Optimizing breeding strategies and crop management for enhancing legume ecosystem services in organic farming

María José Suso[1] and Carmen Mateos[1]

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Abstract

Legumes may facilitate the diversification on the agroecosystem both directly, e.g. via growing legumes in association with cereals, and indirectly by enhancing associated diversity of wild fauna. Organic farming systems attract more pollinators such as bees compared to conventional fields. Our goal is to gain understanding on the nested architecture of the legume crop-bee pollinator-farmer–breeder network by using as exemplar case a bi-crop system, faba bean-spelt. Intercropping management and open-pollination breeding scheme interactively increase number and seed weight suggesting that intercropping intensifies the positive effect of outcrossing breeding scheme (breeding in presence of pollinators) in yield. Moreover, our outcome prompted the development of cultivars, by evolutionary participatory breeding, for organic farming that incorporate traits providing suitable floral resources. Thus, creating opportunities for a synergy between production and pollination ecosystem services.

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Introduction

Legumes may facilitate the diversification on the agroecosystem both directly, e.g. via growing legumes in association with cereals, and indirectly by enhancing associated diversity of wild fauna. Organic systems attract more pollinators such as bees compared to conventional fields (Bartomeus *et al.* 2014). Legumes providing feeding habitats could be especially good for supporting native bees. Local bees could be managed by the farmers as agents of crossing with the aim of increasing intra crop variation. Our goal is to gain understanding on the nested architecture of the legume crop-bee pollinator-farmer–breeder network. We have the vision that the the analysis of this network could help to increase crop resilience and yield potential, on the one side, and to mitigate pollinator decline, on the other side.

Material and methods

In legumes, two major approaches, based on the pollination environment, have been held by breeders: a) inbred line breeding: cultivars are developed under cages that exclude pollinators and enforce self-fertilization and b) open–pollinated cultivar breeding. This approach makes use of the local pollinators as agents of crossing for yield and resilience-mediated by heterogeneity and heterozygosity exploitation. We create a bi-crop system, faba bean-spelt, to compare two cropping

[1] Institute for Sustainable Agriculture (IAS), Spanish National Research Council (CSIC).Córdoba, Spain, www.ias.csic.es, eMail:ge1susom@uco.es

management systems (intercropping vs. monoculture) and different faba bean genepools derived from two breeding schemes. Genepools highly homozygous and homogeneous, derived from selfing vs. highly heterozygous and heterogeneous, derived from open-pollination.

Two-factor ANOVAs (faba bean genepool, and the combinations of intercropping vs monoculture and inbreeding vs open-pollination as main effects, plus the two- way interaction) comparing the cropping management and breeding schemes across gene-pools, were performed on the data from each variable (yield and yield determinants, plant architecture and leaf size and shape). To address issue of the natural selection acting on many traits simultaneously in more detail, the data were subjected to multivariate discriminant function analysis (DFA). DFA, performed for the four combination groups (intercropping vs monoculture and inbreeding vs open-pollination) provides a useful technique to visualize the patterns of change in the response to the different cropping management and breeding schemes and the complex relationship between the plant yield and yield determinants.

Results

Over all our ANOVA results illustrate the influence of breeding scheme and cropping management on yield and yield determinants, plant architecture and leaf size and shape. Intercropping management and open-pollination breeding scheme interactively increase number and seed weight suggesting that intercropping intensifies the positive effect of outcrossing breeding scheme (breeding in presence of pollinators) in yield. Conventional selfing breeding schemes fail to bred for the use of the beneficial effects of local bee-pollinator fauna as agents of crossing. However, open pollination is a method of crossing well adapted to farmer management as well as to site-particularities to make the beneficial effects of heterozygosity and heterogeneity available to farmers in a timely manner (Weltzien *et al*. 2005). This outcome prompted the development of cultivars, by evolutionary participatory breeding that incorporate traits providing suitable floral resources and higher attractiveness for pollinating insects**.**

Table 1: Patterns of change in the response to the different cropping management and breeding schemes. DFA model summary.

Discriminant function	**I**	**II**
Eigen value	0.32	0.14
% variance explained	62.7	26.5
Chi square statistic for testing significance of DF	77.6	30.6
Significance	0.00	0.11
Standardized discriminant function coefficients		
Traits		
Yield determinants		
Seed per plant	-3.08	-0.65
Seeds on the secondary stems	2.75	0.81
Pods on the main stem	1.13	-0.16
Pods per plant	-0.27	-0.81
Seed abortion	-0.38	0.65
Leaflet		
Area	-1.22	-0.27
Perimeter	0.96	0.60

Regarding the DFA, we report the results on the two first discriminant functions (Table 1) because they accounted for around 90% of the variation. The first discriminant function contained highly significant amount of discriminatory power. Three yield determinants traits were found to contribute mostly and significantly to the discrimination among the cropping management and breeding scheme groups. According to the results of the DFA, both intercropping management and open-pollination breeding scheme result in genepools with greater number of seeds per plant distributed on more secondary reproductive stems and larger leaflet size and rounded shape.

Discussion

To achieve improvement objectives related to yield enhancement and biodiversity conservation in legume organic farming, using faba bean and spelt as exemplar case, we propose two mechanisms: utilizing intercropping and open-pollinated breeding schemes as well as breeding, by participatory breeding, for traits that promote beneficial crop-pollinator interactions. In addition, this approach indirectly will benefit farmers by their contribution to the mitigation of pollinator decline. Furthermore, the magnitude of the cropping management and breeding scheme interaction is strongly dependent on the genepool response to the exclusion of pollinators showing specific adaptation of the plants whose parents had been selected under different pollination conditions. The differential response of the faba bean genepools suggests opportunities to use cultivars derived from the conventional selfing schemes on farmer pollination landscapes where the abundance of pollinators has been deteriorated.

References

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