycle of the projects. Several years are needed to observe actual impacts.

Impact pathway: Description of a innovation process/path which highlights the causal relationships between the inputs mobilized by a project, its outputs, and its outcomes, and the 1st and 2nd level impacts

Stakeholder: Person or group (excluding other scientists) (e.g. farmers, agro-industry, extension services, policymakers...) who influences/is influenced by the research.

1.1 Analysis of academic outputs

1.1.1 Methodology to assess academic outputs

The academic outputs of the projects funded through the ARIMNet 2011 Call were analysed in March/April 2018, approximatively two years after the end of the projects, using several sources of information, mainly the Web of Science database and the projects' final reports.

The corpus was built as follows:

1) Search in the **Web of Science™ (WoS):** publications available at the date of analysis (March 2018) acknowledging ARIMNet and/or one of the 10 funded projects (APMED, ARIDWASTE, CLIMED, DOMESTIC, MEDILEG, PESTOLIVE, POH-MED, REFORMA, SAFEMED, SWIPE)
The following equations were used:

Equation 1: FT=((ARIMNET NOT (ARIMNET 2 or ARIMNET2)) OR (ARIMNET2 same 2011) OR "Agricultural Research in the Mediterranean Area" OR (grant agreement Near/5 618127))

This search returned 109 publications.

Equation 2: FT=(((APMed near/2 (project or arimnet*)) OR "Apple and Peach in Mediterranean orchards" OR "ANR-12-AGRI-0001") OR (project NEAR/2 ARIDWASTE) OR (project NEAR/2 CLIMED) OR (arim NEAR/2 DOMESTIC) OR (project NEAR/2 MEDILEG) OR ((project NEAR/2 PESTOLIVE) OR "Contribution of olive history for the management of soil-borne parasites in the Mediterranean Basin") OR ((project NEAR/2 ("POH MED" or Pohmed)) OR "Potato Health - Managed for Efficacy and Durability") OR (((arimnet or arimnet2) NEAR/5 REFORMA) OR ("Resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems")) OR ((project NEAR/2 SAFEMED) OR "Food Safety regulations, market access and international competition") OR ((arimnet* OR 219262) NEAR/2 SWIPE))

This search allowed to identify 7 additional publications (i.e. 116 publications in total)

2) Search in the projects' Final reports (which compile all results, at the consortium level): these reports were delivered by projects' consortia in 2016 (3 reports: APMED, DOMESTIC and SWIPE) or 2017 (7 reports: ARIDWASTE, CLIMED, MEDILEG, PESTOLIVE, POH-MED, REFORMA, SAFEMED).

This search allowed to identify:

- 23 publications referenced in the Web of Science but neither acknowledging ARIMNet nor the project;
- 46 other scientific publications not referenced in the Web of Science;
- 17 technical publications.

In total, we could identify 185 scientific articles, to which we can add at least three books.

We should note however that the reports were delivered between 3 and 15 months after the projects' ends, and that some publications were therefore not available at the time of the report delivery. The number of actual publications could consequently be under-evaluated. Furthermore, Final Reports' exhaustiveness strongly depends on partners' efforts in informing the coordinator of their production, and some national publications, not referenced in the WoS, could thus have been omitted.

1.1.2 Overall scientific & technical production

Overall (Table 1), the ten projects funded through the 2011 ARIMNet joint call generated over 189 scientific peer-reviewed publications (articles, books and book chapters) (18.9 per project in average), of which 83% acknowledged properly the support of ARIMNet or the project, which is satisfying.

The projects published **between 2 and 63 scientific articles**, illustrating a range of productivity levels, mostly linked to the size of the consortium, type of research, and object/scale of the study. We can highlight for example the large production from PESTOLIVE (63 scientific publications), a research project involving a large number of partners.

Table 1. Overview of the academic outputs of the ten transnational research projects funded by the ARIMNet 2011 Call

Project acronym	Scientific papers in WoS	Scientific papers not in WoS	Total scientific papers (WoS+non-WoS)	Books
APMED	14	1	15	
ARIDWASTE	2	0	2	
CLIMED	5	3	8	1
DOMESTIC	1	8	9	
MEDILEG	22	11	33	
PESTOLIVE	51	12	63	
POHMED	8	3	11	
REFORMA	16	3	19	
SAFEMED	10	5	15	2
SWIPE	10	1	11	
TOTAL	**139**	**46**	**185**	**3**

1.1.3 Yearly scientific production

Most of the research papers (87 %) were produced between 2014 and 2017 (i.e. 2 to 4 years after project's start) (Figure 1). However, we notice that several papers are still published in 2018, more than 2 years after the end of the projects, which reflects the time needed for analysing and publishing the results, and the delays linked to rejection/resubmission process for papers submitted in highly ranked reviews.

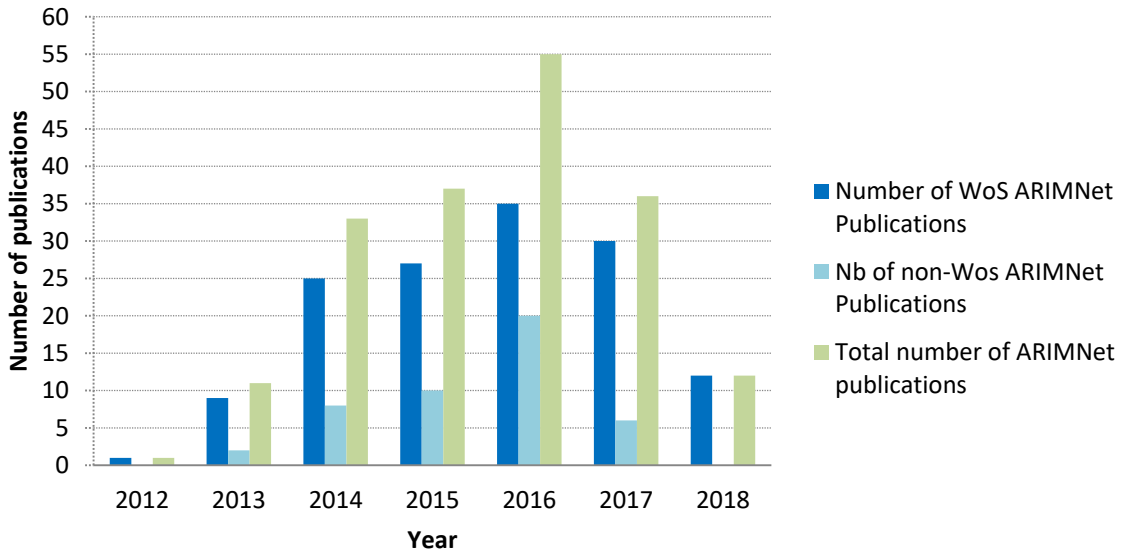


Figure 1. Yearly publications of the ten transnational research projects funded by ARIMNet

1.1.4 Journals and Research Areas

The diversity of the journals publishing ARIMNet-funded projects' results (Table 2) reflects the diversity of the topics addressed, with a predominance in Plant sciences (22%), Agronomy (15%), Horticulture, and Plant pathology. We identify also a large number of papers published in *Options Méditerranéennes*, a journal edited by CIHEAM, dedicated to Mediterranean Challenges, and well known in the Mediterranean Area. Other non-WoS journals are national ones more related to a specific topic/audience such as veterinary/animal science in French or "legumes" communities.

Table 2. Journals where ARIMNet-funded projects (Call 2011) were published

Main Journals (with at least 2 publications)	Nb. of publications	Impact Factor 2 years 2016	Quartile factor
Options Méditerranéennes: Série A. Séminaires Méditerranéens (*)	17		
EUROPEAN JOURNAL OF PLANT PATHOLOGY	8	1,478	Q2
PLOS ONE	6	2,806	Q1
ANNALS OF BOTANY	5	4,041	Q1
Legume Perspectives (*)	5		
ZOOLOGICAL JOURNAL OF THE LINNEAN SOCIETY	5	2,711	Q1
BMC GENOMICS	4	3,729	Q1
FRONTIERS IN PLANT SCIENCE	4	3,948	Q1
JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	4	3,154	Q1
NEMATOLOGY	4	1,162	Q2
PEST MANAGEMENT SCIENCE	4	3,253	Q1
PLANT PATHOLOGY	4	2,425	Q1
Acta Horticulturae	3		
Annales de l'INRAT (*)	3		
CROP & PASTURE SCIENCE	3	1,483	Q1
GENOME BIOLOGY AND EVOLUTION	3	4,229	Q1
Grassland Science In Europe (*)	3		
New Medit (*)	3		
Revue Marocaine des Sciences agronomiques et Vétérinaires (*)	3		

ACTA PHYSIOLOGIAE PLANTARUM	2	1,364	Q2
AGRIBUSINESS	2	0,939	Q2
AOB PLANTS	2	2,238	Q2
APPLIED AND ENVIRONMENTAL MICROBIOLOGY	2	3,807	Q1
BMC ECOLOGY	2	2,896	Q1
BRITISH FOOD JOURNAL	2	1,206	Q3
COMPTES RENDUS BIOLOGIES	2	1,1	Q3
CROP PROTECTION	2	1,834	Q1
Journal of Plant Pathology (*)	2		
MOLECULAR ECOLOGY	2	6,086	Q1
PHYSIOLOGICAL AND MOLECULAR PLANT PATHOLOGY	2	1,139	Q3
PHYTOCHEMISTRY	2	3,205	Q1
PPO Special Report (*)	2		
Revue d'élevage et de médecine vétérinaire des pays tropicaux (*)	2		
SCIENTIA HORTICULTURAE	2	1,624	Q1
SCIENTIFIC REPORTS	2	4,259	Q1
(*) Not indexed in Web of Science			

1.1.5 Geographical distribution of the publications

Among the partner countries participating in the ARIMNet 2011 Call, France and Spain were the most prolific in terms of WoS scientific publications (59 and 52 publications respectively), followed by Italy (38), Morocco (20), Tunisia (14), Algeria (12), Greece (6), Egypt (5), Israel (5), and Turkey (2) (Table 3).

Table 3. Number of ARIMNet-funded projects' WoS publications by country (ARIMNet partners are indicated in bold)

COUNTRY	Nb. of WoS publications
France	**59**
Spain	**52**
Italy	**38**
Morocco	**20**
USA	15
Tunisia	**14**
Algeria	**12**
Greece	**6**
Syria	6
Israel	**5**
Egypt	**5**
Russia	5
China	4
Iran	4
Germany	3
Turkey	**2**
Canada	3
Japan	3
South Africa	2
Croatia	2
United Kingdom	2
Australia	2
Portugal	1

1.1.6 Co-publications

Co-publications are encouraged in ARIMNet-funded projects, as an output of transnational cooperation (Figure 2). Respectively for WoS publications & All publications (i.e. WoS and non-WoS) with at least two countries, only 10 &14 involved two different South East Mediterranean[1] countries (two of the publications are co-authored by South Mediterranean countries only). While 37% & 44% of the publications involve authors from a single country, 38% & 37% involve authors from two countries, and 24% & 19% authors from three or more countries. Multi-country publications were further encouraged in ARIMNet2 Calls as an evidence of the integrated transnational character of the projects.

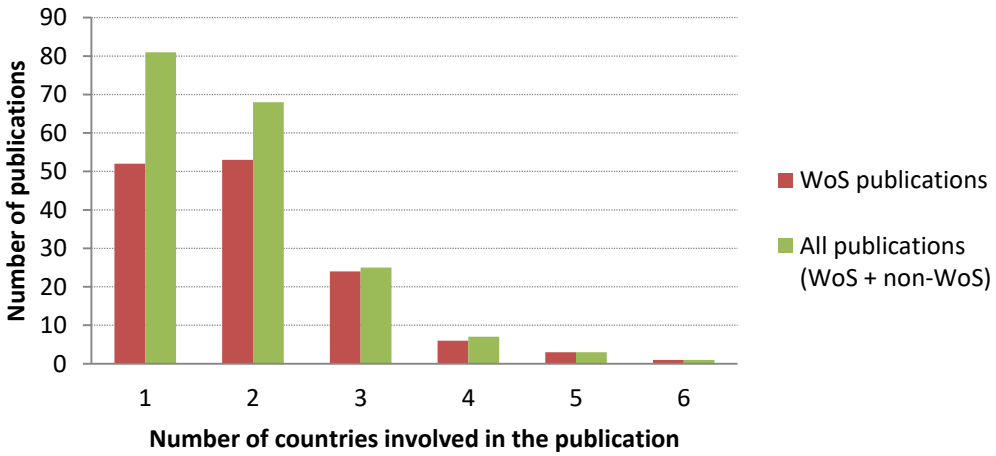


Figure 2. Co-publications from ARIMNet-funded projects (2011 Call)

1.1.7 High impact publications – distribution by top WoS citations

Two publications (Table 4) are *Highly Cited Papers* (HCP), belonging to the top 1% of the publications, i.e. one from the project PESTOLIVE and one from the project REFORMA.

Overall, 14.4% of the publications belong to the 10% most-cited publications in the world, highlighting that the impact of these publications is superior to the world average (which should be 10%). On 3 July 2018, the 139 WoS publications were cited by 594 articles (or 528 citing articles without self-citations).

Table 4. Distribution of ARIMNet-funded (Call 2011) projects' publications by top WoS citations

Tops DF/Year	Nb. citations	Frequency
No answer	13	9.4%
1.00%	2	1.4%
10.00%	18	13.0%
20.00%	16	11.5%
50.00%	44	31.7%
Without top	46	33.1%
TOTAL OBS.	**139**	**100%**

[1] South East Mediterranean Countries: Algeria, Egypt, Israel, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia, Turkey

1.2 Analysis of non-academic outputs

1.2.1 Methodology to assess non-academic outputs

ARIMNet-funded projects yielded a wide range of outputs beyond scientific publications (e.g. technical publications, new products and technologies, models, guidelines, trainings, etc.) and researchers interacted/collaborated with non-academic stakeholders to ensure the adoption/use of their products.

Among the non-academic outputs, we assessed the following ones:

- New products and technological processes (e.g. new candidate crop varieties, plant protection product, etc.);
- Guidelines, handbooks, etc. published to provide evidence-based advice to end-users (farmers, breeders, plant/animal health services…);
- Models, protocols, and other decision-support tools
- Education and training sessions/materials:
    - Academic training/education (e.g. for Master students, PhD students, etc.)
    - Technical training for professionals (e.g. for farmers, state services, etc.)

Non-academic outputs/outcomes were analysed in May 2018 (at least 2 years after the end of the projects) using/crossing several sources of information, including:

- Final reports submitted by project consortia in 2016 or 2017, at least 6 months after their end date, presenting all their results.

- Project brochures (4 pages; see example in Annex 3) designed in March 2016 with the contribution of the project coordinators to communicate about the projects and their outputs (objectives, methodology, stakeholder engagement, added value of transnational cooperation, publications, etc.).

- Abstract Book of all the projects funded through ARIMNet and ARIMNet2, produced in September 2016 with the contribution of the project coordinators, to communicate about the projects and disseminate their key findings.

- Questionnaires sent to project coordinators in February 2017 and filled in by April 2017 (1 to 2 years after project end) specifically designed to assess the innovation potential and degree of maturity of the research projects, based on the Technology Readiness Level (TRL) approach; the aim was to characterise the types of outputs/innovations (incremental/radical) generated by the projects, the implication (level and degree) of end-users/stakeholders (e.g. in project design and problem identification), and the transfer (process, tools, intensity) of these outputs to end-users, for their wider use. A report synthesises the results of this analysis (Annex 2).

- Questionnaires (online survey) sent in November 2018 to project coordinators (10 persons) and Team coordinators, to characterise the main outputs and outcomes (the way outputs are being valorised / used by end-users).

1.2.2 Non-academic outputs and potential outcomes

Besides academic publications, at least 22 technical papers were produced by the projects (Table 5). Seven projects among the 10 funded produced at least a technical paper targeting a non-academic audience.

Table 5. Technical publications from ARIMNet-funded projects (2011 Call)

Project acronym	Technical papers
APMED	**5** (Rivista di Frutticoltura; Meyve Bilimi-Fruit Science; Info Ceta N°2; L'arboriculture fruitière 664; L'arboriculture fruitière 673)
DOMESTIC	**1** (Rencontres autour des Recherches sur les Ruminants 21 : 366)
MEDILEG	**5** (Legume Perspectives 10: 4, 25-26, 31-32; Legume Perspectives 6: 29-31; Legume Perspectives 8: 35-36)
POHMED	**2** (Phytoma 690; La pomme de terre française 593)
REFORMA	**4** (Legume Perspective 4 (special issue, 40 pp.); Legume Perspective 10: 15-17; Legume Perspective 12: 36-38; Informatore Agrario 38: 46-49)
SAFEMED	**4** (Cuadernos de estudios agroalimentarios 1: 111-122, Cuadernos de estudios agroalimentarios 4: 7-12, 47-68, 145-156)
SWIPE	**1** (Agrícola Vergel, 382: 129-133)
TOTAL	**22**

The projects developed academic and non-academic training materials and sessions, and produced a range of information and tools for stakeholders (handbooks, guidelines, models, etc.). Four projects have produced outcomes that should lead to new marketable products or processes (e.g. new crop varieties, new plant protection bio-products) (Table 6).

All the projects promoted mobility of staff and students to meetings, workshops, or specific training sessions. Overall, the ten projects had a very positive contribution to high level education and national/transnational mobility: six projects out of ten supported the training of master/engineering and/or PhD students and allowed the publication of over 57 Master/Engineer theses and 26 PhD theses.

Table 6. Key outputs/outcomes from ARIMNet-funded projects (2011 Call)

	New candidate varieties, cultivars, germplasm	Products / technological processes	Model / decision-making tool	Handbooks, Guidelines	Training (Academic & non-academic)
APMED			X	X	X
ARIDWASTE				X	X
CLIMED				X	X
DOMESTIC				X	X
MEDILEG	X				X
PESTOLIVE		X			X
POHMED	X				X
REFORMA	X	X		X	X
SAFEMED				X	X
SWIPE			X		X

Most of the projects have generated outputs targeting end-users (See example in Table 7).

Table 7. Example of ARIMNet-funded projects' outputs and their main intended beneficiaries	
End-users capacity-building	• Training on apple orchards irrigation and water management: maximizing tree tolerance to pests without compromising fruit production (fruit growers and extension services) (APMED) • Training on the use of a laser to monitor animal performance (CLIMED) • Open day with a visit of field trials by farmers, to discuss best waste management practices for agricultural application (ARIDWASTE) • Interaction between research staff of food legumes programme and stakeholders from the regional and national levels (MEDILEG) • Training of official inspectors and technicians from Government Health Services: co-regulation of parasites in fish; development of a platform to identify parasites by means of molecular biology (SAFEMED)
Handbooks and Guidelines	• Handbook for farmers for the sustainable use of recycled organic materials in intensive crop production systems, in arid and semi-arid regions (ARIDWASTE) • Handbook for legume growers and extension services for cultivation and use in animal feeding of pea- and lucerne-based forage crops (REFORMA) • Manual on Hazard Analysis Critical Control Point and good hygienic practice for food business operators (Egg packing centers, Poultry processing, Casing units); Guidelines for risk-based inspection for imported animal foods (SAFEMED)
Models and other decision-support tools	• Improved models for apple/peach growers of water transport/management, nutritional status, aphid infestation, fruit quality, phenotyping (L-Peach, MAppleT, QualiTree); Protocols and methodologies for phenotyping an Apple core-collection in PHENOARCH phenotyping platform (INRA Montpellier) in FruitBreedomics; • Determination of morphological and eco-physiological traits related to water stress tolerance in apple trees, for geneticists and breeders to integrate in selection scheme (APMED) • Predictive model of whitefly population dynamics and invasion pathways and risk under climate change, for whitefly-sensitive crops growers (SWIPE) • Social, economic and environmental sustainability indicators to approach the efficiency of Mediterranean crop-livestock systems according to a gradient of intensification (sheep, goat, cattle) that can be used by policy makers, practitioners to implement sustainable development pathways (CLIMED) • Regulatory framework to establish and enforce coordination between local actors; Framework on the Interactions between product valorisation and genetic management with a "checklist" of levels where the breed can play a mediating role between product valorisation and genetic management (DOMESTIC) • Update of the import/export EU regulation and directive on plant protection and novel inspection approach; alternative organization model for the Tunisian date supply chain (e.g. collection); strategy for risk management of fish parasites; general marketing standard for Moroccan dates; Prioritization and risk ranking of health hazards and non-compliances of Moroccan fish export (SAFEMED)
Products & Processes	• 5 novel lucerne and 3 novel pea candidate varieties tolerant to water stress (REFORMA) • Legume pre-breeding germplasm (MEDILEG) • Fungicide for Olive tree; biocontrol agents; gene bank (PESTOLIVE) • New cultivars for the sustainable development of potato production around the Mediterranean Basin (POHMED)

1.2.3 Stakeholders involvement

In most of the research projects analysed (> 80%), stakeholders (Table 8) were involved from the beginning of the project in the definition of the research question, to answer specific needs; research teams then relied on formerly established cooperation and networks with farmers and other stakeholder from the sector of interest (advisory services, cooperative, seeds multipliers, etc.). The projects involved in more fundamental research (e.g. PESTOLIVE, SWIPE) show minor interaction with end-users. Overall, all the projects target end-users in the dissemination efforts, through specific technical publications, demonstration days, etc.

Often, however, the stakeholders are not directly and/or formally engaged as partners in the projects, as they are not entitled any specific budget, which is mentioned as a barrier to a stronger participation. This is clearly constrained by funding eligibility rules, by limited public/private cooperation experience and/or interest/availability of the private actors.

The reports and researchers testimonies indicate that research teams are in regular contact and collaborate with different type of stakeholders, e.g. farmers/growers and their networks, extension services, agro-industry, plant/animal state services, the administration and other public/private R&D organisations, etc.

