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Phenotypic evolution of different spinach varieties grown and selected under organic conditions

Serpoly, E.[1], Schermann[1], N., Dawson, J.[2] & Lammerts van Bueren, E.T.[3]

[1] INRA, unité SAD Paysage, 65 rue de Saint-Brieuc, F-35042 Rennes, France
[2] INRA, UMR 320 Génétique Végétale, F-91190 Gif sur Yvette, France
[3] Louis Bolk Institute, Hoofdstaat 24, NL-3972 LA Driebergen, The Netherlands
corresponding author: Estelle Serpoly - estelle.serpoly@rennes.inra.fr

Context – introduction

Organic agriculture needs flexible varieties to buffer the variability of cultivation conditions, to enhance the self-regulation capacity of organic farming systems (Lammerts van Bueren, 2002) and to adapt to the requirements of each farmer (specific markets for example). More and more farmers are looking for such varieties in order to achieve seed self sufficiency. Populations varieties are genetically more diverse than commercial ones. Many organic farmers are interested in such varieties, in order to adapt them to their own conditions. In Europe, farmers take part in participatory plant breeding (PPB) programmes because it is a selection method that can respond to their different needs.

In this context, we conducted an experiment (in the framework of the European project Farm Seed Opportunities) to investigate the evolutionary capacities of spinach population varieties for phenotypic traits of interest for farmers. Indeed, while diversity among spinach varieties based on molecular markers has been studied, there have not been published studies of the diversity of phenotypic traits which are of direct relevance to farmers.

Traits assessed

In italic = quantitative traits, normal = semi-quantitative traits

Petiole and leaf length and attitude, leaf width, colour, shape of apex, thickness and blistering, stem anthocyanin, bolting index (3 dates)

Box 2

Farmers' strategies of selection

MC: **elimination** of the plants not in the type wished (plants wished = big, dark, thick, smooth, lanced shaped and late to bolt)

AVO: **conservation** of the latest plants to bolt and flower

FD: **multiplication** of all the plants of the variety chosen in order to **increase diversity**

Box 1

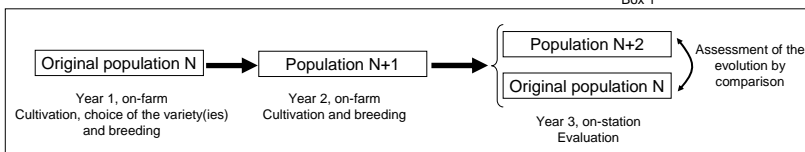
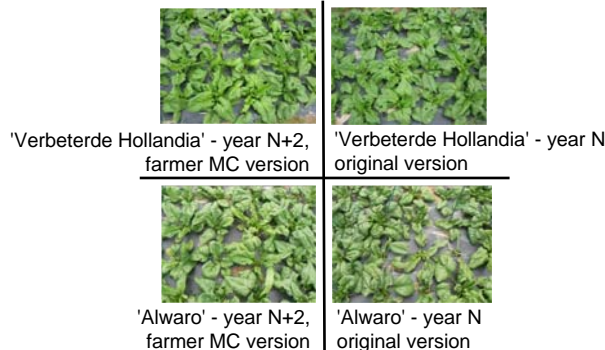


Figure 1: scheme of the experiment



Varieties selected by farmers	Monarch Long Standing	Alvaro	Supergrass	Verbeterde Hollandia	Viking	Wing	Eté de Rueil
Parents	AVO	MC	FD	FD	FD	FD	FD
Petiole length	120	120	120	120	120	120	120
Leaf width	120	120	120	120	120	120	120
Colour	120	120	120	120	120	120	120
Petiole attitude	120	120	120	120	120	120	120
Thickness	120	120	120	120	120	120	120
Blistering	120	120	120	120	120	120	120
Bolting index	120	120	120	120	120	120	120

Table 1: extract of the complete table of the mean values and statistical significance values of the evolution of varieties after 2 years of cultivation and selection in the common experiment at Le Rheu in 2009. mN / mN+2 where mN+2 is the mean of the farmers' version after 2 growing cycles and mN is the mean of the original seed lot



Plants and methods

During a 3-year experiment (2007 to 2009), different populations varieties of spinach (*Spinacia oleracea* L.) were cultivated and selected by 3 organic farmers (MC, AVO and FD) in contrasting environments (two farmers in Western France and one in The Netherlands). The evolution was assessed on station by comparison of the original seed sample with the variety cultivated and selected on farm for two cycles (Figure 1).

- Varieties tested: European populations of spinach not cultivated anymore, seeds coming from national gene banks (of The Netherlands and France)

- Three steps in the experiment: (i) 2007, choice by each farmer of at least one variety out of 20 to be grown and selected for 3 years; (ii) 2007 and 2008: on-farm mass selection within the chosen variety(ies) (see box 1); (iii) 2009: on-station common evaluation of the varieties chosen and selected by the farmers (Le Rheu, Brittany, France).

- Common trial: split-plot design with 3 replicates, sub-blocks composed of the different versions of one variety, i.e. population N from the gene bank and population(s) N+2 from farmer(s).

- Different phenotypic traits of interest for farmers assessed (see box 2), measured on 15 plants per replicate

- Statistical analyses: performed with R software, ANOVA (quantitative traits), Chi² tests (semi-quantitative traits) and ascending hierarchical classification to assess multitrait evolution of varieties



Results

All varieties showed statistically significant evolution (difference between the original version and the version cultivated by farmers): for only one or few traits (Monarch Long Standing, Verbeterde Hollandia and Viking Matador) or more numerous traits (Alwaro, Viking or Eté de Rueil) and they differ on traits on which they evolved (see Table 1).

All measured traits showed significant evolution for at least one variety. When the same trait evolved for 2 varieties, in most cases it was in the same "direction".

While showing a certain evolution, **the varieties conserved their own identity** (the different versions of each variety were always grouped in the AHC) but one, 'Alwaro', seemed to evolve really more ('Alwaro' versions always in different groups of AHC).

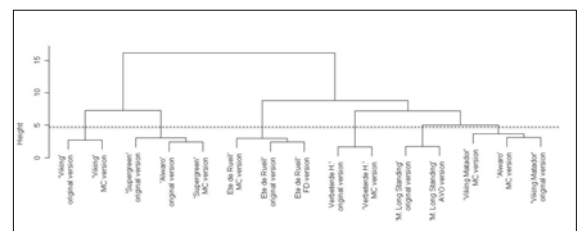


Figure 2: Ascending Hierarchical Classification (AHC) of the different varieties for the different morphological traits

Conclusion – perspective for Organic Agriculture

Even if further experiment would be needed to explore adaptive response of the varieties to farmers selection, our results points out the flexibility of such varieties, which is of interest for participatory plant breeding because of their potential for differential evolution. On-farm conservation and selection is one strategy to maintain or increase cultivated biodiversity in connection with farmers' needs (each farmer having his/her own breeding objectives). By breeding their own varieties, farmers could adapt them to their own conditions, and it is of great interest for organic and low input farming.

These results are also relevant to help policy-makers to adapt the European seed legislation, to recognize on-farm breeding and to take into account evolving populations.



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