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Can conventional breeding programmes provide onion varieties that are suitable for organic farming in the Netherlands?

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Abstract Main stream commercial onion breeders do not select varieties for organic farming, but solely for conventional farming. Seed companies consider the organic market too small to justify investments in breeding for this sector. In order to study if their varieties also suit organic farmers' needs we interviewed four Dutch commercial onion breeders on their breeding programme and selection criteria and compared the outcome with a variety profile composed of the priority traits of Dutch organic farmers. Breeders gave priority to the same storage and bulb quality traits that are demanded by organic farmers, because organic onions are exported to conventional supermarkets that apply the same quality standards to organic and conventional onions. However, organic farmers also need varieties that perform well in the field. Breeders give low priority to field selection. Furthermore, three of the four seed companies only breed hybrids. The cytoplasmic male sterility system used to produce these hybrids does not comply with organic principles. We conclude that at present breeders can provide varieties that meet organic farmers' demands for storability and quality traits, but they should give higher priority to field selection to also improve required field traits. The latter will only occur, if in future the organic seed market will grow. If the organic sector wants varieties developed according to its own principles, it should either set up its own onion breeding programme or seek alliances with breeding companies that are prepared to harmonize their breeding methodology with the organic principles.

Keywords Onion · *Allium cepa* · Organic breeding · Plant traits · Farmers' preferences · Organic principles

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Introduction

Organic growers of onion in the Netherlands rely on conventional breeding programmes to obtain new varieties. However, it has been argued that farmers would benefit from plant breeding programmes that specifically develop varieties that are suitable for use in organic production systems (Lammerts van Bueren et al. 2002; Wolfe 2002). Two main arguments are used to support this thesis. The first argument is that organic farmers perceive and value specific variety characteristics differently from their conventional colleagues. Currently, onion breeders select their varieties based on the demands of the main-stream market. Therefore, the phenotypes of these varieties may not match the ideal that the organic farmers have in mind. Secondly, it is argued that if breeding would take place under organic growing conditions, this would result in varieties that are better adapted to organic farming than the current varieties selected under conventional conditions (Lammerts van Bueren et al. 2002). In this article we explore the first reason for the case of onion in the Netherlands.

Organic farmers have a different view on the ideal set of characteristics of a variety compared with conventional farmers because organic cropping systems differ from conventional farming systems. In the temperate climate of the Netherlands, especially in the early part of the growing season, lower quantities of soil nutrients are available for uptake by the onion crop in organic cropping systems than in conventional systems. This requires a better resource capture by the crop, a higher biomass production per unit of nutrient taken up, and in some cases even a more efficient production of harvestable products per unit of biomass produced. In addition, a more diverse rotation scheme, with a lower frequency of onions, and the absence of synthetic pesticides may also lead to a shift in frequency and severity of priority pests and diseases. Furthermore, organically grown onions are stored in a different way compared to conventional onions (no use of sprouting inhibitors), and this will stress the need for more dormancy. Also processing techniques and consumer preferences may differ between the organic and conventional production chain.

Dutch breeders usually question whether the organic sector needs varieties with traits that differ from the traits considered desirable for the conventional sector (first authors' experience in meetings with wheat, carrot and onion breeders since 1999). Most of them share the view that resistances against pests and diseases are top priority for organic systems, because organic farmers do not apply synthetic pesticides. They argue that this is not different from their own aims, because resistance breeding is a priority in a conventional breeding programme as well. Some breeders have slightly adjusted their view over the years because of experiences with organic variety trials. Those who have shown to adjust their views, acknowledge that while the relevant traits are the same, their relative importance may differ between organic and conventional farming. Nevertheless they are confident that they can supply varieties that also possess the specific characteristics prioritized by the organic farmers. This confidence is based on the fact that they breed for many different markets and therefore have many different varieties in stock. According to the breeders, currently available diversity of varieties is large enough to comply with the demands of all markets, including the organic sector in the Netherlands.

Setting up special breeding programmes for the organic sector would require large financial investments. In the Netherlands almost all breeding is carried out by commercial seed companies. These companies consider the organic market too small to justify such investments (Driessen 2006). Such investments would also not make sense if one can expect that the varieties developed under the current situation are adapted to organic growing conditions and contain the traits required by organic farmers.

In this paper we analyse the selection criteria applied by Dutch onion breeders and compare these with the variety traits prioritized by the Dutch organic growers of onion. The objective of the research was to assess whether the Dutch onion breeding sector can potentially supply the onion varieties demanded by the organic farmers.

