Green Breeding

Bioimpuls Programme 2009-2013: Perspectives on Phytophthora-resistant potato varieties

The heavy outbreaks of Phytophthora in 2007, and again in 2012, reconfirmed the need for resistant potato varieties for the organic sector. Until recently no such varieties were available. In 2009 the Bioimpuls *programme was launched to give more priority to breeding organic, Phytophthora-resistant varieties. In this 10-year programme, wild potato species are crossed with cultivated potato to develop new resistant varieties. Although this classical breeding strategy is a long road, the advantage is that you can select for multiple traits along the way. This brochure presents the results of the first four years of the programme.*

Bioimpuls clones in the wintershow (Photo: Aardappelwereld)

New resistances from wild species

The Bioimpuls breeding programme works on Phythophthora-resistance in three parallel projects with different time horizons (short, medium and long-term). The basis of the programme is crossing modern varieties with Phythophthora-resistant wild potato species, collected several decades ago in Central- and South-America by Wageningen University researchers (see photo, page 2). Crossing wild species with cultivated potatoes is a time-consuming process: it takes three to four back-cross generations – each taking four to five years, so 12 to 20 years in total – to create new parent lines suitable for commercial breeding programmes.

This process is known as pre-breeding. It includes repeated crossings with a modern potato variety to adapt the plant material to our long day length. Furthermore, many selection rounds are needed

Trial field in Wageningen with wild potato species

Making use of material already available

to optimize disease resistance and eliminate wild traits such as long runners, irregular tubers and high glycoalkaloid content. Clearly, the pre-breeding process requires much time and knowledge. Particularly the smaller breeding companies are not able or willing to do this all by themselves; they are glad that this work is done by a government-funded programme such as Bioimpuls.

Thanks to the collaboration of Ronald Hutten, an experienced potato breeder at Wageningen University (WU), we can make use of material from previous research, including 10 different sources of resistance to *Phytophthora* (Table 1). Five of these sources have already been improved to a level that they can be used as parent line for (almost) commercial breeding (short-term project): *Solanum bulbocastanum, S. edinense*, R8 and R9, and Sarpo Mira. Two additional sources of *Phytophthora*-resistance for the commercial breeding programme are Carolus and Athlete, two resistant varieties that recently came on the market. 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

Source	Gene	Varieties	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* (MPT)		Long-term

Table 2. Number of Bioimpuls seeds sown per year

Year	2009	2010	2011	2012
Bioimpuls central location	11362	23257	19965	19950
Bioimpuls prebreeding	900	1352	3513	3733
Breeding companies	5350	9334	10347	13913
Farmer breeders	3570	12451	5213	10365
Total	21182	46394	39038	47961

Stacking genes

Phytophthora infantis is known for its ability to mutate quickly and overcome resistance during heavy outbreaks. Therefore we have to raise as many resistance barriers as possible. As *Phytophthora* has several host-specific pathotypes, it is crucial to have a diversity of resistance genes present in the field, preferably within one variety. We have already made various 'stacked' combinations by crossing parents with multiple resistance genes (from the highest quality resistance sources) and selecting the progeny that have inherited the resistance genes of both parents. In this process we make use of molecular markers to determine whether the resistance shown by clones in field tests is based on single or multiple genes. In this method, DNA is extracted from leaf samples of each resistant plant, to check at the DNA level which progeny have the stacked resistance genes. These plants are kept for further selection.

The potato breeding course in the field

An effective collaborative model

In addition to the long-term pre-breeding programme, Bioimpuls also has activities with a shorter time horizon. With the most advanced breeding lines we are already making some 300 crossings each year. Some 20,000 seeds from these crossings are distributed each year to participating breeding companies and farmer-breeders (see Box 1), and another 20,000 seeds are evaluated by the Bioimpuls central programme (Figure 1, Table 2). These numbers can be compared to a medium-sized commercial breeding programme!

More organic farmer-breeders needed

Before the Bioimpuls programme was launched, there were two farmer-breeders in the Netherlands who selected potatoes under organic growing conditions. They have selected various promising clones, which are currently being tested as potential varieties by commercial breeding companies. To increase the odds of finding new varieties suitable for organic production, it is crucial to involve more organic farmer-breeders and to carry out selection work under organic growing conditions, with organic expertise. It is often said that potato breeding is 'a matter of large quantities', but obviously it is also a matter of attention and skill. Bioimpuls has therefore set up a potato breeding course, to provide farmer-breeders with background information and insights into breeding and selection methods (see Box 2). As a result of this successful course there are now thirteen organic farmer-breeders participating in the Bioimpuls programme (Figure 2). Thanks to their collaboration we have field sites on a range of soil types, which allows us to test for susceptibility to specific diseases. For example, in Oudebildtzijl (Friesland) we have a field site to test (potential) parent lines and promising clones for tolerance to common scab.