Table 8. Categories of stakeholders involved in ARIMNet-funded projects activities

Main type of stakeholder engaged in ARIMNet-funded projects	Examples of stakeholders involved
Farmers & their organisations & extension services	- Animal breeders: goat, sheep, e.g. in Morocco, France, Egypt , Lebanon (CLIMED, DOMESTIC) - Crop producers: apple, peach, olive, potato, legumes, crops… (APMED, PESTOLIVE, POH-MED, MEDILEG, REFORMA) - Cooperatives or large farms (DOMESTIC, APMED) - Irrigation management association (APMED) - Waste management firms (ARIDWASTE) - Forage/Feed crop extension services (REFORMA)
Agro-industry, seed companies…	- Italian forage seeds association/companies (Assosementi) and managers of the selection schemes (REFORMA) - Legume seed production companies (MEDILEG) - Olive nurseries potentially spreading soil borne pathogens (PESTOLIVE) - Laboratory involved in the production and formulation of nematophagous fungi (PESTOLIVE)
Authorities, policy Makers, development agents	- Plant protection services in Morocco involved in olive nursery sanitation (PESTOLIVE) - Official development agency (e.g. ORMVAO) in Morocco - Authorities concerned by animal pest control (e.g. whitefly) (SWIPE) - Food authorities, government inspectors and technicians in charge of sanitary issues (SAFEMED) - Plant breeders involved in enhancement programmes of grain legumes, e.g. faba bean, chickpea and lentil (MEDILEG)

Stakeholders were involved at different stages and with different levels of intensity. Engagement took place during project preparation to identify relevant research questions and possible outputs (e.g. during meetings), during the implementation phase to gather data (e.g. interviews) and implement field trials (e.g. infrastructure set up and field data collection), and after the project to disseminate findings/innovation (e.g. open days, on-farm visits).

The Table 9 below indicates the possible involvement of stakeholders in the projects; in bold, we show the most significant stakeholder roles identified in the 10 projects funded through ARIMNet. All projects have made strong efforts to disseminate their findings to academic and non-academic stakeholders, through meetings, workshops, conferences, publications, social media and/or internet tools (websites). The strongest mobilisation of local stakeholders (mostly farmers, extension services and local authorities) was achieved by means of field demonstration trials and open days (e.g. APMED, REFORMA).

Table 9. Stakeholder engagement during the project cycle and beyond

Stakeholder engagement stage in the project cycle	Stakeholders participation in the project (in bold, the most significant types of participation in ARIMNet-funded projects)
Before the project	**- Definition of relevant expected outputs** **- Provision of fields/land for experiments/studies (agreements)** - Definition of research questions relevant to solve issues faced by the beneficiaries (and society at large) - Design of suitable research protocols - Provision of background data (e.g. time series)
During the project	- **Collaboration to field trials and data collection (e.g. farmers contribute sometimes to data collection)** **- Evaluation of the outputs (e.g. participatory crop evaluation)** **- Dissemination of ongoing research (e.g. open days, workshops)** - Testing of research protocols and tools (e.g. equipment, guidelines, models) - Reorientation of the research to better address objectives
After the project	**- Dissemination of research findings among communities/networks (and transformation of invention to "innovation" adopted by beneficiaries)** - Mid-term / long-term monitoring & evaluation of newly established practices - Set up of new projects capitalising upon the research done

From the analysis of the final reports and answers to the questionnaires received from the project coordinators, several recommendations were drawn to foster innovation in research projects, at different stages of the project cycle:

While preparing the project

- Foster the consultation of stakeholders to identify the needs, challenges, opportunities, linkages, interests, etc.;
- Pay attention to the definition of project's objectives, research activities, partners' roles, together with the partners and stakeholders;
- Seek the involvement of the private sector (it will support the transfer and maturation of the invention into an "innovation").

During the project implementation

- Ensure the participation of interested parties in the project implementation;
- Do not overlook the prototyping phase;
- Validate the results with interested parties;
- Conduct an evaluation of the maturity of the results.

After the end of the project

- Assess innovation's performance: new policies & institutions, capacity building, technologies developed, market linkages, and information & knowledge flows, etc.
- Foster the integration of new projects to continue the scaling up.

1.3 Conclusion

This analysis highlights that the ten projects funded through ARIMNet (2011 Call) have yielded overall a wide range of interesting and useful results, which include academic and non-academic outputs (e.g. scientific and technical publications, new crop varieties) and immaterial results (e.g. networks, flows of knowledge). The projects have strongly contributed to the generation of new scientific knowledge, and to the production of readily available innovations, to a lesser extent. They have also allowed the academic training of engineers, master or PhD students, have fostered researchers' mobility, and have contributed to building capacities and networks among the researchers themselves, but also among stakeholders (farmers, authorities, etc.).

Some of the projects' outputs are actually used by Mediterranean stakeholders (e.g. new varieties, guidelines, models, etc.), and could be considered as outcomes. At this stage nonetheless, evaluating individual projects' impacts in socio-economic or environmental terms is out of reach as the projects have only ended recently. Strengthening the culture of impact and multi-actor collaboration among Mediterranean researchers and stakeholders is key to ensure the transformation of R&I products into outcomes (i.e. things or ideas that are actually used by the society) and ultimately, the generation of impacts in the longer term.

Funding agencies and research organisations should therefore encourage and provide the means for project partners to plan carefully for plausible and coherent impacts at the project design stage, to identify the levers and obstacles to change and innovation (e.g. political, social, economic conditions), to involve the "right" partners (e.g. public/private, multi/transdisciplinary teams, etc.), to build upon existing knowledge being aware of societal needs, and to follow more flexible (adaptive) project and partnership management approaches.

Finally, in order to get a better grasp of the benefits of the projects for the society and the planet in the long term, relevant but reasonable monitoring and evaluation indicators and tools should be used. They should allow to document qualitative and quantitative changes at all scales (e.g. at the plot, farm, landscape, national or even international levels), from all stakeholders' points of views, but probably even more from the perspective of the intended beneficiaries.

ANNEX 1. Research Projects funded by the ARIMNet 2011 Joint Call

Acronym	Project Title	Countries	Coordinator
APMED	Apple and Peach in Mediterranean orchards – Integrating tree water status and irrigation management for coping with water scarcity and aphid control	FR, IL, IT, MO, ES	Pierre-Éric LAURI, Institut National de la Recherche Agronomique (INRA), France
ARIDWASTE	Development of specific agricultural practices with the use of recycled wastes suitable for intensively cultivated Mediterranean areas under degradation risk	GR, IS, IT, ES	Victor KAVVADIAS, Hellenic Agricultural Organization – DEMETER, Greece
CLIMED	The future of Mediterranean Livestock Farming Systems: Opportunity and efficiency of Crop–Livestock Integration	FR, MO, EG	Véronique ALARY, International Centre of Agricultural Research for Development (CIRAD)
DOMESTIC	Diversity and sustainability of the sheep and goat sector	GR, FR, CY, MO	Christina LIGDA, Hellenic Agricultural Organization – DEMETER, Greece
MEDILEG	Breeding, agronomic and biotechnological approaches for reintegration and revalorization of legumes in Mediterranean agriculture	ES, MO, FR, IT, TU, PT, EG, DZ	Diego RUBIALES, CSIC-Institute for Sustainable Agriculture, Spain
PESTOLIVE	Contribution of olive history for the management of soil-borne parasites in the Mediterranean basin	FR, GR, IT, MO, ES, TU, TR	Thierry MATEILLE, Institut pour la Recherche et le Développement (IRD), France
POHMED	Potato Health – Managed for Efficiency and Durability	FR, DZ, MO, EG	Didier ANDRIVON, Institut National de la Recherche Agronomique (INRA), France
REFORMA	Resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems	IT, FR, MO, DZ, IT, USA, TU	Paolo ANNICCHIARICO, Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), Italy
SAFEMED	Sanitary control of food supply, market access and international competition	FR, IT, TU, ES, DZ	Abdelhakim HAMMOUDI, Institut National de la Recherche Agronomique (INRA), France
SWIPE	Predicting whitefly population outbreaks in changing environments	IL, FR, ES, GR, IT, TR, USA	Einat ZCHORI-FEIN, Agricultural Research Organization, Israel

ANNEX 2. Assessment of the innovation potential of ARIMNet/ARIMNet2-funded projects

ARIMNet2 Task 5.4 - Survey on the innovation potential of research projects funded via ARIMNet/ARIMNet2

Report from Pr. Ali Rhouma and Mrs Sanaa Zebakh

1. Objective of the survey

The aim of this survey is to identify the innovation potential from ARIMNet1-funded projects and also to see if there were some preliminary innovations from ARIMNet2-funded projects.

2. Methodology

Technology Readiness Level is traditionally used in selected areas, such space, to assess the maturity of technology. The interpretation and relevance of TRL for other scientific fields such as agriculture and others sectors is useful to assess the degree of maturity of the research results. Technology Readiness Assessment (TRA) points when an organization attempts to determine the maturity of a new technology and/or capability (including required levels of engineering or economics-related performance).

Nine TRL steps were adopted by H2020: TRL 1 – basic principles observed; TRL 2 – technology concept formulated; TRL 3 – experimental proof of concept; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 7 – system prototype demonstration in operational environment; TRL 8 – system complete and qualified; TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

3. Questionnaire (Annex)

In order to help the researchers (coordinators) with the identification of the innovation from the obtained results, we prepared a questionnaire (See ANNEX).
The main questions raised were as follows:

- **Types of innovation/outputs from the research projects**
  - technical process, technological process, social innovation, Product, Method, decision support tool...
  - radical or incremental

- **Implication of the end-users in the project (stage, intensity, process of involvement)**
  - End-users targeted by the project
  - Participation in the identification of the problems/research question
  - Participation in the identification of the objectives of the project
  - Involvement in the implementation of the research project

- **Participation of other stakeholders in the project** (e.g. professional technical/development organisations such as agricultural offices and development groups, technical centres, farmers' unions, farm extension services…)

- **Transfer potential of project's outputs deliverable to end-users**
  - Readiness of the outputs
  - Scale of the experimental test (e.g. Lab scale, small scale, large scale or under real conditions)
  - Transfer plan to promote adoption by end-users
  - Impact (potential/real) of the outputs

4. Results

4.1. Types of innovation in ARIMNet projects

In the different projects funded during the period 2011-2014, the following types of innovations were identified:

- Agronomic and technical package
- Technological process (Example of novel serological diagnostic tools to improve brucellosis control and eradication programs)
- Social innovation (Case of DOMESTIC project)
- Decision-support tools (Case of Project OPRAMED)
  i. Predictive model for the assessment of the *Xcc* introduction risk
  ii. Contribution for the update of the import/export EU regulation and Directive on plant protection
- Agricultural or agro-food products (Case of project REFORMA)

- **Incremental innovations**

The incremental innovations observed in the projects funded through ARIMNet1 and 2 are mainly related to agronomic and technical package.

- **Radical innovations**

The following radical innovations obtained through ARIMNet 1 and 2 are :

- Five novel lucerne varieties
- Three novel pea varieties
- Innovative veterinary diagnostic assays and vaccines
- Replacing the traditional fallow or rangelands exploitation for animal feeding in north Africa by protein-rich, legume-based forage crops
- The stress-tolerant materials derived from the project REFORMA allow for a substantial reduction of irrigation, thus increasing the economic and environmental sustainability of the crop.

4.2. The end-users : their involvement and their role in the projects

In the majority of the funded projects, the end-users were involved since the beginning in the construction in the project. However, for the case of the project AVIAMED and given the very innovative nature of the project and of the products to be developed, it was preferred to have most robust data before engage the end-users.

4.3. Potential Transfer of the project deliverables

- Incremental innovation: large scale

- Radical innovation: Lab scale (two projects REFORMA and PoH-MED).

4.4. Types of innovation in ARIMNet projects

The main innovation obtained by the projects funded in the framework of ARIMNet are listed in table 1.

Table 1. Potential innovations of ARIMNet projects

Project	Innovation	Type
APMED	- New tool for phenotyping studies - New tools for breeders for the genetic selection	Methods
CLIMED	Development of multi-data base Indicators for different Mediterranean crop-livestock systems that can be used by policy makers	Decision-support tool Breeding Programme
DOMESTIC	Understanding and better exploitation of the interactions between livestock production, the environment, and social and economical aspects	Social innovation
MEDILEG	Identification of sources of resistance to Orobanche and foliar diseases in some grain legumes	Decision-support tool Breeding Programme
PESTOLIVE	Identification of sources of resistance to Verticillium New strains of nematophagous fungi	Decision-support tool Breeding Programme

4.5. Types of innovation in ARIMNet2 projects

The main innovation obtained by the projects funded in the framework of ARIMNet2 are listed in table 2.

Table 2. Potential innovations of ARIMNet2 projects

Project	Innovation	Type
REFORMA	- Two technical handbooks guidelines for cultivation and use in animal feeding of lucerne-based forage crops, and the second one guidelines for cultivation and use in animal feeding of pea-based forage and grain crops. - Five novel lucerne varieties - Three novel pea varieties	Agronomic and technical package (incremental innovation Agricultural or agro-food products (Radical innovation)
SAFEMED	Method of inspection	Decision-support tool
SWIPE	Modeling projecting insect-pest population dynamics and supporting environmental decision-making under climate changes	Decision-support tool
ARIDWASTE	Guide of best agricultural practices to use organic amendment in arid and semi-arid regions	Decision-support tool
POH-MED	New solutions for the sustainable development of potato production around the Mediterranean Basin (new cultivars)	Agricultural or agro-food products

SOME USEFUL DEFINITIONS

Innovation : An innovation is understood as the implementation of a new or significantly improved* product (good or service) or production process, improved technology or technique, a new marketing method, or a new method/form of organisation among socioeconomic actors, in the workplace or for external relations (Based on "Oslo Manual", 3rd edition, 2005).
**The improvement is to be assessed compared to existing practices for given socioeconomic actors.*

Main types of innovation

1) Product innovation

It is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. Product innovations can utilise new knowledge or technologies, or can be based on new uses or combinations of existing knowledge or technologies.

2) Process innovation

It is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products.

3) Marketing innovation

It is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Marketing innovations are aimed at better addressing customer needs, opening up new markets, or newly positioning a firm's product on the market, with the objective of increasing the firm's sales.

4) Organisational innovation

It is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations. Organisational innovations can be intended to increase a firm's performance by reducing administrative costs or transaction costs, improving workplace satisfaction (and thus labour productivity), gaining access to non-tradable assets (such as non-codified external knowledge) or reducing costs of supplies.

Research and Development (R&D): In accordance with the approach advocated by the Frascati Manual (Based on OECD's "Frascati Manual", 2002 edition), Research and Development (R&D) is defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications". The term "research and experimental development" is used as synonymous to the term "research and development" and both are abbreviated by the expression "R&D". The term R&D covers three activities: basic research, applied research and experimental development.

Deliverable of a research project: It is a tangible or intangible product/service produced as a result of the research project that can be potentially transferred to following actors from the innovation chain (value chain), i.e. facilitators of transfer.

Replicability: It is the ability to give statistically similar results in identical (same teams and equipment) test conditions.

Reproducibility: It is the ability to be applicable in different environments, by the different operators using different tools.

End-users: Socio-economic actors who would use the deliverable totally or partially.

ANNEX 3. Brochures of the 10 Research Projects funded by the ARIMNet 2011 Joint Call

APMed

2012-2015

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Apple and Peach in Mediterranean orchards – Integrating tree water status and irrigation management for coping with water scarcity and aphid control

- In the context of climate change, we need more research on how fruit trees adapt to water scarcity and on the effects of tree water status on pests and diseases, with an applied issue on how the grower can save water while optimizing fruit quality and orchard profitability.
- Adult apple and peach trees in contrasted environments were used to determine optimized Regulated Deficit Irrigation (RDI) for good yield and reduced impact of pests and diseases. Investigation on apple hybrids also identified promising traits for selection by breeders.
- Decision rules for irrigation must account for crop load. For apple trees, shade-nets reduce water consumption whereas for peach trees, a 25% decrease in water supply compared to crop coefficient-driven irrigation decreases pruning needs and diseases with only a slight reduction of the yield.

Apple
Peach
Water scarcity
Pests
Yield

Objectives

- To explore, on one-year-old apple trees issued from an apple progeny, the genetic range of morphological and functioning adaptations to water restriction, and to analyse how these traits simultaneously interact to determine the potential for tolerance to soil water restriction.
- To analyse on potted- and orchard- apple and peach trees the effects of tree water and nutrient status on aphid infestations and on main storage diseases.
- To investigate on orchard peach and apple trees the effects of tree water status, crop load and nitrogen supply on the decision rule for irrigation scheduling and the effects on yield quantity and quality, and to examine the effects of coloured and shading nets on tree water status and yield.
- To integrate architectural and functional aspects into quantitative models to render satisfactorily the effects of water restriction on fruit size and aphid infestations on fruit trees.

Scientific results & innovation potential

- Both genetic variability and phenotypic plasticity play a role in the response of apple trees to water stress. An applied interest for the breeder is that the reduction of leaf area and the percentage of temporary stem growth cessation are reliable and easy-to-collect proxies to phenotype the effects of water restriction on shoot growth.
- Under Mediterranean sunny conditions, shading is an effective strategy to save water in apple orchards, without negative effects on yield and quality.
- For apple and peach orchards, crop load should be considered to finely tune stem water potential (SWP) thresholds for irrigation scheduling. For a given crop load in peach, reducing irrigation water by up to 25% entails a slight decrease of yield compared to crop coefficient-driven irrigation but significantly decreases post-harvest diseases and summer pruning needs, resulting in an enhanced profitability for the grower.
- For apple and peach trees, aphid infestation is mainly related to shoot growth and only little to nitrogen concentration. Therefore, irrigation strategies should reduce severe pruning to avoid vigorous growth. Restricting water supply limits aphid development through its effect on growth, sap viscosity and leaf temperature.
- In a modelling perspective, Functional Structural Plant Models could now render satisfactorily the effects of water restriction on fruit size and aphid infestations on fruit trees.

Coordinator

Dr Pierre-Éric LAURI
Amélioration Génétique et Adaptation des Plantes,
Institut National de la Recherche Agronomique (INRA)
FRANCE
lauri@supagro.inra.fr

Partners

- Plantes et Systèmes Horticoles, Institut National de la Recherche Agronomique (INRA), **FRANCE**
- Northern R&D, MIGAL, Galilee Technology Center, **ISRAEL**
- EcoPhysiology Group, Department of Agricultural Sciences, University of Bologna, **ITALY**
- Protection des Plantes et Environnement (PPE), Moulay Ismail Faculty of Sciences Meknes, **MOROCCO**
- Irrigation Technology, Institut de Recerca i Tecnologia Agroalimentàries (IRTA), **SPAIN**

METHODOLOGY

Protocols to investigate genetic variability on young-potted trees and shading effects on adult trees

One-year-old apple shoots under water stress (Figure 1)
(Montpellier and Bologna)

- Two apple cultivars, Granny Smith and Starkrimson and 19 hybrids from their crossing.

Water stress management

- Single-shoots were grown in controlled environments, subjected to soil water stress (WS) or well-watered (WW, control). The relative amount of water in the pots was quantified as the Fraction of Transpirable Soil Water (FTSW). WW plants were at 100% FTSW, WS plants at 50% and then 20% FTSW (4 weeks at each WS level).

Measurements on the shoots from the 2 periods

- Shoot morphology: number of leaves, stem length, individual and total leaf area.
- Leaf functioning: photosynthesis, stomatal conductance, stem xylem % loss of conductivity, stem water potential.

Water management and light conditioning (Figure 2)
(Bologna)

Coloured nets

- 4 different light management treatments: control (no net), 50% red, 20% neutral and 50% white shading nets; each subjected to 3 different irrigation levels: 100% (control), 30% and 60% of potential evapotranspiration (ETc).

Measurements

- During the growing season: ETc, plant water status, leaf gas exchange, fruit and shoot growth. At harvest: total yield, fruit size class distribution, fruit colour class.

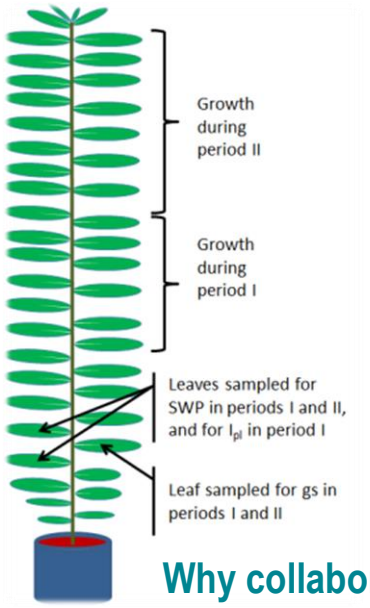


Figure 1. Scheme of a one-year-old apple shoot at the end of the experiment with the two consecutive growth periods. Adult leaves used for leaf functioning study are indicated (P.-É. Lauri, France)

Why collaborating?

- Two fruit crops with high added-values across the Mediterranean area.
- Five countries providing contrasted natural and socio-economic environments: Israel, Morocco and Spain where water saving is a major issue; France and Italy where water saving aims at reducing water irrigation leaching and pollution of the water table.
- Complementary scientific competences: France, Israel and Italy for fruit tree architecture and ecophysiology; Morocco and Spain for fruit tree growing and irrigation management; France, Israel and Morocco for entomology and pathology.
- Mixing researchers, as well as engineers and technicians from experimental stations and extension services, in strong connection with growers.
- Mixing research organizations and Universities and joining efforts towards common challenges.

Figure 2. Experimental orchard for coloured net study (L. Corelli Grappadelli & team, Italy)

Post-harvest diseases

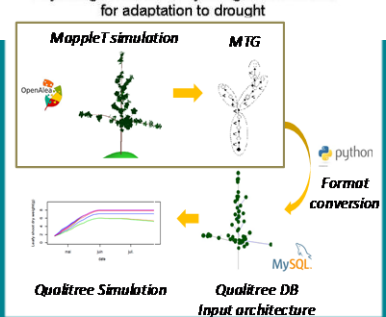
Peach-aphid interactions

Irrigation under water scarcity

Daily fruit growth

Figure 3. General scheme of the four work packages interacting in the five Mediterranean countries

Genetic variability



Plant water status

Leaf gas exchanges

ACHIEVEMENTS

Genetic variability of the young apple tree under water restriction

Both leaf functioning and whole-shoot growth were analysed under water stress (WS) and compared to the well-watered (WW) condition.

- At leaf level, a new index (IPL) was developed to measure photosynthesis on a large amount of individuals in a relatively short time which is a crucial issue for phenotyping progenies.
- At shoot level, a large variability of behaviours across genotypes was shown for stem and leaf growth positively related to stomatal conductance.
- A methodology was developed to analyse, for each genotype, the responses to water stress (WS/WW ratio).
- Results back up the hypothesis of various degrees of iso-anisohydry illustrating the ability of the apple tree to adapt to a large range of biogeographical conditions.
- Leaf area and temporary cessation of stem growth are well indicative of the ability of a genotype to adapt to water stress, which could be useful for phenotyping progenies.