Materials and methods

We followed a case study approach. This approach allowed us to study the object of our research, onion breeding for organic farming, in its complexity and within its context (Verschuren 2003; Yin 1984). The way onions are produced in the Netherlands, under conventional and organic conditions, and how they are used is considered part of the context. The profile of the ideal onion variety as perceived by farmers was used as a reference against which the breeding goals and practices of breeders were compared. The information was collected by applying different methods. These included semi-structured interviews with breeders and key-informants, group discussions with farmers and literature and internet review.

The ideal organic variety profile as perceived by farmers

The traits organic farmers consider crucial in onion varieties were first identified in a meeting with members of the onion commission of the farmers' cooperative Nautilus in 2001. At that time about 140 of the ~200 organic field crop farmers were member of this cooperative. The crop commissions of Nautilus consisted of farmers with affinity to a specific crop and these were delegated by the other members to negotiate product prices and to monitor new developments in the markets and agricultural research. The results of the discussions with the onion commission were summarized in an organic variety profile. To check whether this profile was representative for a broader group of farmers, it was discussed during public field meetings in the two major onion growing regions (Zeeland, Flevoland). These meetings were organised twice a year from 2001 until 2004 to demonstrate results of organic variety trials in the field and at the end of the storage period. Both organic farmers and breeders participated in these meetings. In total about 30 farmers were involved in the discussion on the onion variety profile.

Participating breeders and studying their priority traits and breeding approach

The domestic onion seed market is dominated by five Dutch companies of which four companies agreed to be interviewed. The interviews took place in 2004 and 2005. All four breeders were interviewed at their office, while with three of them a follow-up interview was held in the field at one of their breeding nurseries. In two companies also a member of the commercial staff was interviewed. Interviews were semi-structured and contained the following topics: the breeding programme and selection criteria, their varieties and traits, future priorities and breeding for organic farming. As in all these topics plant traits played a central role, this allowed for cross checking the provided information. In addition, the companies' seed catalogues and websites were studied. Furthermore, a list of the mentioned selection criteria was sent back to the breeders for comments. At the same time they were asked to give a priority score (between 1 and 5) for the various traits. Finally, the breeders were invited to comment on an early draft of the paper.

Context of the research

Dutch organic onion production

In the Netherlands organic onions are mainly grown by large scale field crop farmers. In this paper we only deal with direct-seeded onions, as this is the main way of establishing the crop. With an acreage of about 600 ha in 2004 (CBS 2007) direct-seeded onions are the third most sown organic crop after cereals and potato. Most onions are stored to be able to supply the markets for the longest possible period of the year. About 85% of Dutch organic onion production is exported and major buyers are supermarkets in Germany and the UK (Lammerts van Bueren et al. 2006).

Dutch onion breeding

Dutch onion breeders operate internationally. Within the European Union (EU) the Netherlands is the third onion producing country with 16.000–19.000 ha (CBS 2007; Eurostat 2007). This makes the domestic seed market an important one for Dutch breeders.

At present four of the five main onion breeding companies only breed hybrid varieties for the Dutch market. The onion hybrid breeding system is based on cytoplasmic male sterility (CMS) in combination with fertility restorer genes. This system is present naturally in onion populations, albeit at low frequencies (Banga and Petiet 1958; Havey 2000; Kik et al. 1998). The smallest breeder continues to only breed open pollinated (OP) varieties.

Most current Dutch hybrid and OP varieties are derived from the Dutch landrace *Rijnsburger*. Many OP farmer selections of *Rijnsburger*, which differed in important traits like earliness, sprouting resistance, yield, or bulb shape, were grown in the Netherlands in the early 20th century. Each breeding company has gathered local selections and these form the basis of their hybrid breeding programmes. A few OP selections of the variety *Rijnsburger* are still marketed (e.g. "Balstora", "Julia"). Dutch breeders prefer to use *Rijnsburger* populations for their breeding programme over foreign accessions, because of good storability, bulb shape and colour.

None of the Dutch seed companies runs a breeding programme specifically for organic farming. They consider the current organic market too small to justify such an investment. Because of prospects of a growing market, two companies started to test their breeding material on organic farms. The prediction of an increase of the organic seed market was based on the expectation that the use of organic seeds would become obligatory after a planned revision of the EU regulation on organic farming EEC 2092/91 (Anonymous 1991). However, when the new regulation EC 1452/2003 (Anonymous 2003) proved to be less strict than expected, one of the companies abandoned its organic project. The other company continues to test its inbred lines and hybrids in an organic nursery.

