REFORMA: a new project for identification and selection of resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems

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REFORMA: a new project for identification and selection of resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems

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Abstract. Crop-livestock and feed systems have huge importance for Mediterranean regions to satisfy the increasing demand for animal products, increase the economic stability of smallholders and produce typical animal products with high added-value, while contributing to sustainable farming, environment protection and efficient nutrient cycling. These systems are threatened, however, by the marked insufficiency of high-protein feedstuff, the overexploitation of forage resources, the increasing costs and/or the decreasing availability of irrigation water and mineral fertilizers, and the increasing drought and heat stress arising from climate change. The development of resilient, water- and energy-efficient forage and feed legume crops could definitely alleviate these constraints. This is the objective of the ArimNet project "Resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems (REFORMA)", which joins nine research institutions from Italy, France, Algeria, Morocco, Tunisia and USA in an integrated manner to develop: 1) lucerne varieties with tolerance to severe drought, salinity, heat and grazing; 2) pea varieties with drought tolerance, targeted to grain and forage production; 3) cost-efficient marker-assisted selection procedures, and ecologically-based breeding strategies, for lucerne and pea; 4) lucerne-based and pea-based forage crops, taking into account the legume plant types, the associated grass or cereal species, the level of site drought stress, the acceptability by farmers, the forage quality and the target utilization.

Keywords. Marker-assisted selection – *Medicago sativa* – *Pisum sativum* – Protein feedstuff.

REFORMA: un nouveau projet pour identifier et sélectionner des espèces destinées à l'alimentation animale, résilientes, efficaces en eau et en énergie pour les systèmes agricoles méditerranéens

Résumé. *Les systèmes de culture à destination de l'alimentation des ruminants et des monogastriques sont cruciaux dans les régions méditerranéennes pour satisfaire une demande croissance en produits animaux, accroître la durabilité économique des petits exploitations et assurer la typicité des produits animaux ayant une forte valeur ajoutée, tout en contribuant à une agriculture durable, à la protection de l'environnement et au recyclage des nutriments. Ces systèmes sont menacés par une insuffisance en aliments protéiques, la surexploitation des ressources fourragères, l'augmentation des coûts et/ou la diminution de la disponibilité en eau d'irrigation et en fertilisants, et l'augmentation de la sécheresse et des stress thermiques liée au changement climatique. Le développement de fourrages et d'aliments dont la culture est résiliente, efficace en eau et en énergie pourrait définitivement lever ces contraintes. C'est l'objectif du projet ArimNet "Resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems (REFORMA)", qui*

rassemble neuf équipes de recherche d'Italie, France Algérie, Maroc, Tunisie et Etats-Unis pour développer de manière coordonnée: 1) des variétés de luzerne tolérantes à des sécheresses sévères, la salinité, les fortes températures et le pâturage ; 2) des variétés de pois tolérantes à la sécheresse, pour des productions de graines ou de fourrage ; 3) des procédures de sélection assistée par marqueurs économiquement rentables et des stratégies de sélection ciblant des progrès sur la durabilité des cultures; 4) des cultures fourragères basées sur la luzerne ou le pois, prenant en compte les caractéristiques des légumineuses, les espèces graminées ou céréales associées, le niveau de stress hydrique du milieu, l'acceptabilité par les agriculteurs, la valeur alimentaire et l'utilisation prevue.

Mots-clés. *Sélection assistée par marqueurs* – Medicago sativa – Pisum sativum – *Aliments protéiques.*

I – Introduction

Crop-livestock systems play a strategic role in the Mediterranean basin. They safeguard the economic stability of smallholders in north Africa, and support local economies, which are often based on typical dairy productions, in southern Europe. These systems are threatened by the insufficiency of protein feedstuff, the overexploitation of forage resources, the increasing costs and/or decreasing availability of irrigation water and mineral fertilizers, and the increasing drought and heat stress arising from climate change. The development of resilient, water- and energy-efficient forage and feed legume crops could alleviate all of these constraints. These crops have a reported positive impact on the sustainable intensification, the productive stability and the environment protection in crop-livestock systems (Carrouée *et al*., 2003).