Plant-aphids and plant-diseases interactions

Three plant-pest models were studied, *Aphis pomi* – apple, *Dysaphis plantaginea* – apple (Figure 4) and *Myzus persicae* – peach, on young non-fruiting trees.

- At infestation start, aphid abundance was mostly related to the tree nitrogen status. This relationship weakened over time and there was, later in the season, a positive correlation between shoot development and infestation dynamics. However, infestation remained linked to several amino acids involved in transport or osmoregulation throughout the season. Water restriction uncoupled these relationships.
- A more precise study of sap composition using stylectomy, showed that sorbitol and sucrose concentrations increased with plant growth.
- The increase in sap viscosity under WS may explain why aphids, which fed passively from the phloem, absorbed less sap under WS leading to a reduction of aphid populations on stressed plants.
- In peach orchards, decreasing water irrigation and nitrogen input by 25% compared to the crop coefficient-driven irrigation significantly reduces post-harvest diseases with only a slight yield reduction.

Figure 4. Apple shoot infested by the Rosy apple aphid (*Dysaphis plantaginea*). Infestation is related to individual shoot growth and not to the whole-tree growth (MO Jordan & MH Sauge, France)

Water and nitrogen management techniques to optimize fruit quality

- In peach and apple orchards, reducing by ca. 25% water and nitrogen inputs did not reduce significantly the yield compared to the usual crop coefficient-driven irrigation but reduces the need for pruning. Mediterranean fruit growers can thus cut down their input costs, while preserving the water resource and reducing pollution caused by over-fertilisation.
- From an applied point of view, the question on how to better adjust irrigation to the tree water status was specifically investigated. As already known, stem water potential (SWP) gives relevant thresholds for irrigation scheduling. However, we showed that there were strong interactions with crop load: the demand for assimilates affects leaf functioning, and for the same SWP, low crop load decreases stomatal conductance compared to high crop load (Figure 5).
- In apple, coloured nets reduce the need for irrigation and can therefore mitigate the effects of water stress.

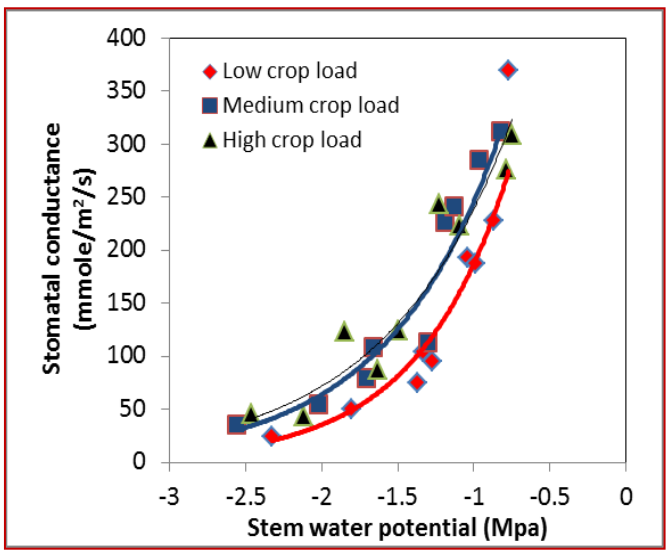


Figure 5. Peach-Nectarine - Crop load affects the relationship between SWP and stomatal conductance (A. Naor, Israel)

Modelling water and nitrogen management techniques

- The modelling objective was to integrate architectural and functional aspects into quantitative models to render satisfactorily the effects of water restriction on fruit size, and of aphid infestations on fruit trees.
- Modelling was based on the existing complementarity between three models already developed by the partners, MAppleT (architecture-based), QualiTree (function-based) and CropSyst (cropping system model).
- One of the output was the development of a multi-year aphid infestation module which showed that the effects of aphid infestation on fruit production was evident only 2-3 years after the first infestation, confirming ongoing field studies.

ACHIEVEMENTS

Stakeholder engagement

In APMed, relationships with stakeholders were developed at various levels:

- France – An experimental station and an extension service were included as subcontractors in the consortium. They focused on irrigation management and effects on labour costs, post-harvest diseases and overall orchard profitability.
- Israel and Spain – Growers networks were interested in irrigation scheduling through a better use of soil and plant sensors.
- Italy – Growers' networks were specifically interested in the use of coloured nets to decrease water use by trees and to improve fruit quality.
- Morocco – Experiments were developed in orchards belonging to some main "aggregators" (large farms). Results were disseminated through regular meetings to small farmers with the practical interest that growers are entitled to cultivate more land if they are able to save water.
- The End-of-Project conference held in Montpellier, France, on 15-16 June 2015, hosted some 70 researchers, engineers and technicians. The main outputs of the APMed project were then presented by all partners. A half-day was also dedicated to more general talks on societal aspects of water in the society such as "water saving policy in Morocco" or "strategical approaches of water management involving all the actors" (Figure 6).

Figure 6. End-of-Project conference of the APMed programme – Montpellier Agropolis, France, 15-16 June 2015

Next steps

- Phenotyping genetic variability for water stress tolerance in the apple tree - Submitted publications and exchanges with breeders in connection with the Fruit Breedomics European Programme (2011-2015).
- Apple response to water stress at two main levels, plant architecture and ecophysiology modelling, and genetic determinism – Ongoing research works at INRA, France, in connection with other French and non-French teams.
- Dissemination towards fruit growers of the emerging techniques and know-how on irrigation scheduling in relation to plant resistance to aphids – Continuous work in the various countries through informal or formal initiatives, e.g. French programme RegPuc (2016-2018).

Do you want to know more?

Contact: Dr Pierre-Éric LAURI

lauri@supagro.inra.fr

Website:

http://arimnet2.net/index.php/researchprojects/apmed1#presentation

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

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Editing: GOURIVEAU F., OLLAGNON M.

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ARIDWASTE

2012-2015

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Development of specific agricultural practices with the use of recycled wastes suitable for intensively cultivated Mediterranean areas under degradation risk

- Development of alternative agricultural practices using agricultural treated wastes and natural zeolites.
- To what extend the co-addition of natural zeolites and treated agricultural wastes could benefit productivity of Mediterranean soils?
- The positive effects of zeolite (clinoptilolite) on biomass and on nutrient status of plant and soils appear when zeolite is mainly combined with compost or reduced doses of fertilizer.

Application practices
Recycled wastes
Degradation
Soil quality
Sustainability

Objectives

- Evaluation of the main treated agricultural wastes (TAW) from different origins.
- Development and demonstration of sustainable alternative cultivation practices for the main market and nutrient demanded crops in Mediterranean by recycling nutrients and water from ATW taking also advantage of the beneficial properties of natural zeolites.
- Integration of appropriate actions and measures that should be adopted at local, regional, national and transnational level.
- Development, implementation and wide dissemination of an integrated, resource-based scenario for the protection and improvement of seriously degraded cultivated soils in the Mediterranean area.

Scientific results & innovation potential

- ✓ Composting involves the valorisation of organic wastes, transforming them into an organic fertiliser product without harmful elements for the soil or pathogens for crops and humans. Use of compost in agriculture will encourage the lower use of other synthetic fertilizers, whose manufacture needs the exploitation of more mineral and energy resources. Therefore, using an environmental and agronomic criteria, the most reasonable would be the use of compost in agriculture to a greater extent than conventional fertilisers.
- ✓ Assessment of the suitability of characterised and selected composts (quality and dose) for the cultivation of different species in pots and plain soil.
- ✓ Alternative fertilization with compost had an overall positive effect in comparison with conventional fertilisation treatment with a mineral NPK (Nitrogen, Phosphorous, Potassium) fertiliser, when soil quality parameters, the nutritional level of crops (e.g. tomato, cabbage, lettuce, barley, corn) and crop yield were analysed.
- ✓ Assessment of the possibility to reduce fertiliser application when compost and zeolite are added to a selected growing medium allowing comparable level of biomass production (zeolite and compost rate in the growing medium: 2-4% and 5-10% respectively).

Characterization of some positive effects on plant growth and soil properties deriving from the addition of compost and/or zeolite:

- Increased biomass,
- Reduction of N leaching,
- Increased availability of nutrients (e.g. P, K),
- Stabilisation of C/N ratio at an appropriate level,
- Increased Cation Exchange Capacity (CEC),
- Reduced nitrate leaching,
- Suppressiveness of compost and zeolite to certain soil-borne pathogens.

Coordinator

Dr Victor KAVVADIAS

Department of Soil Science I of Athens, Hellenic Agricultural Organization “DEMETER”

GREECE

vkavvadias.kal@nagref.gr

Partners

- MIGAL, Galilee Technology Center, **ISRAEL**
- Centro di Sperimentazione e Assistenza Agricola (CERSAA), **ITALY**
- Centro de Edafología y Biología Aplicada del Segura (CEBAS) - Consejo Superior de Investigaciones Científicas (CSIC), **SPAIN**

METHODOLOGY

Our approach involved:

- The assessment of application practices of agricultural wastes (AW) in intensively cultivated crops and reflection on policy issues related agricultural application.
- An extensive characterization of organic wastes to evaluate their suitability for use in the Mediterranean agriculture.
- Pot experiments using selected composts in order to evaluate the effect on plant growth and soil nutrient status.
- Plant response tests where organic amendments and conventional NPK fertilisers were applied in greenhouse; open field experiments, where crop cultivations (barley corn, tomato lettuce, etc.) were carried out in order to determine the feasibility of composts as alternative to conventional fertilisers in the Mediterranean agriculture.
- Development of an integrated scenario for the management of treated agricultural wastes and zeolites in intensive crop production.

Figure 1. Study area

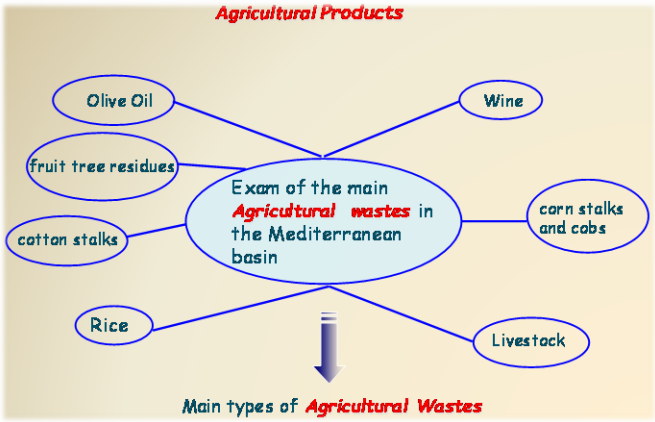

Figure 2. Sources of agricultural wastes

Why collaborating?

- To ensure the safe use of treated agricultural wastes (TAW), specific cultivation practices should be developed after detailed study of environmental conditions, water and nutrients demand of the specific crops related to TAW applications, and impact of TAW on soil and plant parameters. We went a step further, testing the suitability of these treated wastes for agricultural use and defining the specific terms and conditions for their application on different Mediterranean crops.
- Consortium members have substantial experience in the participation and management of international collaborative research projects and support actions that provided the relevant state-of-the-art for ARIDWASTE. Furthermore, some of them have already collaborated with each other or are currently partners in other projects with clear links to ARIDWASTE, which ensures greater levels of understanding and efficiency.
- The project generates a clear added-value towards the sustainable use of TAW in crop cultivation by developing specific application practices for the tested crops as well as a comprehensive land application strategy that considers the total quantity and quality of AW relative to the land base suitable for receiving them.

Figure 3. Phytotoxicity tests, greenhouse and open field experiments

ACHIEVEMENTS

Characterization of TAW

- Characterization of treated/untreated agricultural wastes from each region deriving from olive oil mills, olive husks, wood chips, rice husk, wood bark, grape lees and manure.
- Critical parameters: pH, Chemical Oxygen Demand, Biological Oxygen Demand, Ammonium Nitrogen, Phosphorus, Boron, Metals (Copper, Zinc, Iron, Nickel, Chromium, Manganese), Total oily matter.
- Phytotoxicity tests: in vitro and in pots.
- Selected compost types derived from agricultural wastes were used in the trials to assess the feasibility to reduce chemical fertilisation by adding compost and zeolite.

Greenhouse experiments

- Addition of compost and zeolite in the soil upper layer generally enhanced biomass production compared to the control. Cultivation under a cover, where it is easier to maintain a temperature higher than in open field conditions, allowed plants to better uptake nutrients.
- Soil C content was enhanced by the addition of selected composts, improving the quality of the soil and hence the long-term sustainability of the agricultural system.
- Zeolites mixed with compost significantly improved nutrient availability in soils (e.g. P, K).

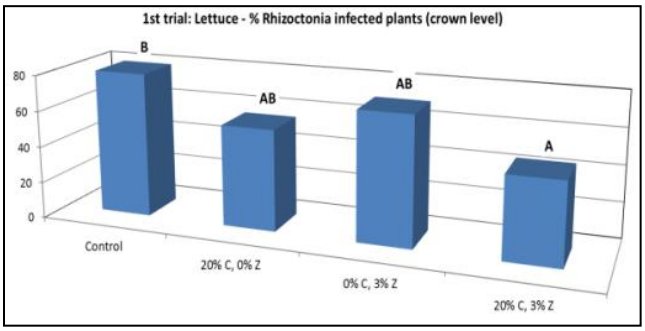

Figure 4. Suppressiveness against *Rhizoctonia solani*

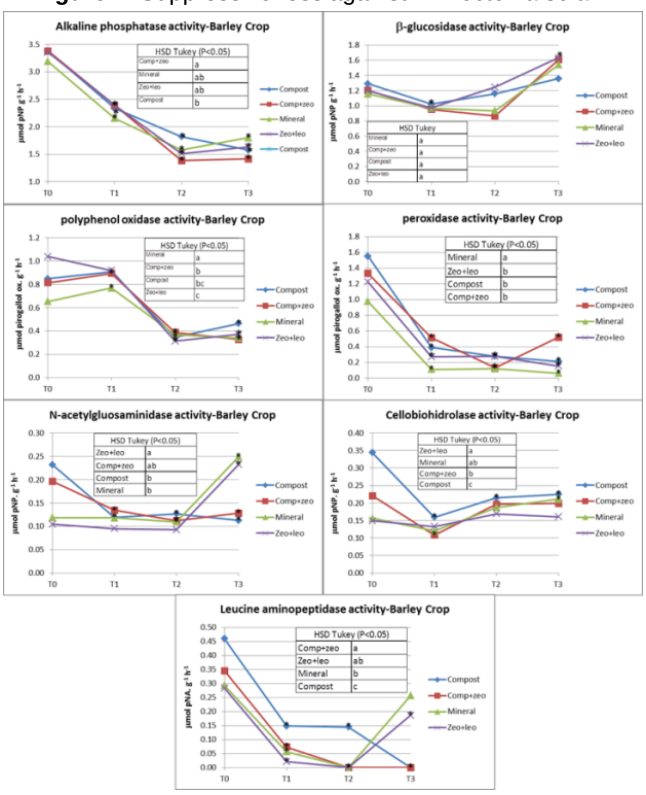

Figure 5. Soil enzymes activity during barley cultivation

Open field cultivations

- Considering the variability of the results of open field trials, the effect of the application of compost and zeolite on crop yields were mostly negligible. They did not improve crop yield compared to compost addition only. Results were consistent with nutrients availability across treatments.

Soil carbon and nutrients

- The organic amendment independently of zeolite benefited carbon and nutrient accumulation in surface soil compared to conventional fertilisation. However, the Na had a greater water soluble fraction in the treatment with zeolite, in the superficial layer. Co-addition of compost and zeolites did not contribute to the nutrient status of the soils, this result being in disagreement with earlier greenhouse results.

Reduction of nitrate leaching

- The addition of zeolite caused a reduction in soil nitrate concentration. This addition to the N source can improve N use efficiency. This is crucial in Nitrate Vulnerable Zones (NVZs) where a specific legislation applies to hinder nitrate contamination of superficial and deep water bodies. Moreover, the use of zeolites as additives of growing media normally adopted for pot cultivation can help preserving the quality of water bodies, limiting the negative effect from a continuous nitrate-based fertilisation, normally still applied through sprinkler irrigation.

Soil enzymes' activity

- The activities of several hydrolases and phenoloxidases and soil respiration were also increased for the soil amendment with the manure compost compared to the mineral fertilisation.

Suppressiveness of compost and zeolite against certain soilborne pathogens

- With regards to the trials carried out on salad species, compost and zeolite showed a potential suppressiveness against *Rhizoctonia solani* at crown level of lettuce and lamb's lettuce plants.

Constraints

- Addition of natural zeolite in a commercial field may be cost prohibitive. Countries with no zeolite may focus their R&D efforts at disconnected substrates where the rhizosphere volume is more limited and requires less zeolite addition at an affordable cost. Soil amendment with zeolite might benefit soil retention for some cationic nutrients in leaching systems such as pots or greenhouses, but in the field, with high compost loads, its effect is minor.

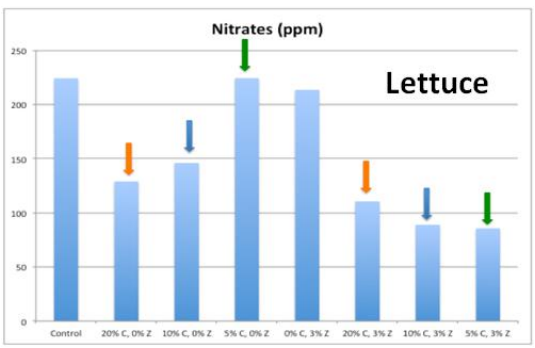

Figure 6. Addition of zeolite allowed a reduction of nitrate concentration when treatments with the same amount of compost are compared

ACHIEVEMENTS

Stakeholder engagement

- The project abstract was published on the website www.euroresearch.com, while several papers were published in the Journal of Hellenic Agricultural Organization – Demeter..
- Project's results were presented at the 26th Hellenic Conference of the Greek Society for Horticultural Science, 15-18 October 2013, Kalamata, Greece. Abstracts were included in the Conference Proceedings.
- On 30 July 2013, the Hula research farm of MIGAL for field crops and vegetables held an open day to present the 2013 research activities – including ARIMNET results in tomato and sweet corn. Over 100 farmers from the region attended the event, listened to the presentation given by the research staff and had the chance to evaluate the effect of zeolite enriched compost for the first time .
- ARIDWASTE was presented in the WASTEREUSE workshop "Experiences and best practices from other European Projects" 22 April 2015, Murcia, Spain.
- Results were presented in the III International Symposium on Organic Matter Management and Compost Use in Horticulture (20-24 April 2015, Murcia, Spain).
- A meeting took place on 14 July 2015 with farmers to present them the key results of ARIDWASTE.
- The main outputs of the project were presented by all partners during the End-of-Project conference held on 26 November 2015 in Athens, Greece, in presence of researchers, engineers, technicians and growers.
- Project's results will be presented on 17-21 October at the III International Symposium on Horticulture in Europe, SHE2016, Chania, Greece.

Reports offered to farmers

Farmers' registration

Visit of farmers to field trials

Workshop in Athens

Figure 7. A few examples of dissemination activities

Next steps

- While the limits of compost and zeolites co-additions in commercialized fields have been identified, guidelines on the management of TAW and zeolites in intensive crop production will be soon published .
- Efforts will continue to evaluate the benefits of compost and zeolite co-addition in soil-less setting and in substrate pot media with specific crops. The appropriate programme for implementation of these actions is under investigation.
- Our Israelian partner focuses now its studies on the benefits of zeolites addition to sandy soils with special reference to K fertilization.

Do you want to know more?

Contact: Dr Victor KAVVADIAS

vkavvadias.kal@nagref.gr

Website: http://www.aridwaste.gr

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Selected publications

- 26th Hellenic Conference of the Greek Society for Horticultural Science, 15-18 October 2013, Kalamata, Greece.
- III International Symposium on Organic Matter Management and Compost Use in Horticulture, 20-24 April 2015, Murcia, Spain.
- III International Symposium on Horticulture in Europe - SHE2016, 17-21 October 2016, Chania, Greece.

Reference: KAVVADIAS V., 2016. ARIDWASTE – Development of specific agricultural practices with the use of recycled wastes suitable for intensively cultivated Mediterranean areas under degradation risk. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

CLIMED

2012-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

The future of Mediterranean Livestock Farming Systems: Opportunity and efficiency of Crops – Livestock Integration

- Mediterranean livestock farming systems have evolved in response to the multiple and complex changes that occurred in the past in the area and they must now adapt to current and future pressures, including the strong demographic growth and urbanization in the coastal line and the high competition for land and water.
- CLIMED aims to assess the technical, economic and socio-ecological viability of crop-livestock systems in the Mediterranean context to help farmers, communities, researchers and decision-makers define management priorities and improve planning so as to deal better with socio-environmental issues. Interactions between livestock husbandry and natural resources (soil, water) through the feeding system vary across farming systems due to farmers' diverse livelihood strategies (e.g. livestock- or crop-focused livelihood) and the resources base. In these systems, biomass management is a pillar of the efficiency of the integrated crop-livestock systems with the important development of cash crops on coastal zones.

Livestock

Ecological intensification

Adaptation

Vulnerability

Socio-ecological system

Objectives

- To identify efficient crop-livestock systems in the Mediterranean context in order to make a better use of water, soil, crop residues, rangeland forages, etc. (resource use efficiency), and to increase their production to meet the rising local demand for safe animal products (socio-economic efficiency).
- To evaluate their adaptive capacity, vulnerability and flexibility in the face of current stresses and changes.
- To assess their socio-ecological co-viability and resilience with regard to demographic growth and in a historical perspective.
- To develop future scenarios and priorities for livestock development in the Mediterranean context to increase the capabilities of livestock systems.
- To strengthen collaboration and interdisciplinary research and innovation between and within national teams from the Mediterranean area through sharing research methods and databases.

Scientific results & innovation potential

- ✓ Based on a literature review of methods and indicators, one of our main achievements is the combination of collecting methods and types of analysis to describe and analyse the crop-livestock integration models in the three countries studied (Egypt, France and Morocco).
- ✓ Data collecting methods extended from global appraisal and family farm surveys to deep follow-ups at the farm and livestock system levels. The analyses of efficiency were based on a multitude of tools ranging from livelihood and micro-economic tools (for economic and social assessment) to environmental tools like the Ecological Network Analysis and Life Cycle Analysis (for environmental assessments).
- ✓ Global results highlighted that livestock at the interface between land management (local) and livelihood diversification (family) plays a vital role in the current rural sustainability although its future will depend on the societal challenges and policy orientation between employment, food security and resources management.
- ✓ Moreover, the function of livestock in biomass management appears crucial for the medium and long term resilience of Mediterranean agrarian systems.

