Developing Collaborative Strategies for Breeding for Organic Potatoes in the Netherlands

E.T. Lammerts van Bueren\textsuperscript{1,2}, R. Hutten\textsuperscript{2}, M. Tiemens-Hulscher\textsuperscript{1}, N. Vos\textsuperscript{3}

\textsuperscript{1}Louis Bolk Institute, Driebergen, The Netherlands
\textsuperscript{2}Wageningen University, UR Plant Breeding, Wageningen, The Netherlands
\textsuperscript{3}Maatschap Familie Vos-De Koeyer, Kraggenburg

Email: e.lammerts@louisbolk.nl

Speakers Bio

Dr. Edith Lammerts van Bueren (1952) has been involved in organic research and teaching for more than 30 years. Currently she leads the Organic Plant Breeding group at the Louis Bolk Institute in the Netherlands and is professor Organic Plant Breeding at Wageningen University. She leads two international networks: the European Consortium for Organic Plant Breeding (ECO-PB) and since 2007 also the Section Organic and Low-input Agriculture of EUCARPIA (European Association for Research for Plant Breeding).

Keywords

potato breeding, Phytophthora infestans, organic agriculture

Paper

Introduction

Dutch organic potato growers strive for a yield of 30–40 Mg/ha in 100–110 days. They have to deal with two main yield limiting factors: low nutrient availability (Van Delden, 2001) and late blight infestation.

The level of available nitrogen in organic production systems in the Netherlands lies approx. between 100–120 kg N/ha (Van Delden, 2001). Average potato yields in Dutch organic farming systems are rather low but also variable ranging from 12 until 35 Mg/ha. The main reason for this year-to-year variation in yield is the variation in timing and severity of late blight attacks, caused by the oomycete Phytophthora infestans. In contrast to other European countries no fungicides based on copper are permitted in organic potato production in the Netherlands. An additional problem for Dutch organic farmers is a national measure which forces every potato grower to kill the vine when \( \pm 7\% \) of the leaf surface is visually affected by late blight to reduce spread of inoculum to neighbouring fields. This measure makes the growing season short in years with an early attack. During the last few years the late blight attacks have been so devastating in organic potato production that its acreage has gradually
decreased from 1555 ha in 2002 to 1217 ha in 2007 with a slight increase in 2008 to 1270 ha.

The organic sector urgently needs appropriate varieties to deal with the constraints of the low-input organic farming system and the pressure of late blight. Conventional breeding programmes do not generate (a sufficient number of) such varieties and commercial breeding companies cannot set up a separate breeding programme for the limited area of organic potato production in the Netherlands. The widely advocated new strategy of cisgenesis, incorporating new resistance genes from related species into the cultivated potato, is not an option for organic agriculture as it remains a genetically modified organism (Lammerts van Bueren et al., 2003 and 2008). Effects of the agronomic toolbox to reduce the susceptibility of a potato crop to late blight are limited (Finckh et al., 2006; Speiser et al., 2006), certainly under the Dutch legal and climate conditions; therefore the Dutch organic sector has only one option to safeguard the Dutch organic potato sector and that is to put all forces together in the umbrella programme BIO-IMPULS for organic potato improvement (www.louisbolk.nl). Within this programme a joint breeding project for better adapted and late blight resistant varieties was planned. With financial support of the Dutch government this organic breeding programme was able to start in 2008 and includes the cooperation of six potato breeding companies, organic farmers and breeding scientists of Louis Bolk Institute and Wageningen University.

This paper will discuss the development of the collaborative setup of this breeding programme.

**Collaborative breeding strategy**

*Structure*

We build on a collaborative structure that traditionally exists in the Netherlands for more than 100 years and is hardly known in other European countries (Van der Zaan, 1999). It is based on a system in which farmer-breeders conduct three years of visual selection in progenies (clones) of crossings made by the involved company breeder, and return the selected and promising clones to the associated breeding company for further testing and selection towards variety registration and marketing, see table 1. When such a selection effort results in a marketable variety the farmer-breeder shares the royalties on for instance a 50-50% base with the involved breeding company. Such cooperating farmers are called 'hobby-breeder' or 'small breeders', however we prefer 'farmer-breeder' to stress the fact that such breeders are farmers who do this activity on a 'no cure, no pay' basis next to their regular seed and ware production of potato.