Box 1. The role of farmer-breeders

Farmer-breeders (also known as 'hobby breeders' or 'small breeders') play an important role in potato breeding in the Netherlands. From the first seedling selection to a fully developed variety generally takes about 8 to 10 years. Farmer-breeders carry out the bulk of this work in the first 3 years, screening large amounts of seeds to select a handful of promising clones. This system has been key to the success of potato breeding in the Netherlands. About 150 farmer-breeders are currently participating. Their work saves commercial breeding companies much time and money, because it is on a 'no cure, no pay' basis. This means that farmer-breeders only receive compensation (shared royalties) if the clones they have selected become registered, marketed varieties.

Box 2. The Bioimpuls potato breeding course and manual

Not only organic, but also conventional growers sign up for the Bioimpuls potato breeding course, and their number is growing. The course is taught by Jan van Loon, a retired but still active and experienced farmer-breeder, who has several varieties to his name. His reputation also draws young plant breeders from commercial companies to the course. Thanks to its success the course has been permanently adopted by the potato sector; as from 2013 it will be run under the auspices of three breeder associations and the Louis Bolk Institute. Furthermore, the material written for the course has been edited into an official Potato Breeding Manual, to be published in September 2013 by the publisher 'Aardappelwereld'. For more information about the course or to sign up, please contact e.lammerts@louisbolk.nl or visit www.louisbolk.nl/bioimpuls

Selecting in the second-year clones at the central Bioimpuls field site in Kraggenburg

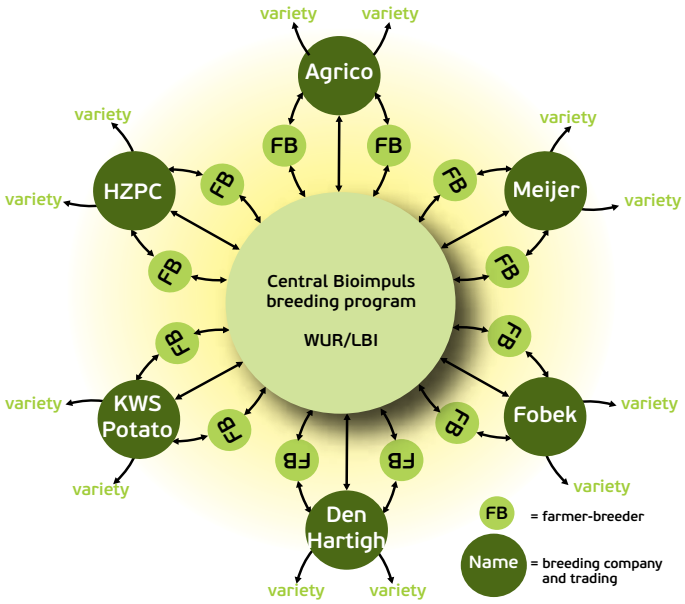

Figure 1. Bioimpuls is a cooperation of WUR, LBI and six breeding companies and several organic farmer-breeders.

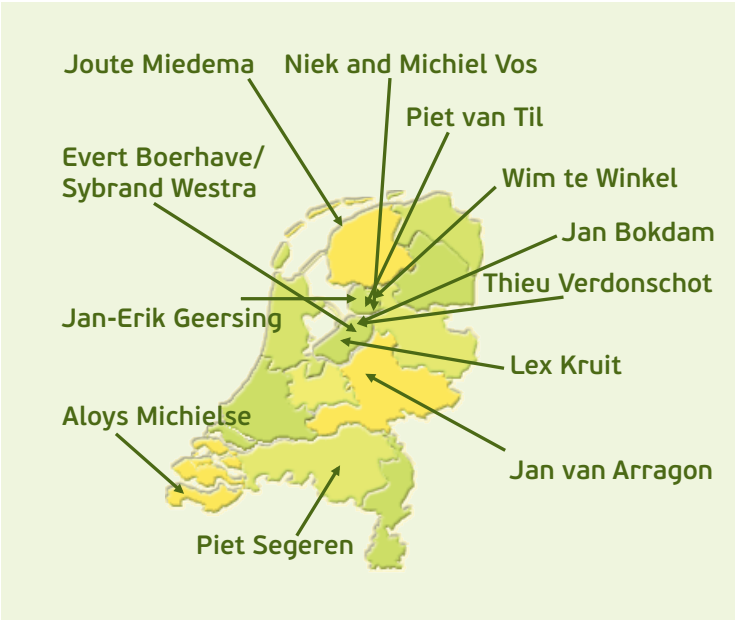

Figure 2. In 2013 in total 14 farmer-breeders were active in Bioimpuls.

The central Bioimpuls field site

Every year some 20,000 seedlings are planted out 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. Over the years more and more clones are dropped from the selection (see Table 3); particularly in years with high disease pressure many clones fail the test. The Phytophthora-resistance of third-year and older clones and parent lines is tested at a special 'inoculation field site' in Wageningen. In addition to this site and the central site in Kraggenburg, new experimental fields are set up each year on three soil types ('conventional clay', 'organic clay' and 'organic sand'), to test the yield potential of third-year and older clones, parent lines and potential new varieties. Based on the results of these yield tests a further number of clones are dropped, while the best varieties and parent lines are selected for further breeding in the next season.