Onion breeding and the organic principles

In the 1990s the organic sector started discussing the compatibility of techniques used in plant breeding with the organic principles (Lammerts van Bueren et al. 2003). While this debate has not been concluded yet, the International Federation of Organic Agriculture Movements (IFOAM), the world umbrella organization for organic farming, has elaborated draft standards (IFOAM 2004). For onion breeding the discussion on the use of hybrid varieties is relevant. The IFOAM draft standards do allow the use of hybrids, but only when these produce fertile seeds. Non fertile hybrids are considered in conflict with the principles of organic farming that were established in a participatory process by IFOAM members (Luttikholt 2007). First of all, non fertile hybrids prevent farmers from reproducing their own seeds and thus achieving a closed system on their farm. Furthermore, this type of hybrids leads to inequity in the breeding system because their breeders profit from free access to OP varieties while they shield off their own varieties for further use by others breeders (Lammerts van Bueren et al. 2003). In the long run preventing exchange of genetic resources among breeders will limit the genetic base of breeding programmes.

It must be noted that, although IFOAM represents the organic sector as a whole, within the EU its standards are not legally binding. In the EU the regulations for organic agriculture are given by the Directive 2092/91 and do not (yet) specify standards for plant breeding other than a ban on genetic engineering (Anonymous 1991). However, in the past the IFOAM standards have influenced the EU law and regulations on organic farming significantly.

Traits desired by organic farmers

Variety traits organic onion growers considered essential, the preferred phenotype and the priority ranking of these traits are summarized in a variety profile for direct-seeded organic storage onion (Table 1). Major problems in onion production are the plant disease downy mildew (causing agent *Peronospora destructor*) and storability. Both reduce the yield of marketable onion bulbs. Another major problem is the large amount of labour required for weeding. However, due to the open canopy structure of an organic onion crop, farmers do not expect that variety characteristics contribute to the suppression of weeds. To make mechanical weed control easier, they prefer plants with a more erect growth habit. Below the most important traits of the variety profile are elaborated in more detail.

Vigorous growth

Farmers assume that a good leaf mass correlates with a more vigorous growth and allows the crop to more easily cope with drought periods in summer. They also assume that appearance of dead leaf tips is associated with stress susceptibility of the variety.

Dutch organic onion farmers apply about 80 kg/ha of nitrogen to their crop (Osman et al. 2005), which is less than the 100 kg/ha of nitrogen that is considered optimal for a conventional onion crop (PPO 2003). Early in the growing season, mineralization of organic fertilizers is slow, which delays the availability of nitrogen. Onion is especially sensitive to nutrient shortage, because it has a rather poor root system (Brewster 1994). Differences in root system size amongst varieties—although small—have been reported and a large root system enhances nutrient uptake (de Melo 2003). An increased colonization of the roots by Arbuscular Mycorrhizal Fungi (AMF) enhances phosphorous uptake and reduces

Table 1 Organic farmers' variety profile for direct seeded storage onion (elaboration of results that were published earlier by Lammerts van Bueren et al. (2005))

Traits	Phenotype preferred by farmers	Priority[a]
In the field		
Vigorous growth		
Leafiness	More leaf mass is better	3
Dead leaf tips	No dead leaf tips	2
Root development	Well developed root system	3
Mycorrhiza	Good host for mycorrhiza	3
Supporting disease and pest management		
Resistance to		
Downy mildew (*Peronospora destructor*)	Resistant	5
Leaf blight (*Botrytis squamosa*)	Resistant	4
Neck rot (*Botrytis aclada*)	Resistant	2
Fusarium (*Fusarium oxysporum* f.sp. *cepae*)	Resistant	2
Thrips (*Thrips tabaci*)	Resistant	2
Waxiness of leaves	Leaves covered with wax	4
Erectness of leaves	Erect position	4
Earliness		
Early bulb swelling	Early bulb formation	5
Earliness (Fall down)	As early as possible to escape downy mildew, but without compromising storability; maximum 127 growing days	5
During and after storage		
Storability	95% of onions storable until April	
Sprout dormancy	No visible sprouts	5
Firmness of bulbs	Firm bulbs	5
Thickness of neck	Thin enough to allow neck closure at ripening, but not so thin that it would reduce leaf mass	5
Skin retention	No naked bulbs	5
Number of skins	≥2 skins	5
Bulb appearance		
Uniformity	Uniform	4
Skin colour	Yellow, not weathered	3
Inner colour	Uniformly white/cream, without visible green veins	3
Net yield	≥35 tons/ha	5

[a] Scale 1–5, with 1 = no priority and 5 = highest priority

the susceptibility to water stress (Harrier and Watson 2003; Sharma and Adholeya 2000).