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
<th>Company breeder</th>
<th>Farmer-breeder</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Choice of parents</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>1</td>
<td>Crossing and harvesting seeds</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>Sowing and raising of 1st year seedlings</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Visual selection in the clones for basic agronomic characteristics</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
Table 1. Sharing of breeding activities in a collaborative model of potato breeding in the Netherlands.

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
<th>Company breeder</th>
<th>Farmer-breeder</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 8</td>
<td>Trials for production, resistances, quality and adaptation</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>5 - 12</td>
<td>Yearly visit and discussion on progress</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>9 - 12</td>
<td>Research for potential market, registration on national variety list, obtaining plant breeder's rights</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>13 - 15</td>
<td>Market introduction, maintenance, collecting of royalties</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>13 -</td>
<td>Yearly accounts and sharing of royalties</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

The farmer-breeder is often involved in the discussion with the company breeder to assess which combinations of traits are desirable and which parents should be crossed to have a chance to meet the goals. In this way the farmer’s experience in growing potato varieties and the breeder’s experience in heritability of traits are integrated. The company breeder is better equipped to make the crossings in the greenhouse and to collect the seeds. In the next spring the seedlings are raised by the company breeders and offered to the farmer-breeder to plant. On average a farmer-breeder yearly plants 500-1000 new seedling clones, some can cope with more. The scale is based on the number of first year clones. Each clone consists of one tuber and is one potential variety. As after the first year the seedling tuber is multiplied vegetative, there is no more segregation and therefore the selection is relatively easy for farmers. Farmer-breeders select for basic agronomic characteristics such as foliage and tuber appearance, length of stolons, tuber size and distribution, and adding their own insights and preferences. The selection percentage is individual, but can for instance be 15% in the 1st year (150 out of 1000 clones), 33% (50 out of 150) in the 2nd year, and 0-30% in the 3rd year (0-15 out of 50). The company breeder will proceed with the clones that are selected by the farmer-breeder and will test them on further quantity and quality traits, and might end up with 1 potential variety that he will send in for the official trials for variety registration.

Contract for sharing royalties
At the start of a collaboration between a breeding company and a farmer-breeder a contract is signed arranging the legal aspects of the collaboration, such as ownership of the genetic resources and sharing of the royalties. When a farmer-breeder’s selection is successful and ends up as marketable variety, it will be registered on the name of the farmer-breeder but the company will represent the variety in the market and will conduct the maintenance. Therefore the company will collect the royalties and will make a yearly account of the received royalties based on the volume of seed and ware potatoes sold. The sharing of the royalties is usually on a 50-50% base, depending on the amount of work done by either party. The yearly selection effort of farmer-breeders has contributed to increase the number of clones selected per year and therefore the chance to be successful. Due to this system in the past, the Dutch potato breeding sector has gained large progress in breeding and about 50% of the released Dutch varieties are a result of this collaborative system (Van Loon, 2007).
Breeding for organic agriculture

Training courses
As the acreage of organic potato is still limited compared to conventional production only few commercial potato breeding companies can make an extra efforts to propagate varieties especially suitable for organic production. But the number of suitable varieties derived from conventional breeding programmes is far too limited to cover all market segments and to safeguard the future of the organic potato sector in the Netherlands. Therefore, steps have been undertaken to set up a unique organic breeding programme, with participation of researchers, breeding companies and organic farmer-breeders.

The first aim was to enlarge the number of farmer-breeders as such a breeding strategy based on a 'no cure-no pay' basis makes it economically feasible to set-up a breeding programme for organic varieties in close collaboration with professional and commercial breeding companies. Until the start of the project only two of the total number of 160 active potato farmer-breeders in the Netherlands were organic farmers. One of these two farmers (Niek Vos) has recently been successful after 14 years of breeding efforts with the selection of the variety Bionica which is now marketed by the associated breeding company C. Meijer B.V. in 2007. In spring 2008 and 2009 the first breeding courses to introduce the basic principles of potato breeding and selection have been organised for interested farmer-breeders who want to consider to join the breeding programme but need more background in formation for an informed decision. With the course farmers get more insight in the breeding process and realize that such a long-term activity needs commitment, skills and time and therefore requires organisational space within their farm management. Of the total of 20 farmer participants five farmers have decided to step in directly. Others might consider to step in at a later stage. Now a total of seven organic farmer-breeders have joined the organic breeding programme. The farmers will be supervised by an experienced potato breeder. Many companies have shown interest in this training course also for their conventional farmer-breeders in future, as no such course existed until now.