Each year in December all participants of the Bioimpuls programme are invited to inspect the potato crates from the yield tests. This way, the breeders can choose from which parent lines they want to order seed 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.

Elimination race

In the winter of 2011/2012, the first group of third-year clones (10) selected by the central Bioimpuls breeding programme was handed over to commercial breeding

Field visit with farmers and breeders

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. The search for new robust varieties is like an elimination race, because the potato has to meet numerous requirements (Table 3). Clones that did well in earlier seasons may fail the next season; only the strongest, most perfect ones are kept. In the long run, the Bioimpuls material should provide several new resistant commercial varieties each year.

Role of commercial breeders

The commercial breeding companies participating in Bioimpuls are doing their share of the work; they have significantly raised their efforts to develop varieties for the organic sector. Their partnership in Bioimpuls has clearly increased their awareness of the need for organic potato varieties, and this offers new perspectives for sustainable and organic potato production. The companies are generally glad to 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 varieties would do well in low-input countries.

In the summer of 2012 the first commercial varieties from the programme were shown on the demonstration fields of the Bioimpuls Knowledge Exchange project: Bionica (Niek's Witte), Carolus, Sarpomira and Vitabella. The next step is to convince the market (see Box 3).

A wish list of traits

Although classical breeding from wild species is a long road, the advantage is that you can select for multiple traits along the way. The organic sector not only needs resistance to Phytophthora, but also to diseases such as Alternaria, Rhizoctonia, common scab and the potato Y virus. A careful choice of breeding parents with low susceptibility to these diseases will

Table 3. Number of seedlings/clones maintined over the years

Sown		Maintained			
Year	Numbers	2009	2010	2011	2012
2009	11362	511	58	31	14
2010	23257		7055	481	122
2011	19965			5721	661
2012	19950				5314

Box 3. Role of the market

One important bottleneck for organic seed potato production is that, outside the Netherlands, organic certification does not (yet) require the use of organic seed material. The Bioimpuls Knowledge Exchange project (2010-2013), run by the Louis Bolk Institute and DLV Plant, has done much work to explore market expansion strategies and to improve the quality of organic ware potatoes. The collaborative EU project 'CO-FREE' (2012-2015), in which eleven countries participate, is building on this work. With the Louis Bolk Institute as one of the Dutch CO-FREE partners, pilot projects are set up to develop the market for new resistant potato varieties. Clearly, all efforts to breed new varieties for sustainable production are wasted if the market does not respond. Market development for new, resistant organic varieties also contributes to European policy to achieve copper-free organic production systems. See http://www.co-free.eu/

The Bioimpuls National Heroes of Taste 2012!

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 maturation is also an important trait to limit the exposure of resistant varieties to Phytophthora spores and reduce the risk of resistance breakdown. The aim is to score at least a 7 for earliness.

Looks and taste

Unfortunately, varieties that work well for growers are not necessarily liked by consumers! As organic growers have repeatedly indicated, a new variety will only capture the market if the potatoes taste and look good (e.g. have a smooth skin). While there will always be personal preferences (such as for mealy or waxy potatoes), flavour characteristics such as 'too sour', 'too sweet' or 'too muddy' are readily recognized. A good-tasting variety is usually a stroke of luck, because flavour is not an explicit selection trait. In 2012 Bioimpuls organized an elaborate tasting test of the most promising third-year clones and commercial varieties such as Biogold and Ditta. It was held at the cooking studio of a participating grower, whose clients joined the tasting test. The best tasting clones were submitted to the national 'Hero of Great Taste' competition, and the jury was impressed. As a result, plant breeding researcher Edith Lammerts van Bueren and potato growers Niek and Michiel Vos earned the title 'National Hero of Taste 2012' (see photo above). Thus, it looks like Bioimpuls is on the right track!

The next step: Phytophthora resistance in tubers?

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. In a follow-up project 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.

The Bioimpuls team:

Edith Lammerts van Bueren, Marjolein Tiemens-Hulscher and Hans Dullaert of the Louis Bolk Institute; Ronald Hutten, Christel Engelen, Rene Alles and Eddy de Boer of Wageningen University (department of Plant Breeding).
This team works closely together with fourteen organic farmer-breeders, as well as six commercial breeding companies: Agrico, Den Hartigh, Fobek, HZPC, KWS Potato, and Meijer.

AGRICO · Meijer · DEN HARTIGH · FOBEK BV · HZPC Growing with our potatoes · KWS

Bioimpuls

Research Programme Green Breeding

The research programme Green Breeding (2010-2019) focusses on breeding of varieties that can cope with less nutrients and water and on resistance breeding to avoid pest and diseases. The research is on potato, leek, spinach and tomato. Next to those projects also some pilot studies are conducted on e.g. chain-approach in breeding and lupine breeding. This programme is financed by the ministry of Economic Affairs including a minimum of 33% in-kind or in-cash contribution of involved companies.

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