Coordinator

Dr Véronique ALARY

Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)

FRANCE

veronique.alary@cirad.fr

Partners

- Department of Animal Production and Biotechnology, Institut Agronomique et Vétérinaire (IAV) Hassan II, **MOROCCO**
- Sheep & Goats Research Unit, Animal Production Research Unit (APRI), Agricultural Research Center (ARC), **EGYPT**
- UMR SELMET (Tropical and Mediterranean livestock systems) and GREEN (Renewable resources and environment management), Institut National de la Recherche Agronomique (INRA), **FRANCE**
- UMR Espace-Développement, Institut de Recherche pour le Développement (IRD), **FRANCE**

METHODOLOGY

Data collecting methods

- Using multiple field approaches: from the agrarian diagnostic at the territorial level to deep follow-ups at the level of livestock systems, passing through family farm surveys to relocate livestock changes in the family story in its environment.
- Using qualitative and quantitative data collection systems.
- Crossing official data and primary data.

Efficiency assessment

- **Social assessment:** Based on narrative approach and resources dynamics (land and labour); trajectories analysis.
- **Economic assessment:** Micro-economics at farm level (productivity; net income).
- **Environmental assessment:** 1) Ecological Network Analysis (ENA) to quantify the fluxes between crop and livestock compartments; 2) Life Cycle Analysis (LCA) for an assessment of the potential sustainable use of rangelands; 3) Efficiency indicators based on land and nitrogen management.

Vulnerability, adaptation and resilience

- **Livelihood approach:** Between assets and diversification.
- **Adaptation:** Based on historical and transversal approach of farms and their environmental situation.
- **Resilience :** Social dimension of adaptive co-management of ecosystems and landscapes (rules of users).

Why collaborating?

- To strengthen **synergies** and scientific collaborations between the partners given the multidisciplinary nature of the project and challenges addressed.
- To boost the production of **analysis methods** (disciplinary, interdisciplinary and comparative analysis).
- To present **new science insights** in more accessible and informative ways to stakeholders, especially to policy-makers and producers.

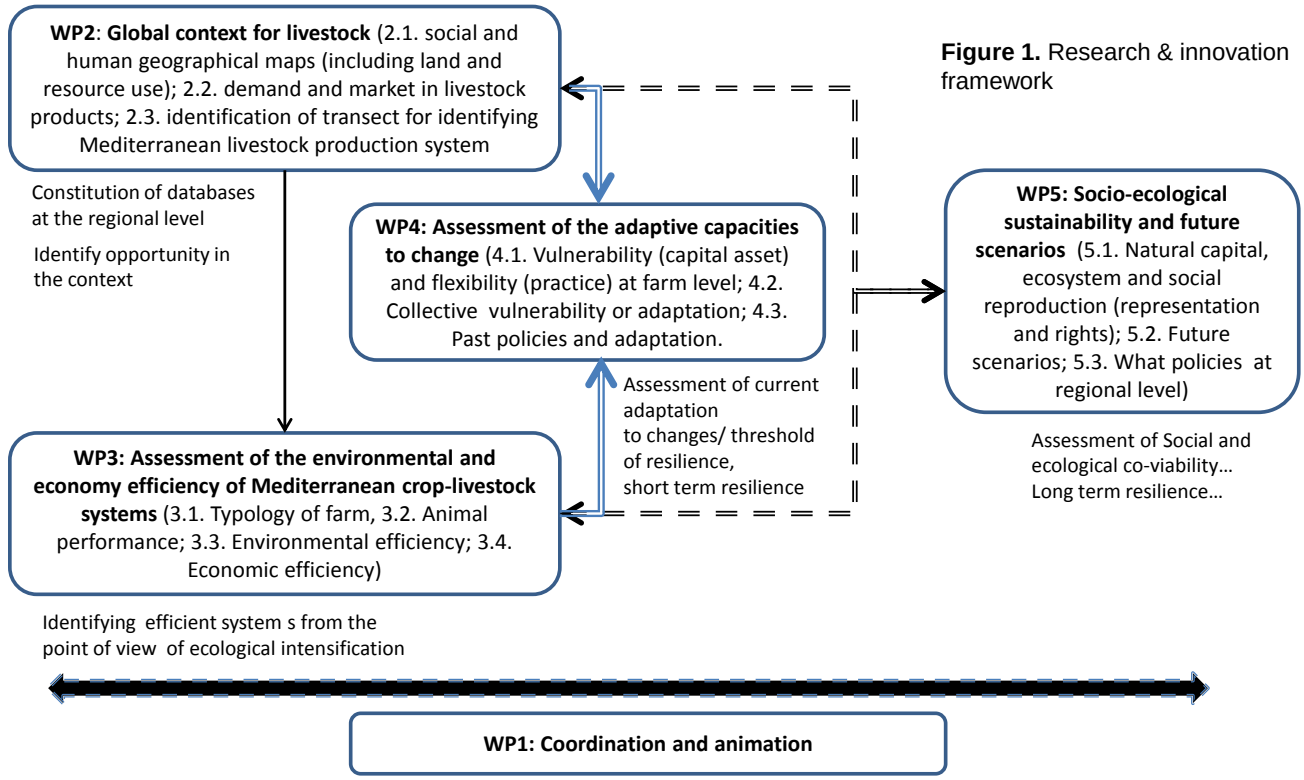

Figure 1. Research & innovation framework

Dry highlands, France

Plain of Gharb, Morocco

New reclaimed lands, Egypt

Figure 2. Livestock systems in various Mediterranean contexts

ACHIEVEMENTS

Global context for livestock

- The objective was to perform historical and geographical analyses to characterize the social, economic and geographical context, its recent development, the prospects, constraints, strengths and opportunities that provide scientific evidence relevant to the understanding of future crop-livestock production systems in the region.
- Three research activities were conducted: bibliography review of past or on-going projects in France, farm survey on 175 farmers in Egypt with a family story and territorial approach in Morocco.

We elaborated a typology of the modalities of crop-livestock integration in each location.

Assessment of the efficiency of crop-livestock systems

- In Morocco, in the Gharb plain, three Master theses have been achieved on themes related to family labour constraints, feed availability fluctuation and its impact on milking activity and milk production costs.
- In France, a review of methods and indicators was carried out. In order to characterize crop-livestock integration at farm level, an Ecological Network Analysis (ENA) was performed to quantify the fluxes between crop and livestock compartments and assess the efficiency of recycling. It was combined with a Life Cycle Analysis (LCA) to assess environmental indicators.
- In Egypt, a series of indicators were determined based on the family farm survey (Figure 3).

All these approaches stressed the crucial function of livestock biomass preservation in the Mediterranean context.

Table 1. Adaptive capacities of systems based on coordination models (South of France, Master thesis, 2015)

Models	Cereal plateau	Agrosilvopastoral system	Plain / Mountain
Types of relations	Neighbour	Inter-individual	Multi-actors
Mode of coordination	Proximity	Mutual agreement	Collective action
Temporal coordination	++	+++	+++
Spatial coordination	+	++	+++
Social coordination	+++	+++	+++

Assessment of the adaptive capacity to changes

- In the Haut-Atlas, in partnership with ORMVAO / IAV in Morocco and IRD / CIRAD in France, the analysis of the territorial system based on the characterization of the transhumance systems and the interactions of the different systems (pastoral, agro-pastoral, oasis systems) in link with the spatial and social organization, put in evidence the specific roles of rules of users in the territorial management.
- In France, a master thesis highlighted the differential roles of social, spatial and temporal coordination in the systems' adaptive process along an agro-ecological gradient of integration (Table 1).
- In the West Delta (Egypt), results show how the successful experiences in these harsh environments are highly dependent on livestock activities for cash funding and soil preservation and, more generally, on the diversification.

Adaptive capacity in the Mediterranean area is strongly based on diversification.

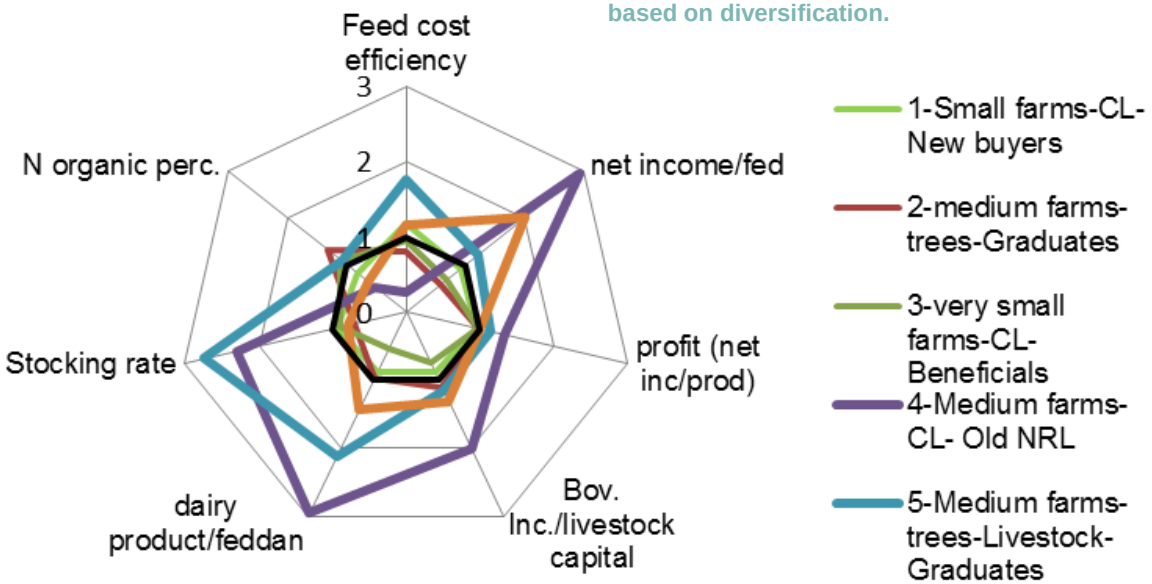

Figure 3. Efficiency profiles according to social categories in reclaimed lands (West Delta, Egypt)

ACHIEVEMENTS

Stakeholder engagement

- An expected impact of the project was a change of the society's opinion on livestock-related activities.
- Without underestimating the risks due to livestock intensification (waste management, CO_2 or methane emission, etc..), the project put in evidence the capacities of this activity to adapt to global changes and also to reduce the vulnerability by different pathways embedded with the multifunctional nature of livestock, both an economic activity and a social and biological asset.
- The impacts on employment, diversification, biomass management are part of the adaptation and vulnerability reduction processes in this Mediterranean environment.

Next steps

- Some indicators have emerged from the three studied countries related to work and net income. Some comparing analyses will be developed.
- Due to the variety of databases in each case study we propose to develop a meta-database that will give the main description of the contents of each country's database.
- This project has allowed to constitute a common knowledge base on crop-livestock integrated systems that can be used for further research projects on the adaptive capacity of these systems as they withstand global changes (especially social and climatic changes).

Figure 4. Sharing of field knowledge between researchers, technicians and farmers (Egypt)

Do you want to know more?

Contact: Dr Véronique ALARY
veronique.alary@cirad.fr

Website: http://climed.cirad.fr

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

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Reference: ALARY V., 2016. CLIMED – The future of Mediterranean Livestock Farming Systems: Opportunity and efficiency of Crops – Livestock Integration. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

Selected publications

- Srairi M.T., Sannito Y., Tourrand J.F., 2014. Investigating the setbacks in conventional dairy farms by the follow-up of their potential and effective milk yields. *Iranian Journal of Applied Animal Science* 5, 255-264
  http://ijas.ir/main/uploads/userfiles/files/Srairi%20(14-46).pdf
- Osman M., Daoud I., Melak S., Salah E., Hafez Y., Haggah A., Aboul Naga A., Alary V., Tourrand J.F., 2014. Animal husbandry complexity in the crop-livestock farming systems of the New Reclaimed Lands in Egypt. *Revue d'élevage et de médecine vétérinaire des pays tropicaux* 67 (4)
- Alary V., Messad S., Daoud I., Aboul-Naga A., Osman M.A., Bonnet P., Tourrand J.F., 2016. Social Network and Vulnerability: A Clear Link in Bedouin Society (Egypt). *Human Ecology* (DOI 10.1007/s10745-016-9807-z)
- Alary V., Aboul-Naga A., Osman M.A., Daoud I., Abdelraheem S., Salah E., Juanes X., Bonnet P., 2016. Desert land reclamation program and family farm land dynamics in the West Delta area of Egypt, 1960-2000. Land use Policy (2nd revision)

DoMEsTIc

2012-2015

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Mediterranean biodiversity as a tool for the sustainable development of the small ruminant sector: from traditional knowledge to innovation

DoMEsTIc
Traditional Knowledge to Innovation

- DoMEsTIc is about biodiversity and farming systems – assessing sensitivities to hazards, and aiming towards the sustainability of the sheep and goat sector. It enlightens the interaction of livestock production systems with the environment, as well as with the social and economical dynamics.
- What are the means by which preserving the production system diversity can ensure adequate level of income for the farmer and the provision of products to the market at an acceptable price and quantity?
- Framework to understand the interactions between management and value-adding strategies for local breeds, to facilitate coordination and cooperation between stakeholders, to identify possible tensions and support favorable dynamics.

Local breeds

Sheep and Goats

Sustainable production

Adaptation

Collective organization

Objectives

- DoMEsTIc aimed to investigate the factors that influence the sustainability of sheep and goat production systems, by examining:
  - the components of the production systems,
  - the role of local authorities and the organisation at territorial level,
  - the supply chain and the factors underlying the profile of sheep and goat farmers, with respect to the chosen milk or meat distribution channel.
- DoMEsTIc addresses the management of sheep and goat local breeds, the collective organisation, factors affecting marketing decisions and stakeholders' involvement.
- The added value of the project is related to the enhancement of available knowledge on the components of the production systems that contribute to the sustainability of the systems, and the development of new methods and models that help to understand the dynamics of local breeds and their role in the rural economy.

Scientific results & innovation potential

- ✓ The main outcomes of DoMEsTIc involve methodologies and frameworks developed to support local breeds and enhance their positive impact on rural economies:
  (1) Regulatory Framework to establish and reinforce coordination between local actors, (2) Value chain analysis and analysis of the factors affecting marketing and channel choice decisions at farmer's level, (3) Framework with a "checklist" of levels where the breed can play a mediating role between product valorisation and genetic management and, (4) Indicators for the assessment of the sustainability of the production systems as a whole, based on the analysis of collected data.
- ✓ The map of collective organization in each situation was described, identifying the main stakeholders for breed management and product valorisation.
- ✓ The analysis revealed the mediating role of the local breed within the livestock farming system and the value adding process, considering it at both the individual and collective level.
- ✓ The innovation potential of DoMEsTIc is linked to the dynamics generated by these tools, enabling increased understanding of the economic, social, environmental and institutional factors that affect the sheep and goat sector, which can be extended to the whole Mediterranean region.

Coordinator

Dr Christina LIGDA
Hellenic Agricultural Organization – DEMETER
Veterinary Research Institute, Thessaloniki
GREECE
chligda@otenet.gr

Partners

- Laboratoire de Recherches sur le Développement de l'Elevage (LRDE), Institut National de la Recherche Agronomique (INRA), Corte, **FRANCE** – lauvie@corse.inra.fr
- Animal Production Unit, Agricultural Research Institute, Lefkosia, **CYPRUS** – georgia.hadjipavlou@ari.gov.cy
- Feeding, Qualification and Environnement in Animal Production, Institut Agronomique et Vétérinaire (IAV) Hassan II, Rabat, **MOROCCO** – a.araba@gmail.com

METHODOLOGY

Production systems

- A case study approach was used as the basis for the research work. Detailed data on the production systems were collected through personal interviews with specific questionnaires to the farmers and other stakeholders. This work aimed to define the main characteristics of the production systems and the resources that contribute to the specificities of the products.

Collective organization

- The map of collective organization was developed by contacting experts in each case. This table registers the different stakeholders, their roles and interactions, the main tools and the main steps identified in the collective action.

Supply chain

- A supply chain analysis was implemented to identify and characterise the main stakeholders involved in the production and valorisation of the products, and their relationships. The work was based on interview data analyses, for a better understanding of the key points of favourable dynamics.

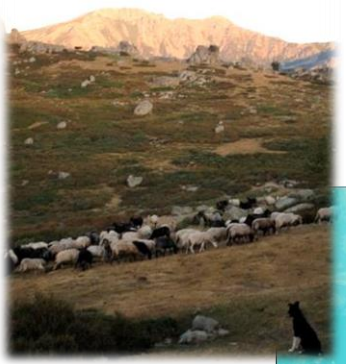
Sustainability

- Sustainability was assessed using specific principles, criteria and indicators classified into three pillars: economic, social and environmental.

Why collaborating?

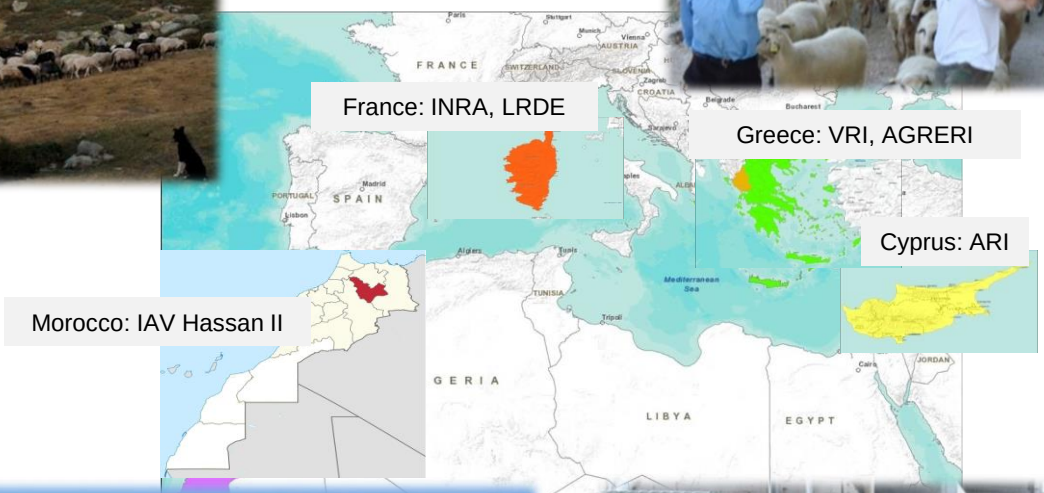
- The collaboration in the frame of DoMEsTIc contributed to the recognition of the diverse and common elements of sheep and goat production systems in the Mediterranean region, the identification of common problems and the development of tools and ways towards the sustainable development of the sector.
- The work plan succeeded in enhancing the interaction between researchers from multiple disciplines and brought new elements in the research that is carried out in this domain at national level.
- The methodologies and frameworks developed aimed at increasing the value of local breeds and their position in the market, and thereby further enhance their uptake in livestock agriculture, with an associated positive impact on rural economies and local communities.

The Corsican sheep



Transhumance flock of Katsika sheep breed in Ipeiros mountains, Greece

Figure 1. Study areas



Mixed herd of local sheep and goat breeds in a pasture of Eastern Morocco

Cyprus Damascus goats

ACHIEVEMENTS

Links between livestock farming systems, local resources and food products

Farming systems and local breeds

- The main outcomes are related to the analysis of the production systems, their values and challenges. The map of the collective organization described the stakeholders, their roles and interactions, but also the possible tensions between them or absence in certain areas of collective management of local breeds and their value adding process.
- The role of local breeds as a link between the production system and the product, was revealed through the comparative analysis of the case studies.
- In general, the connections between a breed and a product in the specific cases were weak, and as a result, the dynamics of the product do not have direct consequences on the management of a single breed.

Social organization

In the analysis of the collaboration framework among actors, the question of the social organization was crucial in all cases:

- When local breed management and product valorisation are coordinated at national level, difficulties for local stakeholders to get involved in these projects are observed.
- Several stakeholders with different viewpoints on what is the relevant product may confront each other in these projects.
- The collective organization influences the orientation of the specification depending on their weight (size, power).
- When product processing depends on a large proportion of farmers from a single large structure, changes in organization, status and/or practices of this structure can have global consequences on the sector.

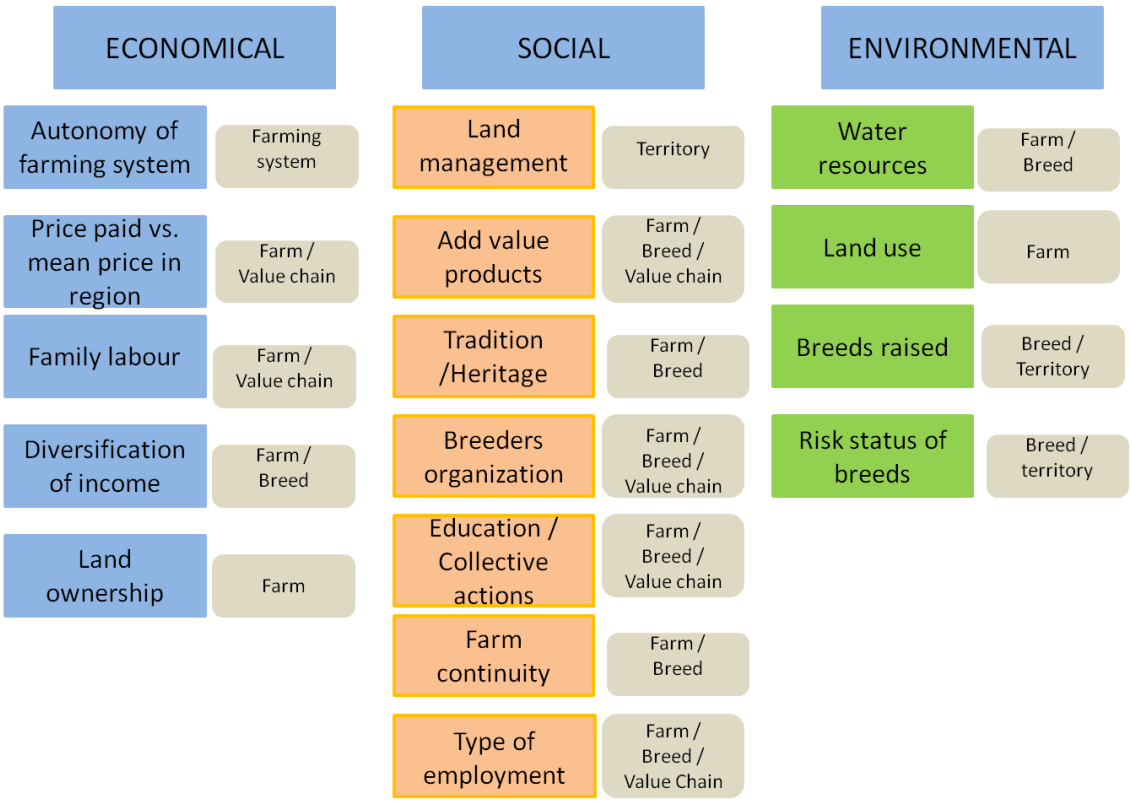


Figure 2. Sustainability indicators and relevance level

Role of local breeds

- The aim of the in-depth analysis was to scrutinize the mediating role of the local breed within the livestock farming system and the product valorisation, both at an individual and collective level.
- The means by which the practices are connected at different levels to maintain coherence among livestock farming systems, local resources (including the breed) and products' selling processes were considered.
- The interactions between management strategies of local breeds and value-adding strategies were used to provide the keys for identifying possible tensions and difficulties, along with positive aspects to support favorable dynamics.