Supporting disease and pest management

Downy mildew is the main problem in organic onion production. This foliar disease usually appears approximately one month before harvesting (July/August). If weather conditions are conducive to the disease, it may rapidly destroy the entire canopy. During the study period none of the commercially available varieties was resistant. Farmers prefer early bulbing varieties to enhance the chance of harvesting onions of a marketable size (>50–60 mm) when the disease appears early. This has become even more important since the Dutch Product Board for Arable

Crop Production (HPA) issued a regulation in 2004 that obliges all farmers to destroy the onion canopy when either at least 3,000 leaves in an area of 20 m^2 are infected with downy mildew or at least 8,000 infected leaves are scattered over an area of 100 m^2. Furthermore, farmers think that varieties with a more waxy leaf are less susceptible to downy mildew.

During storage, neck rot (causing agent *Botrytis aclada*), among other diseases, affects the bulbs. A thin neck (lower part of the stem, which remains on the bulb after harvest) contributes to a healthier bulb during storage. The thinner the neck, the better it cures and the more difficult it is for the pathogens to penetrate the bulb. However, this trait conflicts with productivity, because plants with a neck that is too thin produce a smaller leaf apparatus and smaller bulbs. Therefore, farmers look for a balance between neck size and bulb size.

Storability

The last onions of the season should be storable until April. Important quality traits affected by storage duration are dormancy, bulb firmness and retention of the outer skins. These quality requirements are set by traders and do not differ from what is demanded by the conventional market. However, organic farmers do not use sprouting inhibitors. Besides that, the time from packing to purchase by consumers takes on average 3 weeks, which is considerably longer than for conventional onions. Therefore organic farmers rely more on the variety's ability to store well than conventional farmers.

Currently, organic onions are often stored at lower temperatures (0.5–1°C) than at conventional farms (3–4°C) to delay sprouting. The lower storage temperature increases energy use and financial costs. Bos et al. (2007) estimated that drying and storage of vegetable crops are responsible for 45% of the energy consumption of a Dutch organic field crop farm. So, both for economical and ecological reasons varieties with better storability are needed.

Recent organic variety tests have shown that current varieties differ in dormancy (Osman et al. 2005) and indeed Dutch organic farmers shifted their choice to the variety Wellington, that showed the best performance for this trait: in 2005 Wellington was the most sown onion variety in organic fields (Lammerts van Bueren et al. 2006). However, due to problems with watery scales, the second year farmers reduced the acreage of Wellington, but it remained the second most sown variety. In conventional onion production Wellington does not rank so high (R. van den Broek, personal communication).

Priorities in Dutch onion breeding

Importance of bulb selection in the warehouse versus plant selection in the field

The interviewed breeders estimate that 90% of the time they invest in selection is spent in the warehouse to assess quality of the harvested bulbs at the end of the storage period (early spring). Relatively little time is dedicated to selection in the field. One of the main reasons for selection in the field would be to improve resistance against the major leaf diseases: downy mildew and leaf blight (causing agent *Botrytis squamosa*). However, Dutch breeders agree that the *Rijnsburger* populations they select from do not contain the required absolute resistance against these leaf diseases. Furthermore, they share the opinion that incomplete forms of resistance are not interesting for the conventional market. High levels of resistance against both diseases have been found in *Allium* species that are related to onion (*Allium cepa*): leaf blight resistance in *Allium fistulosum* (Currah and Maude 1984) and downy mildew resistance in *Allium roylei* (Kofoet et al. 1990; van der Meer and de Vries 1990; Scholten et al. 2007). Crosses between *A. cepa* and *A. roylei* only yield few fertile seeds, but the success rate is still higher than of crosses between *A. cepa* and *A. fistulosum* (Kik 2002). About 20 years ago seed companies started selection in progenies of interspecific crosses with *A. roylei*, but due to the complexity of this approach these resistance breeding programmes are not part of the regular breeding programme, but executed as special projects. For the screening of downy mildew resistance, molecular marker technology is applied (Scholten et al. 2007). The availability of this technology makes it possible to replace screening in the field in the early stages of the special resistance breeding projects by laboratory analysis. The latter is also preferred because the preparation of inoculum for artificial infection in the field is difficult.