The limited funding available at the national and international level for forage and feed legume breeding requires, however, to carefully identify a few promising species on which concentrating joint efforts and resources. Lucerne (*Medicago sativa* L.) is the main forage crop in south-European countries and the Maghreb, while pea (*Pisum sativum* L.) is the main feed grain legume in southern Europe and is mainly grown for forage in mixture with a cereal in the Maghreb. Lucerne cultivation in north Africa is traditionally limited to frequently irrigated conditions, but recent results have highlighted the good drought tolerance of Mediterranean landraces that evolved in stressful environments (Annicchiarico *et al*., 2011). Recent pea breeding has improved the traditional drawback of this crop represented by its poor standing ability, but novel varieties have hardly ever targeted regions of the Mediterranean basin.

The on-going development of lucerne genomic resources may allow to explore association mapping for quantitative trait loci (QTL) and to develop marker-assisted selection (MAS) procedures (Li *et al*., 2011). QTL for lucerne drought tolerance have just started to be studied (Julier *et al*., 2010). Genomic resources are increasingly available also for pea genotyping aimed to define MAS procedures (Deulvot *et al*., 2010). More efficient breeding may arise not only from MAS but also from ecological and/or evolutionary approaches that exploit selection under natural (Ceccarelli *et al*., 2010) or artificially-reproduced conditions (Annicchiarico, 2007).

II – The Project REFORMA

1. Objectives

The overall aim of the project is strengthening the economic and environmental sustainability of Mediterranean crop-livestock and feed systems, also by enhancing their self-sufficiency for feed proteins and their ability to adapt to and to mitigate climate change. This is pursued by developing more resilient and more water- and energy-efficient systems based on genetically-improved forage and feed legume species. The specific objectives of the project are:

(i) enhancing the forage yield and persistence of lucerne in Mediterranean environments that are subjected to severe drought stress, high temperatures and/or salinity, by selecting stress-tolerant varieties phenotypically and by defining innovative breeding strategies based on MAS and on ecologically-based selection procedures and adaptation targets;

(ii) defining MAS procedures for enhanced grazing tolerance of lucerne targeted to extensive Mediterranean systems, and for high lucerne compatibility with grass companions;

(iii) producing drought-tolerant pea varieties for grain or forage production, by phenotypic selection in stress environments and by definition of innovative MAS procedures and ecological selection strategies;

(iv) optimizing the cultivation and use of pea- and lucerne-based forage crops with respect to legume plant types, the associated grass or cereal species, the expected level of site drought stress, the acceptability by farmers, and the target forage quality and utilization.

2. Structure of the project

The partner institutions participating to the project are: CRA-FLC (Centro di Ricerca per le Produzioni Foraggere e Lattiero-Casearie, Lodi, Italy); INRA-URP3F (Unité de Recherche Pluridisciplinaire Prairies et Plantes Fourragères, Lusignan, France); INRA-UMRLEG (Unité Mixte de Recherches en Génétique et Ecophysiologie des Légumineuses à Graines, Dijon, France); INRA-MOR (Institut Nationale de la Recherche Agronomique, Marrakesh, Morocco); INRAA (Institut National de la Recherche Agronomique d'Algérie, Alger, Algeria); ENSA (École Nationale Supérieure Agronomique, Alger, Algeria); CNR-ISPAAM (Istituto per il Sistema Produzione Animale in Ambiente Mediterraneo, Sassari, Italy); IRA (Institut des Régions Arides, Médenine, Tunisia); and SRNF (The Samuel Roberts Noble Foundation, Ardmore, USA).

The research activities are accomodated into three Work Packages (WP):

WP 1: *Ecological breeding strategies and variety selection*;

WP 2: *Genomics and definition of marker-assisted selection procedures*;

WP 3: *Assessment and optimization of innovative legume-based crops*.

The contribution of each WP in fulfilling the project objectives is shown in Fig. 1, while the roles of, and interactions among the participating institutions in the various tasks of the three WPs are illustrated in Fig. 2.

Besides achieving the targeted objectives, the project will offer the opportunity to test lucerne and pea germplasm, selection strategies and crop utilizations across a wide range of Mediterranean agricultural environments that span from climatically favourable to severely drought-prone. The emphasis on germplasm evaluation in north-African environments, which experience drought stress levels more severe than those in south-European environments, enables breeding programs in southern Europe to anticipate solutions to cope with the predicted effects of climate change, by developing germplasm and selection approaches which are already valuable for the harsher conditions of north Africa.