Farmers' profiles

- The identified livestock distribution channels and the factors linked with the production system were analysed, determining the profiles of the farmers and their marketing strategies.
- The core constraints that farmers face were identified and the strategies to follow in order to support the sustainability of the sector were revealed, according to their own views.

ACHIEVEMENTS

Stakeholder engagement

- Communication with local stakeholders was pursued at several occasions, from the start of the project through the interviews with farmers and during regular exchanges with stakeholders, i.e. cooperatives, managers of the selection schemes, inter-professional organizations, etc.
- All partners organized small technical visits and meetings with stakeholders. In local workshops and seminars the outputs of the project were presented to the general public.
- In the final seminar held in Rabat (17 December 2014), 80 participants coming from different institutes, universities, breeding organizations and administration from Morocco, actively participated.
- The interest of local stakeholders is in the ways practices are connected at different levels to ensure coherence among the livestock farming systems, local resources (including the breed) and products' selling processes.

Next steps

- Issues that need further investigation concern the development of a methodology to identify existing links between breeds, farming systems and products, which are currently described in more informal ways.
- The comparative analysis developed to characterize the role of local breeds on linking livestock farming system to products, indicated the necessity to increase existing knowledge on actual livestock populations' management practices.
- Specific follow-up activities involving the various stakeholders aim to transform the project's outcomes into development actions, which may set an environment benefiting the sheep and goat sector, as these refer to the factors that influence the farming system, the management of local breeds and the exploitation of the products.

Selection practices	Are the quantity and quality of the product and regularity of the production taken into account in the selection criteria?
Reproduction management	Are constraints for selling animals taken into account? Are lambing periods managed based on the time frame for selling products?
Illustration of the product packaging	Are animals present? Are these from local breeds? Are these combined with other elements of the production system?
Selling process	Are local breeds highlighted in the process?
Perceptions of local breeds	**Are local breeds considered as**: • Having a positive influence on product quality? • A key element of local heritage? • A key element of the production system?

Figure 3. "Checklist" of levels where the breed can play a mediating role between livestock farming system and product valorisation

Do you want to know more?

Contact: Dr Christina LIGDA

chligda@otenet.gr

Website:
http://www.arim-domestic.net

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

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MEDILEG

2012-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Breeding, agronomic and biotechnological approaches for reintegration and re-valorisation of legumes in Mediterranean agriculture

- Legumes are crops of an extraordinary importance for the agriculture and the environment. However, their cultivation is decreasing in most of the Mediterranean countries.
- Our main objective is to stabilize the yield and production of major food legume cultivars adapted to different pedoclimatic conditions encountered in the Mediterranean region.

Legumes
Breeding
Crop protection
Stress resistance
Epidemiology

Objectives

The project goal is to develop methodologies to improve grain legume plant material of high yield potential, resistant to major diseases and abiotic stresses, suitable for sustainable farming systems. This is achieved by:

- Evaluation of current and historic legume germplasm for characteristics of importance to sustainable agriculture in the Mediterranean area.
- Identification of new sources of resistance to major stresses.
- Genetic studies of desired traits and development of specific markers for pyramiding and rapid screening.
- Clarification of the epidemiology of major diseases.
- Development of integrated management strategies.

Scientific results & innovation potential

- ✓ Improved sustainability can be achieved by identifying and providing germplasm to the legume breeding community that can enable increased productivity with a reduced consumption of natural resources.
- ✓ MEDILEG targets the development of legume pre-breeding germplasm resistant to major crop pathogens specific of the Mediterranean region and abiotic stresses such as drought and salinity and throught the refinement of integrated control strategies.
- ✓ The selection of genotypes carrying the desired genes will be greatly facilitated by using molecular markers tightly linked to the desired traits. In this sense, pea is used as a model as the best characterised crop legume.

Coordinator

Dr Diego RUBIALES
Consejo Superior de Investigaciones Científicas (CSIC)
SPAIN
diego.rubiales@ias.csic.es

Partners

- Centre Régional de la Recherche Agronomique de Rabat, Institut National de la Recherche Agronomique (INRA), **MOROCCO**
- UMR IGEPP, Institut National de la Recherche Agronomique (INRA), **FRANCE**
- UMR LEG, Institut National de la Recherche Agronomique (INRA), **FRANCE**
- DISSPAPA Unit, University of Naples Federico II, **ITALY**
- Field Crop Laboratory, Institut National de la Recherche Agronomique de Tunisie (INRAT), **TUNISIA**
- Regional Field Crop Research, **TUNISIA**
- Institut Agronomique et Vétérinaire (IAV) Hassan II, **MOROCCO**
- Plant Cell Biotechnology Laboratory, Instituto de Tecnologia Química e Biológica (ITQB), **PORTUGAL**
- Sakha Agricultural Research Station (SARS), Agricultural Research Center (ARC), **EGYPT**
- École Nationale Supérieure Agronomique (ENSA), **ALGERIA**

METHODOLOGY

(I) Identification of regional priorities

- All partners prospected and provided the information from their own area.
- Based on this inventory, a relevant collection of 10 genotypes per crop and country was composed to serve as project field testing.

(II) Studies on stresses

- Adapted varieties as well as germplasm collections from each country were tested, under both field and growth chamber conditions, to identify sources of resistance to major diseases (Ascochyta blights, rusts, broomrapes, fusarium wilts and chocolate spot) and drought.
- Stability of the resistance (about 40 entries per crop) was studied in multi-environment experiments.

(IV) Marker-Assisted Selection

- Standard markers for mapping in pea were developed.
- Development and/or complementation of molecular maps were conducted with SSR (*Simple Sequence Repeats*) and SNP (*Single Nucleotide Polymorphism*) markers on existing RIL (*Recombinant Inbred Lines*) populations. Analysis of QTL (*Quantitative Trait Loci)*.
- Assessment of genetic progress through (i) phenotyping; (ii) classification using anonymous SSR markers; (iii) a posteriori control of presence/absence of favourable alleles at QTL.
- Marker-Assisted Breeding: identification of markers linked to QTL of interest that could be used for the simultaneous selection for different stresses.

(V) Epidemiology

- Development of SSR markers for pathogen population genetic studies.
- Landscape epidemiology study to identify the origin and impact of different primary inoculums on the epidemic development of *Ascochyta* spp.

(VI) Biological control

- Isolation of phytotoxins produced by fungal pathogens and by root exudates for further chemical characterization.
- Study of the ability to stimulate or inhibit broomrape seed germination.
- Bioassays determination of phytotoxic, antifungal, mycotoxic and allelopathic activities of the pure metabolites isolated.

Figure 1. Food legumes studied: lentil, faba bean, chickpea, pea and common bean

Why collaborating?

- MEDILEG brings together a wide group of cross disciplinary expertise that cannot take place at a National level.
- It adds to the existing legume programs by addressing solutions to the specific Mediterranean constraints for legume production in a collaborative way between research teams across the Mediterranean basin.
- This is achieved through innovative multidisciplinary approaches including the application of biotechnologies (France, Egypt, Portugal, Morocco, Spain), plant breeding (Egypt, France, Portugal, Morocco, Spain, Tunisia), epidemiology (France, Morocco, Spain and Tunisia) and allelopathy (Algeria, Italy, Spain) as the only way to deliver integrated control measures ensuring attractiveness of legume cultivation for farmers, with associated benefits to the rural economy and to the environment, while reducing dependence from imports.

Figure 2. Cooperative multidisciplinary initiative to promote legume revalorisation in Mediterranean agriculture

ACHIEVEMENTS

(I) Definition of ideotypes

- Inventory of existing data on constraints for legume production were constructed with regard to agronomic performance, resistance, adaptability and nutritional value leading to the definition of desired phenotypes for each crop suitable for each area.

(II) Studies on stresses

- Reliable screening methods were developed for the most relevant stresses under both field and growth chamber conditions.
- Sources of resistance were identified, resistance mechanisms were characterised at the cellular and physiological level, and the stability of resistance was studied in multilocation experiments.
- The inheritance of drought tolerance was studied in multilocation field trials and laboratory experiments.
- The pathogenic variability among the disease-causing organism was also investigated.

(IV) Marker-assisted selection

- Genetic markers linked to stresses were identified. RILs segregating for resistances were analysed to test the stability of the putative QTL in different environments and genetic backgrounds.
- Marker-Assisted Breeding: the process of transferring genes and QTL from a donor line to recipient lines in order to obtain genetic material that fit the defined ideotypes was initiated.

Figure 3. Some of the stresses covered. 1st row: ascochyta, chocolate spot, broomrape and rust on faba bean; 2nd row: ascochyta, powdery mildew, broomrape and rust on pea; 3rd row: ascochyta, rust and fusarium on chickpea and rust on lentil

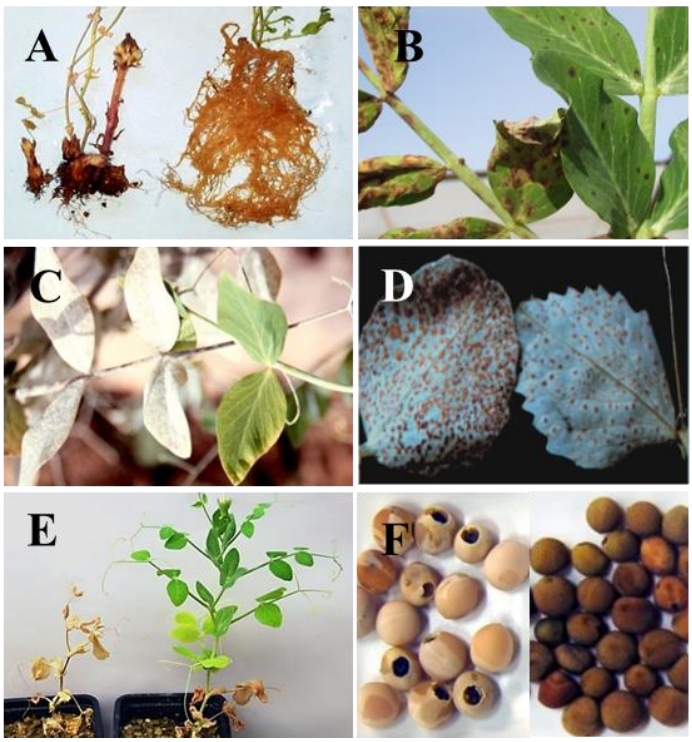

Figure 4. Symptoms of main pea diseases or pests on susceptible (left) and resistant (right) pea accessions: (A) Broomrape, (B) Ascochyta blight, (C) Powdery mildew, (D) Rust, (E) Fusarium wilt, (F) Weevil

(V) Epidemiology

- The pattern of genetic variation among populations of pathogens/parasites was analysed.
- A landscape epidemiology study was designed and carried out to identify the origin and the impact of different primary inoculum sources on the epidemic development of *Ascochyta* spp.
- Complementation of resistance with other methods for disease management of legume crops was developed in field trials.

(VI) Biological control

- Protocols were delivered for the extraction and purification of bioactive metabolites (phytotoxins, herbicides, phytoalexins).
- Structure of new bioactive compounds with original carbon skeleton was determined.
- Phytotoxic, antifungal, mycotoxic and allelopathic activities of the pure metabolites were isolated and characterized.
- Key derivatives for structure confirmation and structure-activity relationships were studied.

ACHIEVEMENTS

Stakeholder engagement

- The processes developed are designed to have a broad application by ensuring the faster development of more resistant varieties in other crop plants and for other multi-stress conditions, ensuring that scientific results can be fully applied by growers.
- Because of the additional services provided by legume crops, this is an important outcome. Unfortunately, profits from legumes to breeding companies are relatively low, so there are few participants in the sector. Therefore, legume research, except for that on soybean, is mainly carried out by the public sector in most of the world, and particularly in the Mediterranean region. The active involvement of these national agencies ensures proper implementation and dissemination to farmers.

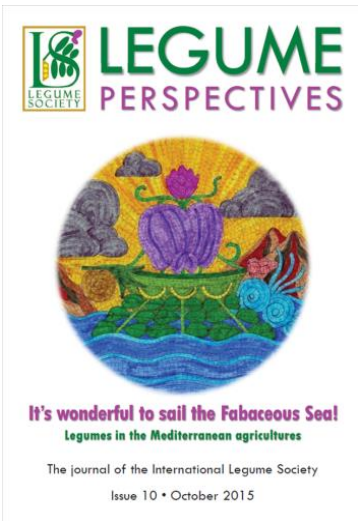

Figure 5. Example of joint dissemination product: Issue 10 of Legume Perspectives, jointly with REFORMA

Next steps

- Using legume-based cropping systems will make Mediterranean agriculture less dependent on N fertilisers and self-sufficient for protein supplies which will consequently decrease its dependency on imports. Outcomes of MEDILEG will serve to accelerate crop breeding and management. However, an effective Mediterranean network that can fully exploit this should be maintained to ensure improved food and feed security for the Mediterranean region.

Figure 6. Example of joint dissemination activity: active participation at the 2016 International Pulses conference in Marrakesh (Morocco), 18-20 April 2016

Figure 7. Example of joint dissemination activity: Final project meeting at the 2nd International Legume Society Conference in Tróia, Portugal, 11-14 October 2016

Do you want to know more?

Contact: Dr Diego RUBIALES
diego.rubiales@ias.csic.es

Website: http://www.ias.csic.es/medileg

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Reference: RUBIALES D., 2016. MEDILEG – Breeding, agronomic and biotechnological approaches for reintegration and re-valorisation of legumes in Mediterranean agriculture. *ARIMNet2 Highlights Series*

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Selected publications

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PESTOLIVE

2012-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Contribution of olive history for the management of soil-borne parasites in the Mediterranean basin

PESTOLIVE aimed at knowing and understanding:

- Olive tree diversity around the Mediterranean basin (including wild olive).
- The diversity of soil-borne parasites (SBP), i.e. plant-parasitic nematodes and pathogenic fungi.
- The diversity and the effects of pest antagonisms (e.g. olive resistance, mycorrhizae, nematophagous fungi and microbial products as future biopesticides).

Several new SBP and antagonist species were detected and the relationships between their diversity, olive domestication and intensification (from wild to high density cultivation), soil and climate were established. Wild olive material as genetic added value for resistance breeding was examined against some SBP.

Olive
Breeding
Management
Domestication
Soil-borne parasites

Objectives

- The diversity of wild and cultivated olive trees (WP1) was analysed to understand co-evolutionary patterns between SBP and the olive tree.
- The spatial distribution of SBP and microbial antagonists was explored to investigate correspondences between olive tree and parasite diversity and life-strait genetic variation involved in SBP communities forced by anthropisation (WP2).
- Resistance against SBP was tackled in order to look for new resistance sources from ancestral olive material and to assess the durability of the resistance in terms of time remanence and of parasite diversity conservation (WP3).
- The capacity to manage SBP communities in a soil diversity conservation approach was assessed considering the very large range of olive production systems in the Mediterranean countries (WP4).

Scientific results & innovation potential

- ✓ The diversity of wild and cultivated olive trees was analysed to extend previous data from research with new samplings in Crete, Italy, Morocco, Spain, Tunisia and Turkey.
- ✓ The list of olive SBP was updated, especially where they were underestimated (e.g. Crete, Morocco, Tunisia, Turkey). New nematode species were described. We focused on the diversity of root-knot nematodes (high damaging species in nurseries) and on wilt disease fungi.
- ✓ Anthropogenic forces (from wild olive to high density cultivation) reduce species richness and disturb community structures that become pathogenic. Olive producers must develop resilient cultivation strategies.
- ✓ Characterization of wild olive diversity revealed high levels of variability allowing to select new resistance sources to SBP for genetic breeding. Unfortunately, no obvious resistance was observed in three wild olive accessions from Spain. But wild accessions must be extended to provide resistance sources for breeders.
- ✓ Mycorrhizae and nematophagous fungi were also surveyed and their efficiency was established, allowing for new biocontrol agents to be used.

Coordinator

Dr Thierry MATEILLE
Institut de Recherche pour le Développement (IRD),
UMR Centre de Biologie pour la Gestion des Populations
FRANCE
thierry.mateille@ird.fr

Partners

- Université Paul Sabatier (UPS), **FRANCE**
- Institut National de la Recherche Agronomique (INRA), **FRANCE**
- National Agricultural Research Foundation (NAGREF), **GREECE**
- Istituto Agronomico Mediterraneo (IAM) Bari, **ITALY**
- Istituto per la Protezione Sostenibile delle Piante (IPSP), Consiglio Nazionale delle Ricerche (CNR), **ITALY**
- Institut Agronomique et Vétérinaire (IAV) Hassan II, **MOROCCO**
- Institut National de la Recherche Agronomique (INRA), **MOROCCO**
- Faculté des Sciences et Techniques El Gueliz, Université Cadi Ayyad Marrakech, **MOROCCO**
- Faculté des Sciences d' Agadir, Université Ibn Zohr, **MOROCCO**
- Faculté des Sciences de Tétouan, Université Abdel-malek Essaadi, **MOROCCO**
- Instituto de Agricultura Sostenible (IAS-CSIC), **SPAIN**
- Instituto Andaluz de Investigación y Formación Agraria (IFAPA), **SPAIN**
- Institut National Agronomique de Tunisie (INAT), **TUNISIA**
- Laboratoire Ressources et Amélioration Génétiques de l'Olivier, du Pistachier et de l'Amandier, Institut de l'Olivier, **TUNISIA**
- Institut Supérieur Agronomique (ISA), **TUNISIA**
- Bati Akdeniz Agricultural Research Institute, **TURKEY**
- Olive Research Institute, **TURKEY**

METHODOLOGY

An ecological approach

- SBP are everywhere encountered as communities (species and/or population mixtures). SBP control strategies in Mediterranean producing countries appeared to be designed based on their own constraints, and depending above all on parasite diversity.
- PESTOLIVE strived to understand the ecological mechanisms that govern SBP diversity and distribution, and aimed at determining how to manage SBP communities to get less or non-pathogenic communities.
- Basically, the methodology considered three ecological periods (i.e. olive post-glacial refuges in Morocco and Turkey, domestication since the ancient history, and modern breeding and cropping) and made the hypothesis that transport of cuttings rooted in soil substrates during the last two periods contributed to present SBP communities.
- This framework allowed to analyse past co-adaptation processes between olive-trees and SBP, and the consequences of olive cultivation and intensification on local diversities.

Methods used

- More than 1,300 soil and olive leaf samples were collected.
- Olive trees, SBP and microbial antagonists were characterized with morphological, biochemical and molecular technics.
- Correspondences between SBP diversity and environmental and climatic variables were analysed with specialized statistics.
- Olive and SBP suitability/resistance tests and assays with microbial antagonists were conducted under controlled laboratory conditions.
- Nematophagous fungi were produced by Solid State Fermentation (SSF).

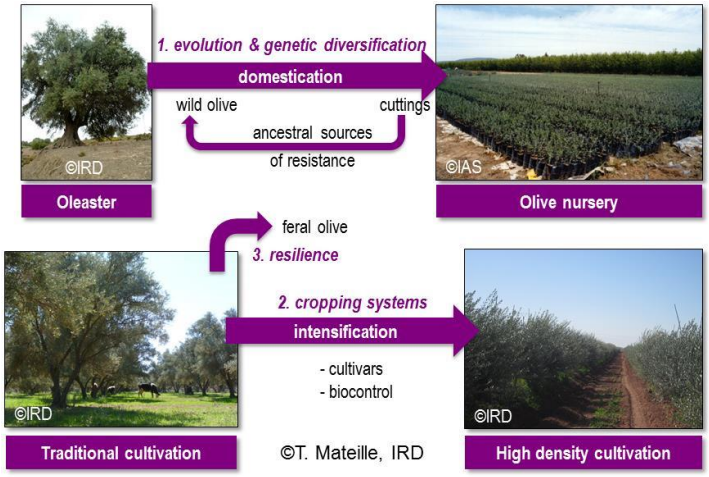

Figure 1. Systemic methodological approach in PESTOLIVE. Responses of pest diversity and development to olive domestication and intensification

Why collaborating?

A pan-Mediterranean research and training network was a necessary prerequisite for addressing most of the issues targeted by PESTOLIVE. Technical competences were crossed with research thematics. Then the best research teams able to meet PESTOLIVE issues were:

- Olive diversity, evolution and breeding: France (Univ. Paul Sabatier Toulouse and SUPAGRO Montpellier), Morocco (Univ. A. Essaadi Tetouan and INRA Marrakech), Spain (IFAPA Cordoba), Turkey (ZAIM Izmir).
- Nematode systematics, diversity and ecology of communities: France (IRD Montpellier), Greece (NAGREF Crete), Italy (IPSP Bari), Morocco (Univ. I. Zohr Agadir and IAV Agadir), Spain (IAS-CSIC Cordoba), Tunisia (INAT Tunis and ISA Sousse), Turkey (BATEM Antalya).
- Diversity and pathogenicity of fungi and fungus control: Italy (IAMB Bari), Morocco (IAV Agadir and Univ. C. Ayyad Marrakech), Spain (IAS-CSIC Cordoba), Tunisia (IO Tunis).
- Plant-resistance: Spain (IAS-CSIC Cordoba).
- Biocontrol agents: Italy (IAM Bari and IPSP Bari), Morocco (Univ. I. Zohr Agadir), Spain (IAS-CSIC Cordoba).

