Participatory Potato Breeding Model Involving Organic Farmers and Commercial Breeding Companies in the Netherlands

Edith T. Lammerts van Bueren[1,2*], C. Engelen[2], R. Hutten[2]

[1]Louis Bolk Institute, Hoofdstraat 24, 3972 LA Driebergen, The Netherlands;
[2] Wageningen University, Wageningen UR Plant Breeding, The Netherlands

*Correspondence: e.lammerts@louisbolk.nl

Summary

Organic farmers urgently need cultivars resistant to *Phytophthora infestans.* Such cultivars also need to be adapted to other traits important for organic farming systems. One goal in the first five years of this ten-year, public-private partnership was to establish a program within the Dutch potato breeding system that includes farmer breeders working in close collaboration with six commercial breeding companies and two research institutes. To meet the goals we have involved 14 organic farmer breeders through setting up a yearly breeding course. A pre-breeding program is now running to introgress late blight resistance from wild relatives into cultivated material, and to make crossings with advances genitors to distribute seeds to farmer and commercial breeders for selection. In this paper a short overview is given of the results of 2009-2013.

Introduction

The heavy outbreaks of Phytophthora in 2007, and again in 2012, reconfirmed the need for resistant potato cultivars for the organic sector. Until recently no such cultivars were available. For a country such as the Netherlands, with a high percentage of potato production and a maritime climatic favourable for late blight, only fully resistant cultivars can serve Dutch organic potato production. However, although late blight resistance is also important for conventional agriculture, the priority is not as high as for the survival of the organic sector.

To develop a larger number of resistant cultivars adapted to organic growing conditions we aimed at involving organic farmers to join the selection process. The organic sector not only needs resistance to *Phytophthora*, but also to diseases such as *Alternaria*, *Rhizoctonia*, silver scab and potato Y virus. A careful choice of breeding parents with low susceptibility to these diseases will increase the odds of robust progeny. Additionally, desired traits are nitrogen use efficiency and sufficient dormancy (to exclude the need for chemical germination inhibitors during storage). Early tuber filling and mid-early maturation is also an important trait to limit the exposure of resistant cultivars to *Phytophthora* spores and reduce the risk of resistance breakdown. As *Phytophthora infestans* is known for its ability to mutate quickly and overcome resistance during heavy outbreaks, there is a need to raise as many resistance barriers as possible. Knowing that *Phytophthora* has several host-specific pathotypes, it is crucial to have a diversity of resistance genes present in the field, preferably within one variety.

In 2009 the Bioimpuls Programme was launched with financial support from the Green Breeding Programme under the condition of 40% in-kind contribution from the breeding industry. In this 10-year program, wild potato species are crossed with cultivated potato to develop new,

resistant cultivars. The Bioimpuls Programme is divided into three parallel work packages with different time horizons (short, medium and longterm). The basis of the program is to cross modern cultivars with *Phytophthora*-resistant wild potato species collected several decades ago in Central and South America. In this paper we present the results from the first four years of the program.

Material and Methods

Genetic resources

Due to the Wageningen University (WU) breeding program, we can make use of material from previous research, including 13 different sources of resistance to *Phytophthora (*see Table 1). Five of these sources have already been improved to a level that they can be used as parent line for commercial breeding (short-term work package): ABPT, Carolus, Athlete, VR95-98 and Sarpo Mira. Carolus and Athlete are two resistant cultivars that recently came on the market and contain additional resistance genes. The remaining resistance sources still require several years of pre-breeding before they become suitable genitors for commercial breeding (medium and long-term projects).

Table 1. Sources of late blight resistance applied in Bioimpuls, update 2013.