Pre-breeding
Next to the above mentioned breeding activities of farmer-breeders in cooperation with commercial breeding companies to come to new varieties in the short term, there is also a need for a long-term pre-breeding activity generating new genitors including new sources of Phytophthora infestans resistance that have been identified in current projects by Wageningen University. Therefore specific crossings have been made including such new sources of resistances as Solanum bulbocastanum (Hermsen and Ramanna 1973), S. berthaultii, and S. oka-dae. These new sources of resistances should be integrated in a genetic background that also includes the other required traits for organic potato as much as possible in different combinations.

The long term pre-breeding activities will be conducted by breeding researchers of the project to cross wild relatives with new resistance genes with diploid or tetraploid forms of the cultivated potato to make them available as genitors for the commercial breeding activities. The aim is to conduct all steps under organic, low-input growing conditions to cover all traits essential for successful organic potato production. The organic programme will not only focus on late blight resistance but will include other important traits for varieties adapted to organic growing conditions, such as nitrogen uptake and use efficiency, Rhizoctonia and early blight resistance, early tuber setting and bulking. However, in this new organic breeding programme resistance against late blight will be first priority.
Collaboration between central organic (pre-)breeding programme and commercial breeding

The organic potato breeding programme now includes the cooperation of six commercial breeding companies which are already involved in the propagation of organic seed potatoes. The seven farmer-breeder groups are all attached to one of the involved breeding companies. The farmer-breeder groups can yearly receive seedling clones from the central organic breeding programme conducted by Louis Bolk Instituut and Wageningen University and/or from their commercial breeding company. The breeding companies can produce crossings with their own selected parents but can also derive new genitors from the central organic breeding programme. By a contract between the central breeding programme and the involved farmer-breeder and breeding companies, it is agreed that when in future varieties will be registered derived from plant material from the central breeding programme 10% of the royalties will flow back to the programme so that the programme can partly generate its own income for future breeding activities.

In 2008 the first crosses for commercial variety selection have been made within the central breeding programme and some 10,000 seeds have been distributed among the farmer-breeder groups and another 10,000 seeds will be planted in the selection fields of the central breeding programme itself.

As Wageningen University has conducted a small pre-breeding programme in the past years, already genetic resources containing promising new resistance genes are available to include in this joint organic breeding programme.

![Collaboration diagram]

Figure 1. Overview of the collaboration between the central organic potato (pre-)breeding programme, the farmer-breeder (FB), some independent small breeders (SB) and named commercial breeding companies in the Netherlands, 2009.

Discussion and conclusions

As the organic sector refrains from a GMO based solution to obtain late blight resistance, and as yields have been too low in the recent years to make organic potato production economically feasible, the Dutch organic sector is now aiming at increasing the traditional breeding activities towards appropriate varieties that comply with the organic principles of the organic agriculture. Innovation appears by introducing a traditional strategy in a new, organic context which generates new knowledge and new research questions.
As in many European countries, the Dutch government has withdrawn more and more its financial support for pre-breeding activities. This means that only a few, large breeding companies can afford a long-term pre-breeding programme to introgress new resistance genes from wild relatives through classical breeding to develop a broad spectrum of genitors. Without public financial support increase of the pre-breeding activities to combine new late blight resistance genes with other important traits for the organic sector would not have been feasible.

Such an organic breeding programme can only be successful and economically feasible when the number of organic farmer-breeder will increase in the near future and together evaluate at least 20,000 clones per year. Potato breeding is a long-term activity and is a continuous search for new resistance sources, pre-breeding and commercial breeding. The recent release of a new late blight resistant variety shows that with efforts of more organic farmer-breeder the selection of a range of varieties suitable for organic potato production in the future is achievable.

However, the genes that will be used in the organic breeding programme are race-specific R-genes. This kind of resistance is assumed to be not durable, especially when sexual reproduction of the pathogen is occurring with both mating types of the oomycete being present. Therefore classical (as well as GMO) approaches would require constant addition of new R-genes, and pyramiding of these genes in many different combinations. Marker assisted breeding using freely accessible markers will be a necessary instrument to achieve adequate pyramiding.

The conventional breeding programmes can benefit from such a broad pre-breeding programme aiming at varieties adapted to low-input farming conditions as a necessary element towards sustainable agriculture. It is one of the arguments of the breeding companies that have expressed their commitment to cooperate in this organic programme.

References