Figure 2. Study areas and partners involved in PESTOLIVE

ACHIEVEMENTS

Olive domestication and breeding

- Molecular dating analyses performed on plastid genome of oleasters and cultivated genotypes revealed three main lineages and support the existence of three long-term refugia: lineage E1 in the Near East (including Cyprus) and the Aegean area, and E2 and E3 in the Strait of Gibraltar.
- Comparison of the geographical pattern of plastid diversity between wild and cultivated olives indicates the cradle of the first domestication in the northern Levant followed by dispersals across the Mediterranean basin.
- These three lineages have provided the essential foundations for cultivated olive breeding.

SBP / olive co-adaptation

- Fine scale analyses at country level as in Morocco indicated that mountains were able to limit the dispersion of nematode species and of E2 and E3 olive lineages on both sides of the Rif Mountains (fragmentation processes).
- Molecular analyses of the infra-specific diversity of nematode species must be continued in order to link it with olive diversity.
- SBP invasion processes from nurseries to orchards were highlighted: for example in Morocco, very low level of diverse populations of *Meloidogyne arenaria*, *M. hapla*, *M. spartelensis* and *Meloidogyne* spp. were detected in plant refugia (Rif and Atlas mountains) while high populations of *M. javanica* were widespread in orchards.

Olive resistance to SBP

- Host suitability tests revealed that root-knot nematodes developed more on the wild olive accessions used than on cultivars, but disease severity was lower on wild olive, suggesting tolerance mechanisms.
- Several *Verticilium dahliae* pathotypes were detected and they were all pathogenic on wild olive and cultivars.
- The combination of nematodes and pathogenic fungi was very deleterious for olive plantlets.

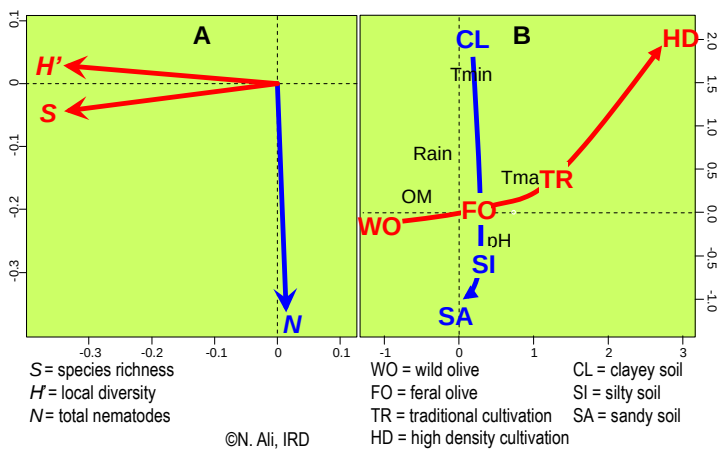

Figure 4. Co-inertia analysis between nematode diversity (A) and olive modalities and soil texture (B). Species richness and local diversity are reduced by olive domestication and intensification, when nematode population levels are led by the soil texture

Figure 3. *Verticilium* wilt disease on olive. This disease is due to defoliating pathotypes of *Verticilium dahliae*

Response of SBP diversity to olive domestication and intensification

- Plant-parasitic nematodes (PPN) were used as models, because of their high diversity: more than 200 species were detected all around the Mediterranean basin.
- Several new species were detected and characterized.
- Rich PPN communities were observed in wild olive areas and share different species, mostly persistent (especially *Xiphinema* spp.). The cultivation of olive trees lead to a strong richness erosion and favours high pathogenic and colonizing species such as *Meloidogyne* spp. and *Pratylenchus* spp.
- Comparing traditional and modern orchards, it is obvious that this erosion is strengthened when olive trees are cultivated according to high input strategies (high density, irrigation, fertilizers, pesticides).
- These observations confirm that plant production is more impacted by the structure of pest communities than by the population level of emblematic species.

Biocontrol agents

- The effect of various antifungal bioproducts (made of *Bacillus* spp., *Trichoderma* spp., etc.) was tested on *V. dahliae*. They significantly reduced the soil inoculum and protected olive roots from invasion.
- PESTOLIVE showed first evidence of high diversity of mycorrhizae associated with olive roots. These symbiotic fungi are able to protect plant roots from PPN and pathogenic fungi. However, their high specificity to environments implies to take into consideration the specific soils where the mycorrhized olive trees will be established.
- Several species of nematophagous fungi were isolated from nursery substrates. These fungi are able to parasite PPN with diverse trapping organs or to kill them with toxic compounds. The most efficient strains for biocontrol were selected, and their production was successfully performed by SSF on agro-industrial by-products (e.g. sugar cane bagasse) at a pilot scale.
- The evaluation of these biocontrol agents should lead new nursery processes by introducing them in cutting substrates and new cultivation practices for successful adaptation in orchards.

ACHIEVEMENTS

Stakeholder engagement

- Olive wood parks must be certified free from pests to be sold or exported, but PESTOLIVE showed that the large distribution of very pathogenic SBP in orchards could be primarily due to widespread introductions from nurseries. This observation should lead to a strengthening of the legislation in nurseries to invite them to ensure healthy substrates. Plant protection organizations have been informed.
- Nematophagous fungi were isolated from nursery substrates. SSF is an economic and ecological process for industrial production of filamentous fungi, because it uses agro-industrial by-products as carbon substrates, and it is easy to lead climatic conditions (especially dry air stresses for sporulation) in fermenters. In this way, the SSF production of fungal biopesticides was a success. This process will be patented and transferred to bio-product industries.

Next steps

- Understanding the evolution of olive trees around the Mediterranean basin remains a challenge for plant breeding. Olive world germplasm banks (Morocco, Spain and Turkey) will be completed with wild accessions in order to provide new candidates for breeding.
- Olive-SBP co-phylogeny studies should continue. That may open new insights in order to look at new resistance sources and to understand how olive diversity may lead the SBP diversity and then their pathogenicity.
- We have seen that olive intensification leads to an erosion of the SBP diversity and increases populations of the most pathogenic SBP. Some options could be proposed to reverse this trend such as diversified farming systems (diversification and crop rotations, intercropping), conservation agriculture (minimum tillage, cover crops) and organic farming able to enhance suppressive soils.

Figure 5. Production of a microbial biopesticide. The nematophagous fungus is produced on dry sugar cane bagasse by Solid State Fermentation (SSF)

Do you want to know more?

Contact: Dr Thierry MATEILLE

thierry.mateille@ird.fr

Website:
www1.montpellier.inra.fr/CBGP/pestolive

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Reference: MATEILLE T., 2016. PESTOLIVE – Contribution of olive history for the management of soil-borne parasites in the Mediterranean basin. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

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PoH-MED

2013-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Potato Health - Managed for Efficiency and Durability

- Potato is a major crop in Mediterranean countries, and a major trade product (seed; early ware) with high phytosanitary stakes. The PoH-MED project thus targets the sustainable potato protection in Mediterranean environments.
- To this end, it is built around three target activities: 1) To characterise pathogens and their adaptive patterns, 2) To identify and integrate innovative control measures, and 3) To transfer knowledge.
- The research activities carried out in PoH-MED allowed: 1) To show similar genetic structures in populations of major pathogens (*P. infestans*, *P. atrosepticum* and *R. solani*) in Europe and Northern Africa; 2) To identify promising candidates of natural origin (olive extracts, pathogen filtrates) for effective biocontrol, and 3) to set up demonstration trials for cultivar choice.

Potato

Disease management

System sustainability

Biodiversity

Transfer and dissemination

Objectives

- Potato is a strategic crop on both sides of the Mediterranean sea: it is both a wholesome food and industry source, a major cash crop, and an important object for trade (seed from Europe, early potatoes for fresh markets from Northern Africa).
- From an agronomic point of view, potato is vulnerable to a wide range of pathogens, and as such is subject to many pesticide applications, both on seed and during vegetation. Its inclusion in highly intensive systems (i.e. short rotations) involving (at least in southern countries) other Solanaceae (pepper, tomato, etc.) only reinforces this vulnerability.
- The aim of PoH-MED is to provide keys for a more sustainable protection of potato crops around the Mediterranean basin, by: 1) Understanding the distribution, genetic variability and adaptation abilities of major pathogens, 2) Discovering protection means more sustainable than synthetic pesticides, and 3) Disseminating knowledge and building capacity.

Scientific results & innovation potential

PoH-MED was intended to yield:

- ✓ Academic knowledge and information about pathogen distribution, genetic structures, and relationships around the Mediterranean basin.
- ✓ Insights into new control methods, and their biological basis, applicable for more sustainable potato protection strategies in the future.
- ✓ Opportunities for dissemination and adoption of available control means (e.g. resistant cultivars) by growers.
- ✓ Training and capacity building through shared student tuition.

Figure 1. A potato field (*Photo: R. Corbière - INRA – UMR IGEPP – Rennes)*

Coordinator

Dr Didier ANDRIVON

Institut National de la Recherche Agronomique (INRA)

Institut de Génétique, Environnement et Protection des Plantes

FRANCE

didier.andrivon@rennes.inra.fr

Partners

- École Nationale Supérieure d'Agronomie (ENSA) El Harrach, **ALGERIA**
- Laboratoire de Microbiologie Appliquée, Université Bejaia, **ALGERIA**
- Faculté Sciences et Techniques Laboratoire de Microbiologie, Université Hassan 2, **MOROCCO**
- Fédération Nationale des Producteurs de Plants de Pomme de Terre, **FRANCE**
- Centre National de Contrôle et de Certification, **ALGERIA**
- Laboratoire Électrophysiologie des Membranes, Université Paris VI - Jussieu, **FRANCE**
- Groupement National Interprofessionnel des Semences, **FRANCE**
- Institut Technique des Cultures Maraîchères et Industrielles, Amirouche Fatiha, **ALGERIA**
- Département de Biologie Moléculaire, Institut National de la Protection des Végétaux (INPV), **ALGERIA**
- Central Administration for Seed Certification, **EGYPT**

METHODOLOGY

Research: from fields to labs and back

- The project relies on research activities starting from the fields (pathogen sampling), going into labs (molecular typing of isolates, mechanistic assessment of defence mechanisms, etc.) or under controlled conditions (temperature adaptation, pathogenicity tests) and then back to trial or demonstration fields (cultivar assessment).

Training and capacity building

- Training and capacity building were an integral part of the project strategy. It primarily involved scientific stays by PhD students in partner's labs to learn about new protocols and techniques.

Dissemination activities

- Demonstration platforms are efficient means to increase awareness and adoption of innovations by end-users. They were used within PoHMED mainly as cultivar demonstration fields, and supplemented the more classical means of information sharing through publications in scientific and technical journals and communications at scientific workshops and conferences (Figure 2).


DOSSIER

Mildiou en France : P. infestans sous surveillance

Le réseau d'épidémiosurveillance du mildiou de la pomme de terre permet de suivre les populations de *Phytophthora infestans*, ses résistances aux fongicides et ses contournements de résistances variétales. C'est utile.

ROSELYNE CORRIÈRE*, CATHERINE CHATOT**, ROMAIN MABON* ET NICOLAS MARIETTE*

...erian Phytophthora infestans populations ...otypic structuration on potato and tomato ?

Ann Microbiol (2012) 62:1411–1417
DOI 10.1007/s13213-011-0391-6

ORIGINAL ARTICLE

Molecular typing of *Pectobacterium carotovorum* isolated from potato tuber soft rot in Morocco

Meriam Terta · Souad Azelmat · Rajaa Ait M'hand · El Hassan Achbani · Mustapha Barakate · François Bouteau · Moulay Mustapha Ennaji

Received: 25 August 2011 / Accepted: 14 November 2011 / Published online: 3 December 2011
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Figure 2. Publishing scientific and technical achievements from PoH-MED

Why collaborating?

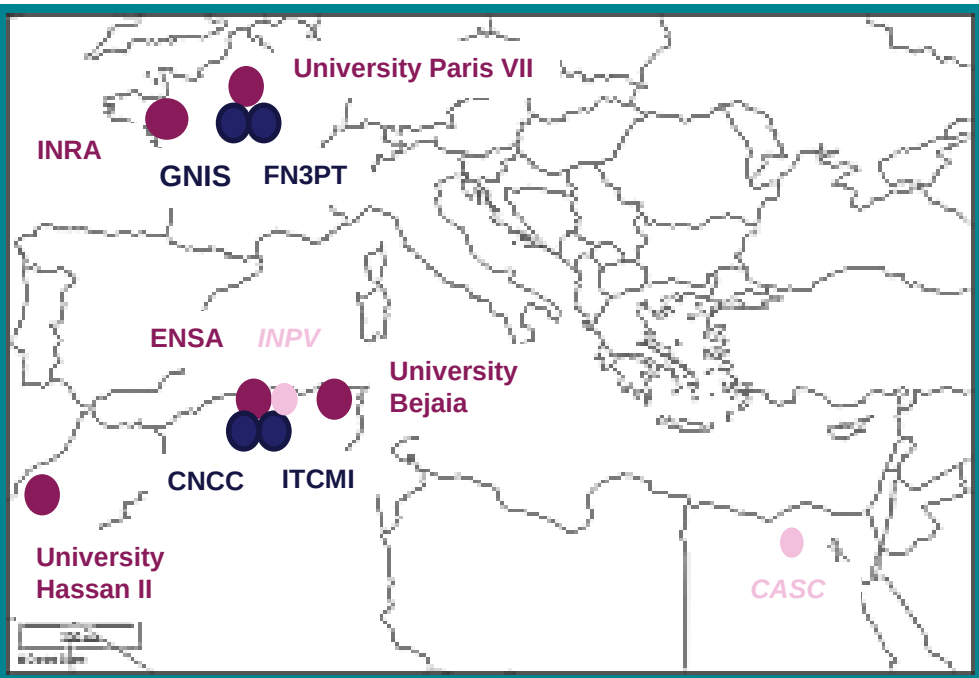
- Any project aiming at the development or improvement of agronomic systems needs the involvement of multiple actors: academic research, higher education, and extension. Furthermore, the sheer diversity of environments and local situations within the Mediterranean area make multilateral collaborations highly fruitful.
- Therefore, the initial PoH-MED consortium included 11 partners from 4 countries (Figure 3). Although administrative difficulties forced two partners to retire from the project, the partners still represented a wide range of competences, disciplines and positioning along the innovation chain.

Figure 3. PoH-MED Partners

Academic - research and higher education

Extension

Initial consortium member, but retired from operation for administrative reasons



ACHIEVEMENTS

Typing pathogen populations

Characterisation

Pathogen sampling and molecular typing have shown strong similarities but also occasional differences between population genetic structures in Northern Africa and France:

- *Rhizoctonia solani* populations in France and Algeria are dominated by one single genetic group, AG3-PT.
- The complex of soft-rot bacteria in France includes both *Pectobacterium* and *Dickeya* species, the latter genus being absent from Morocco. Within *Pectobacterium*, the French complex includes *P. atrosepticum*, *P. carotovorum*, *P. wasabiae* and *P. brasiliensis* (Hélias *et al*., 201?), which is also present and emerging in Morocco (Kettani-Halabi *et al*., 2013) alongside *P. carotovorum* (Faquihi *et al*., 2015).
- *Phytophthora infestans* populations in France and Algeria include mainly clonal lineages 13_A2 on potato and 23_A1 on tomato; lineage 6_A1 is also present in France, but was not detected in Algeria so far. By contrast, lineage 2_A1, now very rare in continental Europe, is still widespread in Algeria (Corbière *et al*., 2015).

Adaptation patterns and mechanisms

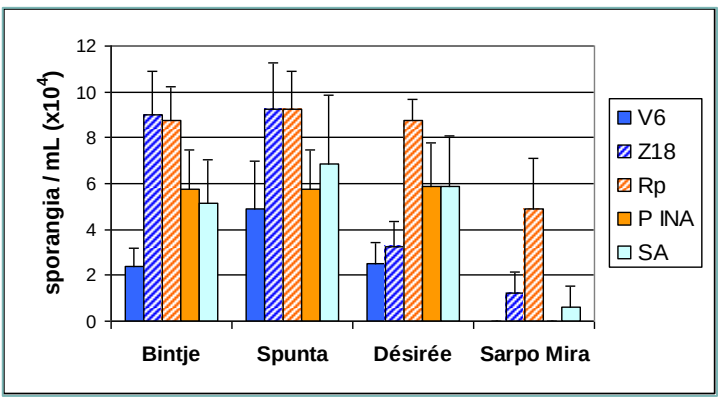


Figure 4. Spore production by five *P. infestans* isolates on four potato cultivars, showing specific adaptation of isolate *Rp* to the resistant clone Sarpo Mira (Belkhiter *et al.*, 2013)

- To survive and thrive, pathogens, like all living beings, must adapt to the diverse environments they occupy. For pathogens, an essential part of the environment is their hosts, and their eventual resistance.
- We showed through controlled biotests that natural isolates of *P. infestans* can adapt rapidly to the highly complex resistance of cultivar sarpo Mira, although this genotype is still seldom deployed in agriculture (Figure 4). This fast adaptation potential makes sustainable control more difficult to achieve, and imposes that every new control method be integrated in a comprehensive strategy combining multiple means to prevent rapid breakdown through pathogen evolution.

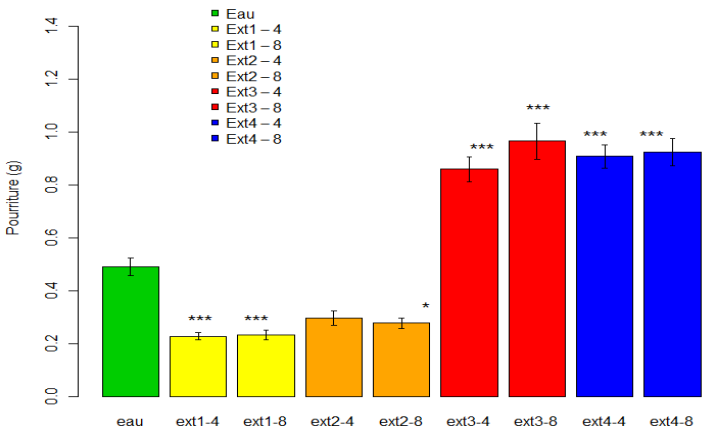


Figure 5. Total rot weight induced by *Pectobacterium atrosepticum* in half tubers of potato cv. Spunta previously treated with olive (Ext. 1 and 2) or carob (Ext. 3 and 4) at different doses prior to inoculation with the pathogen. Olive extracts significantly reduced rot weight, contrary to carob extracts which tended to increase disease severity

Innovative control solutions

- We focused on biocontrol solutions based on two types of natural products: 1) Native plant extracts and 2) Molecules secreted by the pathogen and recognised by the plant. The rationale is to use these as signal molecules to trigger defence reactions in the plant, able to reduce the severity of infection upon subsequent attacks by the pathogens.
- This approach allowed in particular to show that olive extracts, and particularly one of the molecules present there – hydroxytyrosol – reduces the severity of bacterial soft rot compared to water treated controls (Figure 5; Ouanas *et al*., 2016). However, other plant extracts either did not affect or even increased disease severity. These results provide good perspectives for the production of new agrochemicals while exploiting natural resources locally abundant.
- We also looked for genetic resistance to local pathogen populations: Figure 6 below shows a cultivar evaluation trial set up in Algeria for investigating the resistance to late blight (*P. infestans*) in 2015.

Figure 6. Cultivar evaluation trial set up in Algeria for resistance to late blight (*P. infestans*) in 2015

ACHIEVEMENTS

Training

- PoH-MED supported experimental activities in several PhD theses that were started just before or during the project by S. Belkhiter, M. Terta, L. Beninal, N. Mariette and S. Ouanas.
- PoH-MED promoted long-term studentships in France, in particular those from M. Terta to University Paris VII (3 months) and of S. Ouanas to INRA Rennes (18 months).
- PoH-MED encouraged the participation of researchers to international conferences and workshops, including the last two Euroblight meetings in Cyprus (2013) and Romania (2015).

Dissemination

- PoH-MED generated a number of scientific and technical publications (Figure 2), some of which are listed below. Further manuscripts have been recently submitted or are currently being drafted.

Figure 7. PoH MED as a budding network of collaborations. Participants to the PoH-MED meeting in Rennes, 2014

Next steps

- Since the project was granted an extension until August 2016, it is ongoing and several experiments are still underway. We are planning to have the final meeting during the autumn of 2016, possibly next to the Microbiod3 conference in Mohammedia, on 24-26 October 2016. Discussions are underway to assess the practicality of such an organisation.
- After the project administratively ends, we plan to continue collaborations (Figure 7) on population monitoring, and resistance elicitation and management. The joint supervision of Algerian PhD students (Ms S. Belkhiter and Mr L. Beninal) is already in place, and an application for a mobility grant (PROFAS B+) has been prepared to finance the 10-month stay of Ms Belkhiter at INRA Rennes in 2016-2017. Several joint papers are also being prepared, and should be submitted for publication in the coming months.

Do you want to know more?

Contact: Dr Didier ANDRIVON

didier.andrivon@rennes.inra.fr

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Reference: ANDRIVON D., 2016. PoH-MED – Potato Health - Managed for Efficiency and Durability. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

Selected publications

- Kettani-Halabi M., Terta M., Amdan M., El Fahime E.M, Bouteau F., Ennaji M.M., 2013. An easy, simple inexpensive test for the specific detection of *Pectobacterium carotovorum* subsp. *carotovorum* based on sequence analysis of the pmrA gene. *BMC Microbiol* 13:176
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- Raoul des Essarts Y., Cigna J., Quêtu-Laurent A., Caron A., Munier E., Beury-Cirou A., Hélias V., Faure D., 2016. Biocontrol of the potato blackleg and soft-rot disease caused by *Dickeya dianthicola*. *Appl. Environ. Microbiol*. 82, 268-278. doi:10.1128/AEM.02525-15.
- Ouanas *et al*., 2016 – Plant Pathology *(under revision)*

REFORMA

2012-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Resilient, water- and energy-Efficient FORage and feed crops for Mediterranean Agricultural systems

- Crop-livestock and feed systems have a huge economic importance in Mediterranean regions, but are threatened by feed protein insufficiency, grassland overexploitation, decreasing irrigation water, and increasing drought, heat, and cost of fertilizers.
- REFORMA aims to alleviate these constraints by developing new breeding methods and varieties that enhance lucerne adaptation to drought, salinity, grazing, heat and mixed cropping and pea drought tolerance, and by optimizing lucerne- and pea-based crops.
- Extensive germplasm evaluation and innovative genotyping-by-sequencing molecular characterization were exploited to develop genomic selection models with good ability to predict lucerne or pea genotype breeding values in specific environments.