Source	Gene	Cultivars	Time
ABPT	*S. bulbocastanum* (BLB2)	TOLUCA, BIONICA	Short-term
CAROLUS	?	CAROLUS	Short-term
ATHLETE	?	ATHLETE	Short-term
VR95-98	VR95-98 (R8)	VITABELLA	Short-term
SARPOMIRA	Sarpomira (R8)	SARPOMIRA	Short-term
2424A(5)	r8 differential (R8)		Mid-term
2573(2)	r9 differential (R9)		Mid-term
EDIFRI-3	*S. edinense* (EDN)		Mid-term
BCP 326-3	*S. brachycarpum* (BCP)		Long-term
IOP 273-1	*S. iopetalum* (IOP)		Long-term
SCR 849-6	*S. sucrense* (SCR)		Long-term
BUK-510-2	*S. bukasovii* (BUK)		Long-term
MPT 364-1	*S. multiinterruptum* (MTP)		Long-term

Markers

To develop cultivars with a durable late blight resistance, stacking of resistance genes is a necessity. To identify clones with stacked resistance genes, we apply molecular markers to determine whether the resistance shown by clones in field tests is based on single or multiple genes. We have the ability to use molecular markers for resistance genes R8, R9 , BLB2 and EDN. At Wageningen UR, more research is conducted to develop markers for other sources of resistance.

The participatory model
In addition to the longterm, pre-breeding program, Bioimpuls also has activities with a shorter time horizon. With the most advanced breeding lines the central breeding program is making some 300 crosses each year. Some of the seeds from these crosses are distributed each year to participating breeding companies and farmer-breeders, and some are evaluated by the Bioimpuls central program (Figure 1).

The farmer-breeders carry out the bulk of this selection work in the first 3 years of the selection cycle of seed lots yearly distributed, screening large amounts of seeds to select a handful of promising clones on a "no cure, no pay" basis. Farmer-breeders only receive compensation (shared royalties) if the clones they have selected become registered, marketed cultivars.

Each year in December all of the participants of the Bioimpuls Programme are invited to inspect the potato crates from the yield tests. This way, the breeders can choose which parent lines they want to order seed from for the next season. In addition, breeding companies can look for any interesting third-year or older clones that they want to test at their facilities to see if these clones are good enough to be released as cultivars.

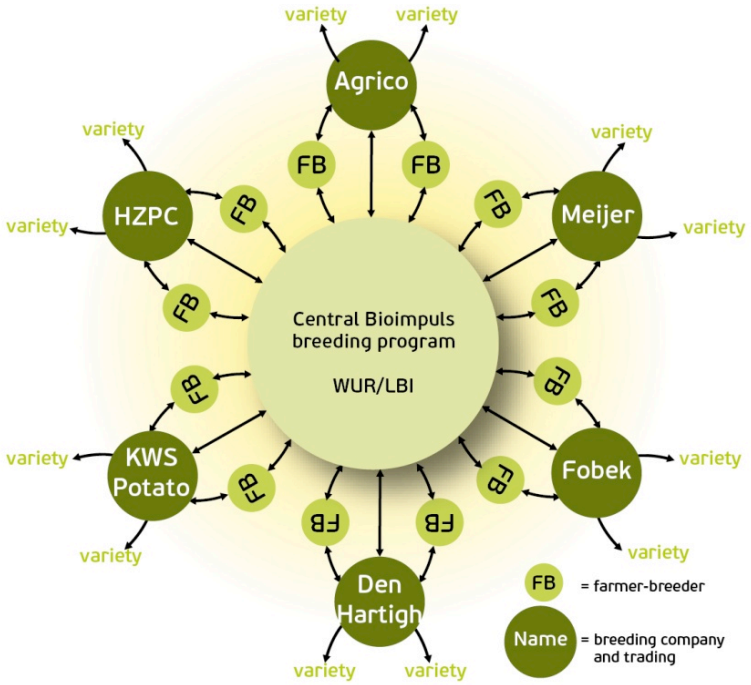

Figure 1. The organization structure of Bioimpuls, including the central breeding program, farmer-breeders, and six commercial breeding companies.

Breeding course and manual
A yearly potato breeding course was set up to provide farmer-breeders with background information and insights into breeding and selection methods. Furthermore, knowledge on practical

potato breeding was collected by interviews with experienced farmer-breeders and breeders to compose written material for the course.