The transfer of know-how among partner institutions will be favoured by two final training workshops. A freely-available electronic handbook will promote optimal cultivation methods for innovative forage crops and optimal diets including these forages or pea grain. This and other dissemination actions will spread the project results among farmers and other stakeholders.

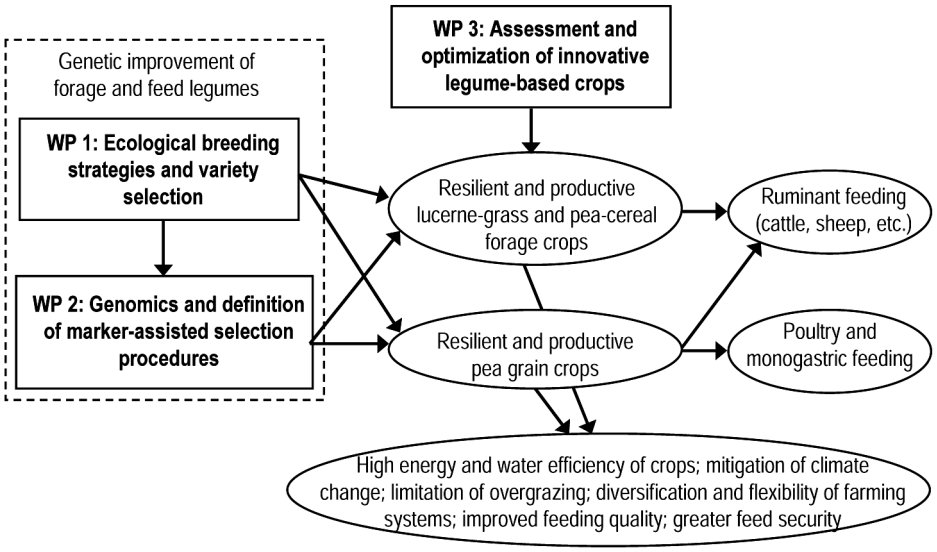

Fig. 1. Contribution of each research WP to the project objectives.

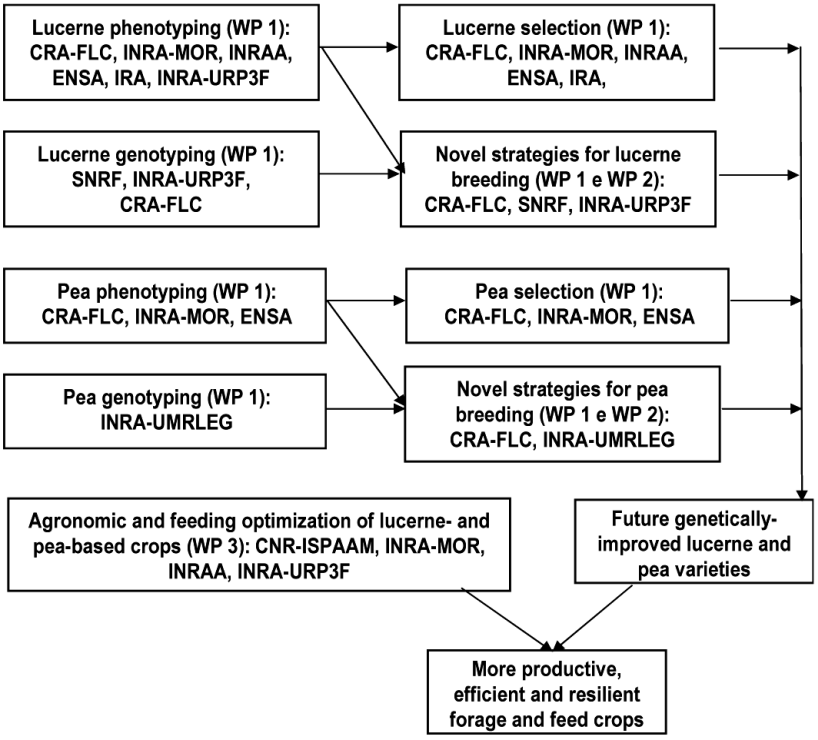

Fig. 2. Roles of and interactions among the partner institutions in relation to the project targets.

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