Drought tolerance
Forage crops
Genomics
Grain legumes
Plant breeding

Objectives

- Enhancing the forage yield and persistence of lucerne in Mediterranean environments prone to severe drought, salinity, grazing or heat stress, by selecting phenotypically stress-tolerant varieties and by defining innovative genome-enabled and ecologically-based selection procedures.
- Producing drought-tolerant pea varieties for grain or forage production, by phenotypic selection and definition of innovative genome-enabled and ecologically-based selection procedures.
- Optimizing the cultivation and use of lucerne-based and pea-based forage crops in different drought-prone Mediterranean environments, by assessing different pea-cereal and lucerne-grass mixtures, other mixtures and pure stand crops in terms of yielding ability, resilience, forage quality and acceptability by farmers.

Scientific results & innovation potential

- ✓ Large genetic variation emerged for breeding value of lucerne (alias alfalfa) and pea genotypes under various stress conditions, supporting the breeding of these crops for specific stress-prone environments.
- ✓ An evolutionary pea breeding scheme that exploits natural selection under drought stress proved valuable and cost-efficient.
- ✓ Genomic selection reached accuracy levels sufficient to potentially offset phenotypic selection for lucerne forage yield, and showed high predictive accuracy for pea grain yield under severe drought stress.
- ✓ Pea-cereal forage crops tended to out-yield vetch-based mixtures or cereal monocultures, and ranked high in farmer-participatory evaluations.
- ✓ Although most research work awaits completion in 2016, owing to delays in its implementation, our preliminary results confirm the high interest of pea and lucerne for more sustainable cropping systems and the scope for improving the resilience and breeding efficiency of these species via genomic selection and evolutionary breeding approaches. Various stress-tolerant varieties of lucerne and pea will be selected within the project.

Coordinator

Dr Paolo ANNICCHIARICO

Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro di Ricerca per le Produzioni Foraggere e Lattiero-Casearie [CREA-FLC], Lodi

ITALY

paolo.annicchiarico@crea.gov.it

Partners

- Institut National de la Recherche Agronomique, Unité de Recherche Pluridisciplinaire Prairies et Plantes Fourragères, Lusignan, **FRANCE** [INRA-URP3F]
- Institut National de la Recherche Agronomique, Unité de Recherche en Agroécologie, Dijon, **FRANCE** [INRA-URAgro]
- Institut National de la Recherche Agronomique (INRA), Centres Régionaux de Marrakech et de Rabat, **MOROCCO** [INRA-MOR]
- Institut National de Recherche Agronomique, Division des Agrosystèmes de l'Est, Sétif, **ALGERIA** [INRAA]
- Ecole Nationale Supérieure d'Agronomie, Alger, **ALGERIA** [ENSA]
- Consiglio Nazionale delle Ricerche, Istituto per il Sistema Produzione Animale in Ambiente Mediterraneo, Sassari, **ITALY** [CNR-ISPAAM]
- Institut des Régions Arides, Médenine, **TUNISIA** [IRA]
- The Samuel Roberts Noble Foundation, Forage Improvement Division, Ardmore, OK, **USA** [Noble F]

Lucerne and pea crop improvement

Ecological breeding and variety selection

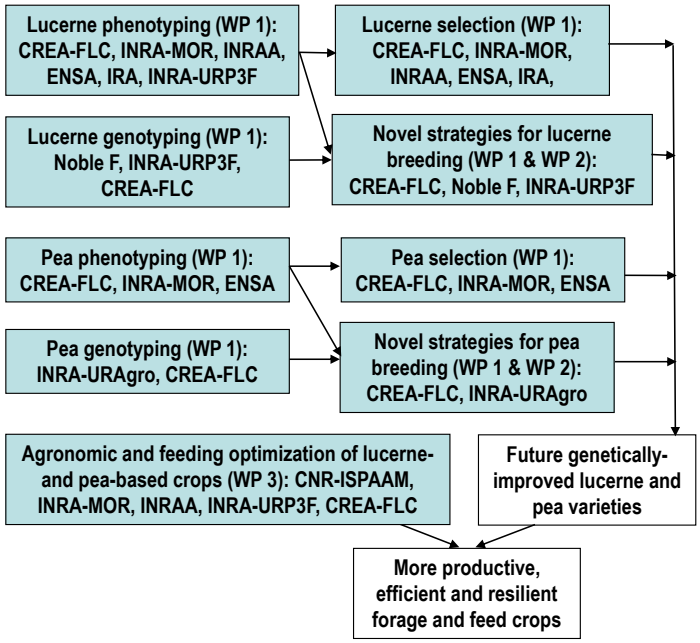
- Large breeding populations of lucerne genotypes and pea advanced lines underwent yield testing in different stress prone agricultural environments for phenotyping and variety selection (Figure 1). Phenotyping platforms were used to assess their ability to reproduce genotype responses in drought-prone sites, for implementing evolutionary selection, and for heat tolerance studies.

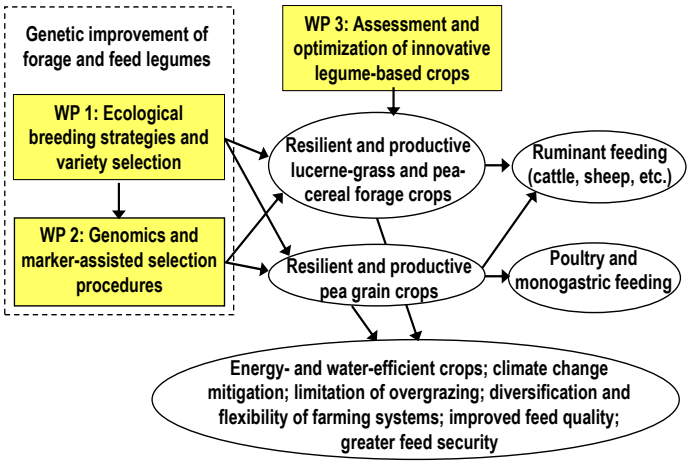
Genome-enabled selection

- Lucerne and pea reference populations were genotyped by genotyping-by-sequencing (GBS) methods, to define genomic selection models for yield in specific conditions and for genome-wide association (GWAS) studies.

Legume-based crop optimization

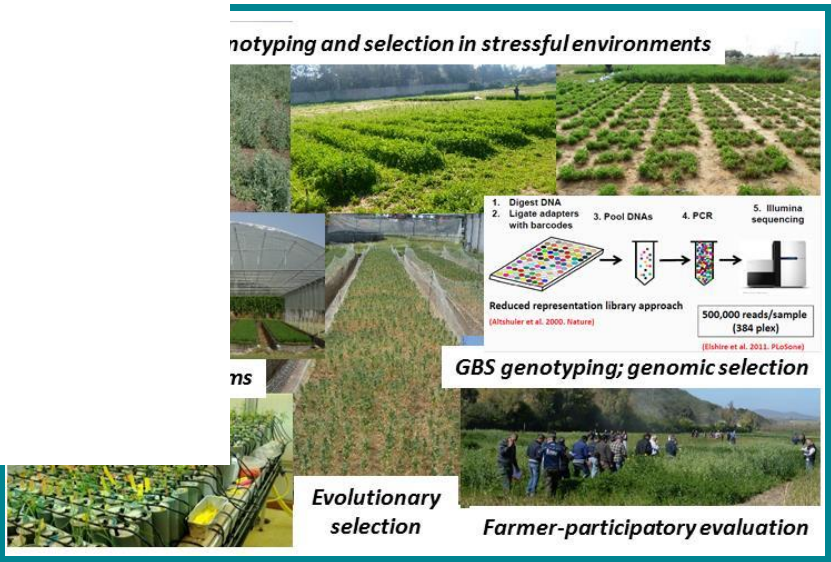
- Innovative forage crops including pea (semi-dwarf or tall) common vetch or Narbon vetch in pure stand, binary and complex mixtures with oat and triticale, and lucerne (erect or semi-erect) in pure stand, binary and complex mixtures with tall fescue and cocksfoot, were evaluated for yield





the technical challenges required for the development of genome-enabled selection tools.

- Identifying opportunities for long-term cooperation between breeding programmes that share similar challenges and target environments.
- Improved understanding of adaptive responses of innovative crops and genotypes (through testing across climatically-contrasting sites).
- Exploiting plant responses in harsh environments of north Africa to improve the adaptation to climate change of crops and varieties in southern Europe.



ACHIEVEMENTS

Ecological breeding and variety selection

Lucerne

- Large numbers of half-sib families (over 150) tested in large phenotyping platforms showed modest correlation for forage yield or persistence across moderate and severe drought. Only moderate correlations emerged across pure stand and mixed stand with grasses.
- On-going trials in agricultural environments will allow to assess correlations across platform and field conditions, different stress types (drought, salinity), and different drought-prone sites. Synthetic varieties will be bred from each testing site from locally best plants.
- Growth chamber experiments highlighted fairly modest genetic variation for heat tolerance.

Pea

- Inbred lines issued by an inexpensive evolutionary breeding scheme implying natural selection under severe drought for three segregating generations were 18% higher yielding under severe drought than lines conventionally bred by a single-seed descent scheme.
- Varieties will be selected after completing the on-going phenotyping of 315 lines in various drought-prone sites.

Genome-enabled selection

Lucerne

- GBS provided many polymorphic SNP (Single Nucleotide Polymorphism) markers (10,000-15,000 for 20%-50% genotype missing data thresholds) for a reference population including 154 plants. Best genomic selection models for plant breeding value (based on yields of plants' half-sib families) in moisture-favourable conditions revealed accuracy (i.e. correlation between modelled and observed values) near 0.35 (Figure 4). This may imply definitely greater gains per year for genomic selection than phenotypic selection. GWAS revealed many QTL (Quantitative Trait Loci) with small effect, further reinforcing the interest of a genomic selection approach.
- Genomic selection for drought-prone, saline or grazed environments and forage quality, and GWAS, will be explored after completing the on-going phenotyping.

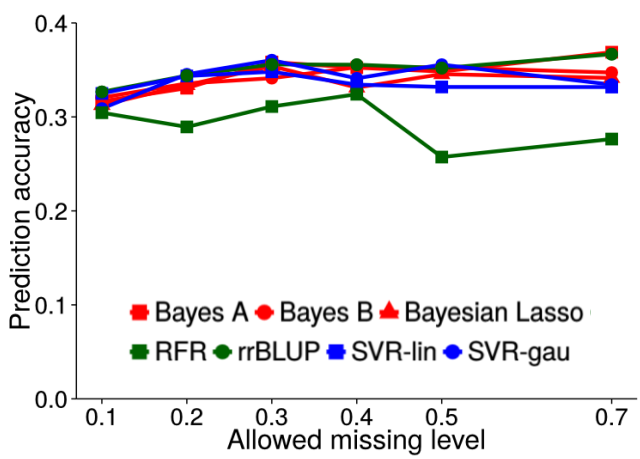


Figure 4. Accuracy of genomic selection models for lucerne breeding value (for varying genotype missing data thresholds). Genomic selection is accurate enough for implementation

Pea

- GBS provided at least 2,500-3,000 polymorphic SNP markers in three connected crosses between elite parent lines (each cross including 105 lines). Genomic selection displayed outstanding accuracy (> 0.70) in two crosses, and high accuracy (> 0.50) in one cross, for prediction of grain yield under severe terminal stress in phenotyping platforms. A preliminary GWAS study showed extensive co-localization of yield and early flowering (stress escape) QTL, and mostly small-effect QTL for drought resistance.
- A robust genomic selection model will be developed after completing the field phenotyping in drought-prone sites. More thorough GWAS studies are under way.

Legume-based crop optimization

- Results for 16 annual crops averaged across two years (2014-2015) and two rain-fed sites highlighted the high yield and farmers' acceptability of pea (in pure stand or mixed stand with oat) as a rain-fed forage crop (Table 1), confirming the interest assigned to pea in this project.

Table 1. Yield and farmers' global acceptability score of 16 forage crops, averaged across two years and two regions (Sardinia; inland Morocco). Pea in pure stand or mixed stand with oat combined high yield with high farmers' acceptability

Crop	Dry matter yield, t/ha	Farmers' score, 1-5 (5=highest)
Semi-dwarf pea	6.96	4.40
Tall pea	7.18	4.41
Common vetch	4.94	4.37
Narbon vetch	2.90	3.60
Oat	7.20	3.53
Triticale	5.91	2.82
Semi-dwarf pea - Oat	6.51	3.61
Tall pea - Oat	7.14	4.11
Semi-dwarf pea - Triticale	5.95	3.80
Tall pea - Triticale	6.39	3.91
Common vetch - Oat	6.77	4.07
Common vetch - Triticale	5.74	3.83
Narbon vetch - Oat	5.62	3.74
Narbon vetch - Triticale	4.81	3.38
Peas - Cereals complex mixt.	6.58	3.75
Vetches - Cereals complex mixt.	6.22	4.13

- These two-year results also revealed modest farmers' acceptability of cereal pure stands, a trend for mixtures to out-yield the mean yield of their components' pure stands (mainly in Morocco), and some advantage of complex mixtures over binary mixtures in Sardinia.
- Results from the same trials indicated good forage yield and persistence of lucerne in pure or mixed stand – even in Morocco, where lucerne is usually irrigated. This reinforces the project aim to breed drought-tolerant lucerne varieties for use in rain-fed systems.
- Final indications from 2014-2016 testing in these sites and one site in inland Algeria will allow to thoroughly assess perennial crops and compare them to annual crops. Forage quality data under generation will allow to consider crop utilization in crop recommendations.

ACHIEVEMENTS

Stakeholder engagement

- The extensive participation of farmers to crop evaluation allowed to verify project goals and to identify and promote the most promising legume-based crops.
- Relationships with scientists and extension officers were stimulated by two scientific workshops (Rabat and Médenine) and three seminars organized by the project - with two more workshops planned in 2016. Visits to the experiments were organized for seed companies in Italy.
- The project will produce a free electronic handbook of guidelines for cultivation and use of lucerne- and pea-based crops aimed to extension services and farmers.
- Results are disseminated via talks and posters in major conferences (EUCARPIA, FAO-CIHEAM, Int. Legume Soc., Plant & Animal Genome) and scientific articles.
- Experiment activities offered opportunities for training of students and young researchers, also through stages.
- REFORMA showed large scope for implementing more resilient, water- and energy-efficient, self-sufficient feed systems based on genetically improved legumes.
- Inter alia, REFORMA issued the first study of genome-enabled prediction of lucerne plants' breeding value, and unprecedented genomic selection results on pea.

Figure 5. Project's relationships with stakeholders

Next steps

- Project activities and variety breeding (producing at least 3 candidate varieties for both lucerne and pea) will be completed using 2016 field data. We will also exploit data from two institutions (INTA, Argentina; IFC, Serbia) that joined our phenotyping work with own funds.
- The inclusion of pea or lucerne candidate varieties in variety registration trials (or other variety trials) will provide verification and promotion of this new material.
- Our results on genome-enabled and ecologically-based selection procedures could modify in depth the strategies of lucerne and pea breeding for stressful environments.
- Their application in new regional breeding programmes could allow, inter alia, to compare our phenotypic selections with new material bred by genomic selection.
- Pea- and lucerne-based crops that showed highest yield and farmers' acceptance should be tested in on-farm trials, using lucerne and pea varieties bred by the project (presumably more adapted than those tested hitherto).
- Besides verification of innovative breeding techniques and most promising innovative crops, research and support actions will be needed for strengthening pea and lucerne seed production systems in Mediterranean areas.

Do you want to know more?

Contact: Dr Paolo ANNICCHIARICO

paolo.annicchiarico@crea.gov.it

Website: http://reforma.entecra.it

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Selected publications

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Reference: ANNICCHIARICO P., 2016. REFORMA – Resilient, water- and energy-Efficient FORage and feed crops for Mediterranean Agricultural systems. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

SAFEMED

2012-2016

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Food safety regulations, market access and international competition

- Significant agricultural trade between the Southern and Northern Mediterranean countries is a privileged field for the establishment of a bilateral food safety co-regulation, both effective in reducing the health risk and in implementing more equitable economic relationships.
- Our research investigated the economic organization of fruit and vegetables supply chains in the EU and South Mediterranean countries, and consumers' behaviours and their role in diminishing food risk. Microbiological studies dealt with risk assessment analyses and the development of good practices guidelines.
- We characterized the typologies of import chains, consumers' profiles towards food risks and South public policies to ensure safety in South domestic markets. Moreover, we provided empirical and theoretical evaluations of the role of relevant elements on which can be based food safety co-regulation policies between North and South.

Food safety

Regulation

Supply chain organisation

Consumer health

Market access

Objectives

- SAFEMED aims at analysing the conditions for an international co-regulation of food safety between North Mediterranean countries (France, Italy and Spain) and South Mediterranean countries (Algeria, Morocco and Tunisia).
- We developed a multi-criteria analysis to conciliate the following objectives: 1) Ensuring food safety of imports, 2) Ensuring food safety in domestic markets, thus protecting the health of South Mediterranean consumers, 3) Maintaining a sufficient quantity of production, available in domestic markets, 4) Allowing international market access to southern countries' products.
- SAFEMED focused on the characteristics of the economies on the two Mediterranean sides and on the organisation of fruit and vegetables supply chains. An important role is given to trade and intermediate sectors. We analysed the value sharing between intermediate stakeholders located in importing countries and local stakeholders. This value sharing is taken as an indicator of the equity in North/South trade relationships.

Scientific results & innovation potential

- ✓ Empirical and theoretical evaluations of the role of relevant elements on which can be based food safety co-regulation policies between North and South: Nature of the standards in the North and South, control systems at the borders of the EU, control system in the countries of origin of European imports, cooperation for improving logistics infrastructure and the training of farmers, control delegation (private self-controls).
- ✓ Economic progress through the development of applied microeconomic models: 1) Price formation models to domestic markets in a food safety regulation context of South's domestic markets, 2) Model adapted to comparative analysis of liability rules in terms on risk efficiency (risk reducing) and economic efficiency.
- ✓ The models provide the basis for the development of decision support tools based on operational research and computer programing.
- ✓ Progress in the understanding of consumer's reaction to food risk.
- ✓ Development of risk assessment and management tools of parasites (fishery products).
- ✓ Development of guides of good practices applied to brined green olives, capers, dates, fishery products and animal products (Hazard Analysis Critical Control Point - HACCP).

Coordinator

Dr Abdelhakim HAMMOUDI
Institut National de la Recherche Agronomique (INRA),
Unité Alimentation et Sciences Sociales (ALISS)
FRANCE
abdelhakim.hammoudi@ivry.inra.fr

Partners

- Università di Bologna, Dipartimento di Scienze e Tecnologie Agro-Alimentari, **ITALY**
- Agronomic and Veterinary Institute (IAV) Hassan II, **MOROCCO**
- Institut National de la Recherche Agronomique de Tunisie (INAT), Département d'Economie-Gestion Agricole et Agroalimentaire, **TUNISIA**
- Universidad de Almería, Departamento de Economía Aplicada, **SPAIN**
- École Nationale Supérieure d'Agronomie (ENSA), Laboratory of Food Technology, **ALGERIA**
- University of Bejaia, Operational Research Department, Laboratory LAMOS, **ALGERIA**

METHODOLOGY

Quantitative and theoretical analysis

- The core of our approach lies on the crossing between the formal analysis in the framework of the microeconomic and industrial economic theory and the implementation of empirical economic and microbiologic surveys.
- Producer, exporter, importer and consumer surveys as well as experimental economics are conducted in South or North countries with both common and specific products according to the nature of the issues. Descriptive statistical analysis, data analysis, econometrics and experimental economics are used to treat the data. Empirical studies aim at building stakeholders' profiles and identifying their role in achieving efficient food safety regulations.
- Theoretical studies are built in order to 1) Characterize the rational strategies of dominant actors in North importing countries, 2) Determine the price formation process in the south domestic market, and 3) Identify the potential link between the export sector and domestic sector in South Mediterranean countries.
- In the microbiological field, audits and surveys of food establishments are conducted, professionals receive assistance, food business operators get trained, and laboratory analyses are performed.

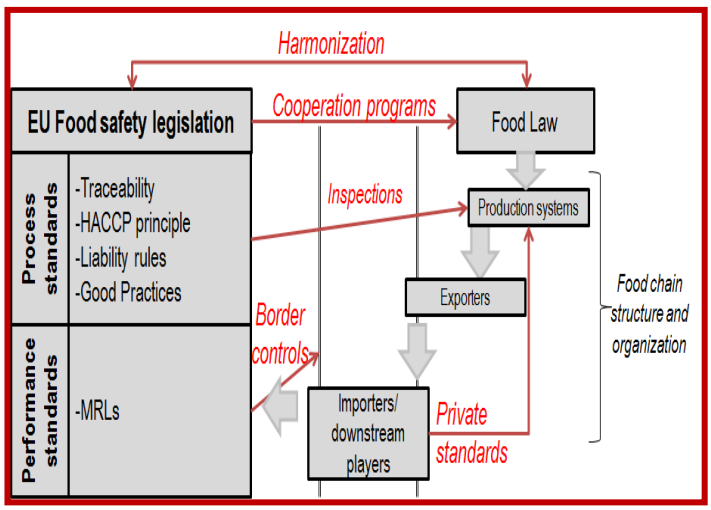

Figure 1. European Union food safety regulations and North/South supply chain interactions. Context of empirical and theoretical studies

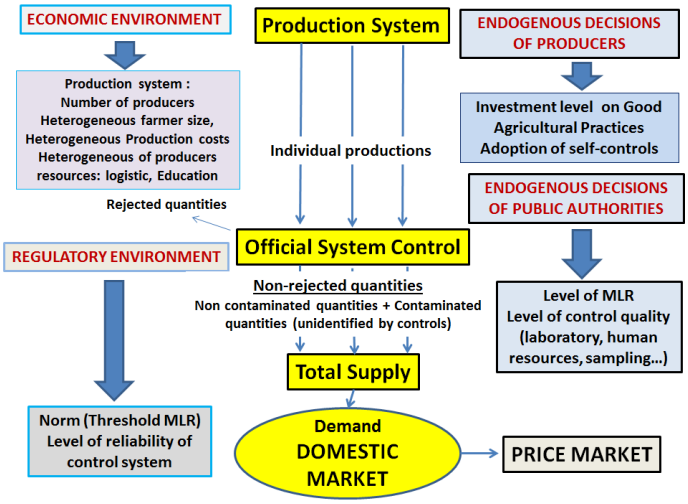

Figure 2. Representation of market interactions in the theoretical models of price formation associated with South domestic markets.