The central Bioimpuls field site
Every year some 20,000 seedlings derived form crossings are planted at the central Bioimpuls field site in Kraggenburg (Noordoostpolder). At the end of each season, suitable clones are selected and placed into storage, to be tested again in the following year. The *Phytophthora*-resistance of third-year and older clones and parent lines is tested at a special "inoculation field site" in Wageningen. In addition, yield trials are set up each year on three soil/farming types ("conventional clay," "organic clay" and "organic sand"), to test the yield potential and quality traits of third-year and older clones, and parent lines. Based on the results of these field trials, selections are made for further testing and crossing in the next season.

Results and Discussions
Table 2 shows the number of seeds sown from 2009-2012. The total number of 40,000 seeds sown per year meets the size of a breeding program of a mid-large potato breeding company.

Table 2. Number of Bioimpuls seeds sown per year, 2009-2012

Year	2009	2010	2011	2012
Bioimpuls central location	11,362	23,257	19,965	19,950
Bioimpuls prebreeding	900	1,352	3,513	3,733
Breeding companies	5,350	9,334	1,0347	1,3913
Farmer-breeders	3,570	1,2451	5,213	1,0365
Total	**21,182**	**46,394**	**39,038**	**47,961**

Next to the need for developing pre-breeding activities introgressing resistance from wild relatives, it was also considered crucial to involve more organic farmer-breeders and to carry out selection work under organic growing conditions with organic expertise.

We joined the existing Dutch potato breeding system of farmer-breeders (also known in the Netherlands as "hobby breeders" or "small breeders") that still play an important role in potato breeding in the Netherlands, which is unique for Europe (Tiemens-Hulscher et al., 2013). Their work saves commercial breeding companies much time as the farmer-breeders do the first three selection rounds eliminating approximately 95% of the potato genotypes. They have selected various promising clones, which are currently being tested as potential cultivars by commercial breeding companies.

Before the Bioimpuls Programme was launched, there were only two farmer-breeders in the Netherlands who selected potatoes under organic growing conditions. As a result of this successful course there are now fourteen organic farmer-breeders participating. Thanks to their collaboration we have field sites on a range of soil types, which allows us to test for susceptibility to additional diseases. For example, north of the Netherlands (Oudebildtzijl, Friesland) we have a field site to test (potential) parent lines and promising clones for tolerance to common scab.

The commercial breeding companies participating in Bioimpuls are doing their share of the work. They have significantly raised their efforts to develop cultivars for the organic sector. Their partnership in Bioimpuls has clearly increased their awareness of the need for organic potato cultivars, and this offers new perspectives for sustainable and organic potato production. The companies collaborate with organic farmer-breeders, as this enables them to field-test their breeding material under "real-life" organic growing conditions. Some companies consider the organic sector an important and growing market for their future range of products. Others are eyeing new export possibilities, as the new robust cultivars would do well in conventional agricultural systems in low-input countries.

In the summer of 2012 the first flow of commercial late blight resistant cultivars: Bionica (Niek's Witte), Carolus, Sarpo Mira and Vitabella, were shown on the demonstration fields to introduce them to a larger group of (organic) potato growers. And in the winters of 2011/2012 and 2012/2013, the first groups of third-year clones (10 and 13) selected by the central Bioimpuls breeding program were handed over to commercial breeding companies. We hope to produce enough promising material each year that this can become a yearly event. The breeding companies and their marketing departments will be testing these clones for various traits at various locations.

Outlook

Although classical breeding from wild species is a long road, the advantage is that you can select for multiple traits along the way. Our expectation for the long run is that the Bioimpuls material should provide several new resistant commercial cultivars each year. So far, breeding has mainly focused on resistance to *Phytophthora* in foliage. However, it has become clear that resistance is not always equally effective in the tubers. In the coming years the Bioimpuls Programme will therefore test for both foliage resistance and tuber resistance, and we hope to gain a better understanding of the underlying mechanisms of tuber resistance and its link to foliage resistance, and to apply this knowledge in selective breeding.

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