Why collaborating?

The issues addressed are of common interest to all Mediterranean countries and call for transnational cooperation, especially because of:

- Intense trade activities between the targeted countries of the region which require more co-ordination of safety regulations.
- Trade complementarities and trade competition between the countries involved in the project.
- Existence of bilateral and multilateral cooperation institutions in the region which favour the establishment of co-regulation of food safety devices.
- Disciplinary complementarities between research centres and universities involved in the project: industrial economics (France), microbiology (Morocco, Algeria), consumer economics (France, Morocco), operations research (Algeria), microeconometrics and statistics (France, Italy, Spain, Morocco, Tunisia, Algeria).

Table 1. Methodologies, products and targeted countries

METHODOLOGIES	TOOLS	PRODUCTS	TARGETED COUNTRIES
EMPIRICAL STUDIES	Producer/exporter surveys	▪Dates ▪Tomatoes	▪Algeria, Morocco, Tunisia ▪Morocco, Tunisia
	Importer surveys	▪Fruit and vegetables (general) and some common North products ▪Fishery product	▪Italy, France, Spain ▪Morocco
	Survey of institutional operators	▪Fruit and Vegetables (general)	▪Italy, France, Spain, Tunisia
	Experimental economics	▪Tomato, salad ▪Fruit and vegetables	▪Italian consumers, Italian products versus Morocco imported products
	Consumer survey	▪Fruit and vegetables	▪Morocco, local and tourist consumers
	Case studies	▪Cucumber ▪Cucumber, Tomatoes ▪Bologna Wholesale ▪Perpignan Wholesale	▪Spain: Cucumber Crisis 2011 (Interview: Costa d'Almeria Enterprise), ▪Morocco, Spain, France, Italy, Germany (Data Analysis of RASFF & Eurostat bases). ▪Italy (interviews) ▪France (interviews)
	Audits and surveys of food establishments	▪Fishery Products	▪Morocco
THEORETICAL STUDIES	Industrial economic models of price formation	▪General, with reference to fruit and Vegetables sector	▪Reference to South countries domestic markets. ▪Domestic/export sector relationships
	Model of vertical relationships	▪General, with reference to Fruit and Vegetables sector	▪Reference to legal rules in South countries
	International trade models	▪General, with reference to Fruit and Vegetables sector	▪General, with reference to North importer-South exporter relationships
OPERATIONAL ACHIEVEMENTS: MICROBIOLOGY, EPIDEMIOLOGY	Surveys, audits, data treatments, risk analysis	▪Dates, brined green olives, capers, fishery products, animal products	▪Morocco

ACHIEVEMENTS

Regulation in south domestic markets

- Several food safety regulation regimes exist in the South Mediterranean countries: 1) a specific regime associated to domestic markets, and 2) more diverse regimes dealing with export sectors.
- By identifying through theoretical modelling the potential links between South countries export sectors and south domestic markets, we deduce potential public strategies to create/amplify the spillover effect between the two sectors in order to reduce the risk in the domestic market.
- The difficulties in complying with norms and standards in the South are not only mechanically linked to the level of compliance costs but also to the economic, the organizational and logistic environment of operators.
- An effective import safety policy is not systematically synonymous with strengthening standards (e.g. low threshold microbiological risk assessment (MRLs)) but with an effective combination of 1) Adequate adjustment of maximum limit of residue thresholds, 2) Homogeneity and effective control at the European entry points, 3) Public-private partnership that stimulates the coordination of European importers as part of a delegation of responsibility, 4) Bilateral or multilateral agreements between Europe and North Africa to favour the emergence of an efficient control system at the country of origin.
- Food security objectives (i.e. food quantities) and qualitative objectives (i.e. health quality) are not always incompatible in South countries' domestic markets.

Microbiological risk assessments

- Risk assessment and management of parasites in fishery products (Morocco).
- Epidemiological study on parasites nationwide.
- Determination of the geographical distribution of microbiological hazards associated with imported seafood: Vibrio and Norovirus from Asia, *Listeria monocytogenes* from Europe and Salmonella from African countries.

Table 2. Main causes of notification for imported seafood as determined by Pareto chart

Causes of notification	Origin of import			
	Europe	Asia	Latin America	Africa
Fraude				
Histamine				
Biotoxines				
Carbone monoxide				
Additives				
Heavy metal				
Contamination microflora				
Sensory defects				
Parasites				
Pathogens				
Cold chain (poor)				
Irradiation				
Veterinary drug residues				

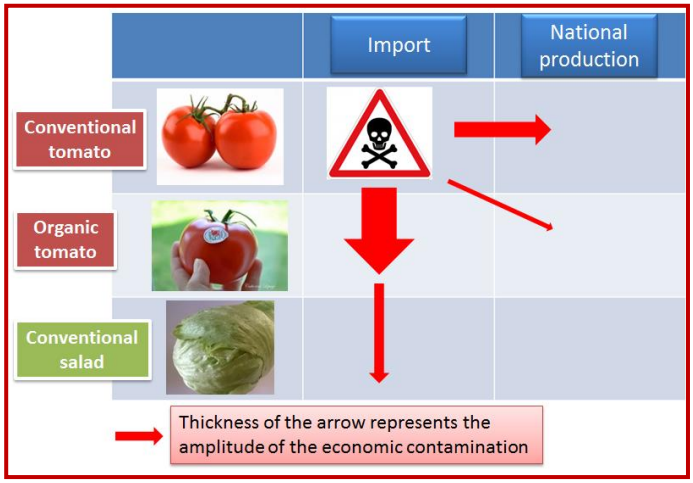

Figure 3. Consumer behaviour towards a negative information on chemical contamination of a foreign conventional product

Food risk and consumer behaviour

- Empirical evaluations of demand and experimental economics procedures are conducted to identify consumer behaviour towards sanitary risk: endogenizing of boycott phenomena, preferences between local and imported products in case of negative information on food safety (North), behaviour of tourist consumers (South).
- Conventional sectors (fruit and vegetables) can expect an undifferentiated consumer boycott (whatever the country of the crisis' origin), but the national preference dominates when it comes to reorienting consumption to a label sector: 1) In the event of a health crisis on a foreign conventional product, consumption moves more towards the national labelled sector (organic product) of the same product rather than to the national conventional substitute of the incriminated foreign product, 2) Local organic products are a safe haven in the event of negative information on chemical contamination (pesticide) concerning a foreign conventional product. However, foreign organic products are never a safe haven.

Food safety policies and North operator's reactions

- European importers increasingly demand private standards to their South suppliers who thus contribute to their rapid spread to protect themselves from the loss of market opportunities. However, different private standards' diffusion rates exist in North countries' markets.
- The heterogeneity of operators and organisational chain structures determine the food safety strategies of fruits and vegetables importers in North countries. Each operator defines its own safety strategies according to the typology of his suppliers and clients. In some North countries, product's specialization of importers seems correlated to safety requirement.
- The heterogeneity of resources allocated to the control systems of EU entry points reduces the effectiveness of normalisation policies and thus the risks associated with imports. Although it is relatively demanding, standardisation strategies based on the obligation of results in the North are weakened by the heterogeneity of official controls at EU entry points (heterogeneity of human and material resources affected to these points).

ACHIEVEMENTS

Stakeholder engagement

Useful conclusions which could help to enlighten public decisions

- Notably by identifying some potential international coordination variables, some potential intra-sectors and inter-sectors coordination, some types of effective public private partnership.

Development of guides to good hygiene

- Guides to good hygiene practices and their approval by the competent Moroccan authority: 1) For vegetable products (brined green olives, capers and dates), 2) For animal products: elaboration of HACCP manuals for egg packing centres, poultry processing (cuts, packaging) and casing units.
- Improvement of sampling plans to identify parasites.
- Proposal of guidelines and inspection procedure based on risk for imported foods of animal origin.

Academic and professional training activities

- Training of official inspectors and technicians.
- Organisation of seminars and workshops dealing with co-regulation of parasites in fish.
- Development of a platform to identify parasites by means of molecular biology.
- Promotion of North/South exchanges between PhD students through the organisation of workshops associated with research and training programs.
- Creation of a dynamic of discussions and scientific exchanges between professional and SAFEMED researchers from South countries illustrated by the organisation of a professional and academic Workshop on the development of the quality of the date sector in Algeria, Tunisia and Morocco (Biskra, Algeria, February 2015).

Figure 4. Session of practical training for fish inspection and control

Next steps

- Continuous collaborative works between partners in ongoing projects through the extension of SAFEMED research to some issues identified during the project.
- Consolidation of the research training of young researchers from South partners (notably Algeria and Tunisia) with the creation of specialisation programmes in sustainable food issues with cross approaches of industrial economics, quantitative economics and operational research. The programme implies a cooperation between INRA-France, University of Bologna (Italy), University of Bejaia (Algeria) and INAT (Tunisia).
- Development of decision support programmes by developing the existing theoretical advances on price formation modelling.
- Continuous coordination with professionals and quality control institutions for the implementation of standards and best practices.

Do you want to know more?

Contact: Dr Abdelhakim HAMMOUDI

abdelhakim.hammoudi@ivry.inra.fr

Website:
https://www6.inra.fr/orfiquad/Projets

For more information on the ARIMNet2 Network

www.arimnet2.net

Contact: arimnet@arimnet.net

ARIMNet2 is an ERA-Net coordinated by INRA (France). It has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 618127

Selected publications

- Hammoudi A., Grazia C., Surry Y., 2014. « *Sécurité sanitaire des aliments : régulation, analyses économiques et retours d'expériences*», Edited book, Ed. Hermes-Lavoisier, 322 p.
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Reference: HAMMOUDI A., 2016. SAFEMED – Food safety regulations, market access and international competition. *ARIMNet2 Highlights Series*

Editing: GOURIVEAU F., OLLAGNON M.

SWIPE

2012-2015

Project funded via the ARIMNet 2011 Transnational Joint Call

Highlights

Predicting whitefly population outbreaks in changing environments

- The sweet potato whitefly *Bemisia tabaci* is one of the most devastating plant pests throughout tropical and subtropical regions. Its ability to transmit over 200 types of plant viruses makes it the largest threat to many crops. While in the past its distribution was limited to temperate zones, during the last two decades, it has invaded every continent except Antarctica. As global warming continues, whitefly populations are expected to increase, and with them pesticide applications and subsequent environmental contamination.
- SWIPE involved 13 institutes from 6 countries and brought together scientists from various disciplines, covering a broad range of expertise. It was initiated to identify the factors involved in *B. tabaci* population outbreaks and to use the information gathered to develop models able to predict such changes.
- The SWIPE team thrived to determine how future changes in temperatures will affect population dynamics of the insect pest, taking into account genetic variability and symbiotic associations.

Bemisia tabaci
Pest invasion
Climate change
Precision agriculture
Symbiont

Objectives

- We aimed to understand the effects of genetic variability and symbiotic associations in the context of interactions between temperature patterns and insect performance.
- To achieve this goal, the following objectives were pursued:
  - Determine the geographic distribution of *B. tabaci* genetic groups, their population genetic structure and symbiotic complement around the Mediterranean basin;
  - Determine whitefly invasion routes within the Mediterranean basin;
  - Determine the respective influence of nuclear and symbiotic variations on stress resistance;
  - Model the influence of climate change on whitefly population outbreaks;
  - Establish a network of researchers.

Scientific results & innovation potential

- ✓ The combined effort of the SWIPE team resulted in a new modelling framework for projecting pest population dynamics and supporting environmental decision-making under climate change.
- ✓ Together with the invasion risk assessment performed, the modelling framework developed will allow the necessary incorporation of pest risk assessment and simulation models into comprehensive management planning systems of both natural and agricultural ecosystems in response to global warming.

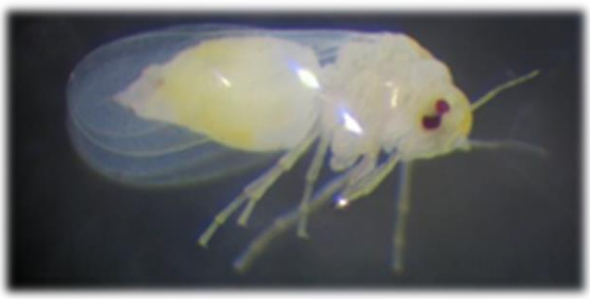

Figure 1. The sweet potato whitefly (*Bemisia tabaci)*

Coordinator

Dr Einat ZCHORI-FEIN
Newe Ya'ar Research Center, Agricultural Research Organization (ARO)
ISRAEL
einat@volcani.agri.gov.il

Partners

- LBBE, University Lyon 1, **FRANCE**
- Dept. of Evolutionary Genetics, Cavanilles Institute for Biodiversity and Evolutionary Biology, University of Valencia, **SPAIN**
- Dept. of Environmental and Natural Resources, University of Western Greece, **GREECE**
- Dept. of Entomology, The Hebrew University of Jerusalem, **ISRAEL**
- Portici Unit of IPP, CNR-Istituto per la Protezione delle Piante, **ITALY**
- Hellenic Agricultural Organisation-"DEMETER" Institute of Olive Tree, Subtropical Crops and Viticulture, Laboratory of Entomology and Agricultural Zoology, **GREECE**
- Dept. of Plant Protection, Ankara University, **TURKEY**
- Dept. of Entomology, University of Arizona, **USA**
- Laboratory Molecular Entomology, University of Crete, **GREECE**
- Instituto Valenciano de Investigaciones Agrarias, **SPAIN**
- Plant health Research Dept., Ankara Plant Protection Central Research Institute, **TURKEY**
- Dept. of Plant Protection, Cukurova University, **TURKEY**
- Dept. of Geography, Hebrew University of Jerusalem, **ISRAEL**

METHODOLOGY

(i) Genetic groups and symbiotic bacteria

- To identify the genetic groups found around the Mediterranean, over 480 whiteflies were collected in 48 sampling efforts in five countries and analyzed by using molecular techniques.
- The bacterial symbionts carried by each individual whitefly were also determined.

(ii) Symbionts' influence on host stress resistance

- The influence of the symbionts associated with *B. tabaci* on parasitoids, thermal and pesticide resistance as well as on virus transmission capacities were studied by both analyzing the bacterial genomes and conducting field and laboratory experiments.

(iii) Invasion routes

- Various data sources were used to determine potential whitefly invasion routes: a) Geographic distribution; b) Amount of potential host plants transported to the EU; c) Presence or cultivated area of host plants in the EU; d) Number of *B. tabaci* interceptions.
- The risk of arrival and entry to a given country was calculated.

(iv) Population outbreaks model

- Computational approaches were applied to model changes in the population dynamics of *B. tabaci* under anticipated climate change for the next decades. To insert into the model data on the performance of the insects under real conditions, field-experiments were performed in four countries (Figures 2, 3) to determine life history traits of the whitefly under varying temperatures.

Why collaborating?

SWIPE was designed as five highly interconnected work packages. Close collaboration among the different SWIPE partners was an absolute must for carrying out the different activities and achieving our goals:

- Insect samples were collected by five partners from specific host plants in their own countries. Half of these samples were shipped to Israel and half to France for symbiont and genetic analyses.
- Insecticide resistance experiments were performed in Greece on samples collected in Spain and Turkey.
- Most importantly, partners from Turkey, Spain, Greece and Israel established field experiments using the same host plant species and following identical protocols. All researchers involved followed the developmental time of the insect pest in their own countries, and created the largest available dataset of information gathered under natural conditions.
- The data jointly produced were summarized and incorporated into the model, and facilitated the development of a tool that can predict whitefly population outbreaks.

Figure 2. Experimental field sites in Israel (A), Turkey (B) and Spain (C)

Figure 3. Specific sites for which climate change and its influence on the pest population has been predicted by the model developed

ACHIEVEMENTS

(i) Genetic groups and symbionts

- Analyses of the whitefly samples revealed that each of the countries participating in the project had a unique combination of genetic variants, and that the composition of bacterial symbionts vary among populations of the same genetic variant in different geographic areas.
- Because the pattern of association between *B. tabaci* variants and the profile of the symbiotic communities is very clear, specific control methods can be designed for each geographic area.

(ii) Symbionts' influence on host stress resistance

- One of the main observations was that the genome of the bacterium genus *Cardinium* exhibits characters that suggest its role in defending the host against parasitoid wasps.
- The genome prediction result was supported by both field and laboratory experiments.
- This information can be used by those practicing biological control, which may now be able to improve the efficiency of natural enemies, both at the insectary and greenhouse level.

(iii) Invasion routes

- The invasion analysis indicates that all countries around the Mediterranean are highly susceptible to pest invasions. Italy, Greece and Turkey and to a lesser extent Spain, were identified as the probable routes for *B. tabaci* introduction.
- The analysis additionally identified Brazil and the USA, and in Europe, France and Spain, as countries at risk for *B. tabaci* exportation (Figure 4). Interestingly, this is not correlated with the number of interceptions (highest in India, Thailand and Israel), which suggests that control efforts may not be targeted at the riskiest countries.

Figure 4. Likelihood of *B. tabaci* invasions. The index considers the probability of *B. tabaci* reaching the country without being intercepted. Reddish colours indicate a higher risk. Some countries are not shown due to insufficient data

(iv) Population outbreaks model

- The climatic model developed predicts that temperatures around the Mediterranean will increase ca. 1.5 - 2.5°C on average until 2050.
- Whitefly populations are in turn expected to be 5-10 times larger, with the pest active season starting earlier and ending later. Warm spring and autumn seasons might lead to 'all-year-round' presence of *B. tabaci*, but hot summers may decrease population sizes at some locations.
- Overall, the combined effort resulted in a new modelling framework for projecting pest population dynamics and supporting decision-making under climate change. The weather generator developed allows exploring the dynamic response of *B. tabaci* to a large variety of temperature patterns, as well as the determination of the main factors controlling population size in addition to the mean annual temperature.

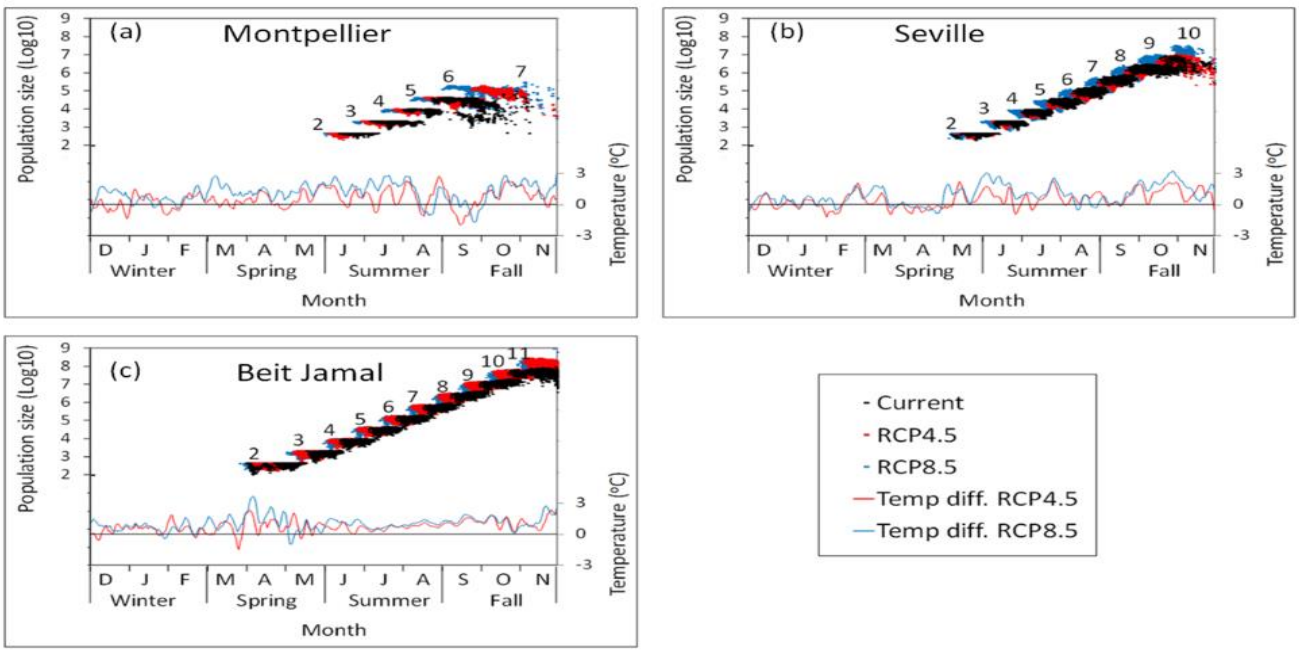

Figure 5. Model prediction of *B. tabaci* population outbreaks in three of the locations sampled (see Figure 3)

Stakeholder engagement

Three main aspects of the SWIPE results are relevant to a number of entities:

- Invasion risks should be considered by plant protection authorities.
- Industry could make use of the information on parasitoid resistance.
- Ministries responsible for agriculture, extension agencies, grower associations, etc., could apply the model for various uses.

Figure 6. The SWIPE team, Napoli, 2015

Figure 7. The typical field experimental setting used by all partners (left) and a weather station (right)

Next steps

Several actions need to be taken in order to promote the application of the results obtained as a part of the SWIPE project:

- The model, currently based on *Solanum nigrum* data, should be calibrated for specific crops of interest such as watermelons, cotton, tomatoes and beans.
- The model should be made available to relevant authorities.
- Each interested country could establish a website for farmers where model predictions will be published. This could help planning crop rotation, planting time and pest control.
- Various parts of the SWIPE team continue to collaborate under different national and international funding schemes.

Do you want to know more?

Contact: Dr Einat ZCHORI-FEIN
einat@volcani.agri.gov.il

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www.arimnet2.net

Contact: arimnet@arimnet.net

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Selected publications

- Santos-Garcia, D., Rollat-Farnier P.A., Beitia F., Zchori-Fein E., Vavre F., Mouton L., Moya A., Latorre A., Silva F.J., 2014. The genome of *Cardinium* cBtQ1 provides insights into genome reduction, symbiont motility and its settlement in *Bemisia tabaci*. *Genome Biology and Evolution* 6 (4): 1013-1030
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