Although all breeders give low priority to selection in the field, there are clear differences in the way they take plant traits into consideration. The four breeders can be divided into two pairs. The first pair gives no or very little attention to field observations: one breeder states that he does not take any plant characteristics into account at all and the other explains that he merely takes rough field notes, but that these have very low priority in his final decision making. For both breeders, a good performance in the field will ultimately result in high yield and high quality bulbs and as they already select for bulb quality, selection in the field becomes redundant. The other pair of breeders indicates that they make frequent field observations, but also state that if they find highly productive onions with good quality traits they will select these anyway, regardless of other plant traits. When using a plant with good bulb traits, but unfavourable leaf traits, in a hybrid cross they try to compensate for this by choosing an inbred line with favourable plant leaf traits as the other parent.

Comparison of breeders' priorities and the organic variety profile

Table 2 lists the traits breeders select for and the importance of each trait.

Bulb quality traits and net yield

As mentioned in the previous section, all breeders consider the traits they observe in the warehouse more important than field traits. Breeders mention the same traits—high net yield, skin retention, bulb firmness, bulb shape, uniformity, sprouting resistance—and priorities are similar. The reason for this is that breeders follow the demands of onion traders because these usually buy specific varieties from farmers. Hence fulfilling traders' preferences is crucial for seed sales.

A strong focus on some of the traders' quality requirements has trade-offs. Breeders agree that strong selection for bulb firmness goes at the expense of yield. Some also attribute the problem of watery skins, which appears in some years, to a strong emphasis on breeding for skin retention. Finally, a high level of resistance to sprouting conflicts with their own interest to produce sufficient amounts of seeds for a competitive price. Therefore they are continuously looking for the most optimal balance between the traits that are required by the different stakeholders.

The traits mentioned above are also top priority for organic farmers. This is because the bulk (85%) of Dutch organic onions is exported to conventional supermarkets. For both organic and conventional onions Germany and UK are main export markets within the EU (Baas and Pals 2006; Lammerts van Bueren et al. 2006). As traders apply the same standards for both organic and conventional products, here priorities of breeders and organic farmers overlap.

Only breeders' efforts to improve dormancy cannot be explained by a similarity in current market demands. This trait has low priority for conventional farmers, because they use the chemical sprout inhibitor maleic hydrazide (MH). Nevertheless, breeders have selected for this trait, because they received signals that the supermarkets would ban the use of chemical MH in due time. Whether they will continue to give priority to this trait remains doubtful, because the discussions on MH did not result in a prohibition. Therefore, at this moment, varieties with a longer dormancy do not have a comparative advantage on the conventional market.

Like organic farmers, breeders also look for a thin neck to prevent storage diseases. As a thinner neck results in a smaller leaf apparatus and hence lower yields, they look for a balance. According to one breeder, a too thin neck also makes the onion more susceptible to stress.

Earliness

The most important selection trait in the field is earliness. Dutch breeders distinguish three maturity classes (early, intermediate and late) and within each class they look for the earliest lines. They assess this trait by recording the date of 50% of leaf fall down. For conventional agriculture earliness is important because it increases the chance of dry and warm days during harvesting and during the period the bulbs are left on the field for curing (end of August or beginning of September). Although organic farmers also give priority to earliness, they have an important additional reason: to escape an attack by downy

Table 2 Storage onion traits breeder select for and their priorities within two selection phases: in the field and after storage in the warehouse. All breeders give higher priority to selection in the latter phase

Traits	Priority[a] for conventional market				Change in priority if breeder would also select for organic[b]			
	Breeders				Breeders			
	A	B	C	D[c]	A	B	C	D[c]
In the field					>	>	>	=
Vigorous growth								
Seed emergence	4	1	4	5	<	>	=	=
Plant vigour	5	4	1	5	=	=	>	=
Leafiness	3	3	4	4	>	=	=	=
Leaf colour	2	3	2	3	>	=	>	=
Dead leaf tips	3	4	1	4	>	=	>	=
Root development	4	2	1	5	>	>	=	=
Supporting disease and pest management								
Resistance to								
Downy mildew (*Peronospora destructor*)	5	3	5	1	=	>	=	=
Leaf blight (*Botrytis squamosa*)	5	3	5	1	=	>	=	=
Fusarium (*Fusarium oxysporum* f.sp. *cepae*)	1	3	1	1	=	>	=	=
Leaf health	5	3	5	5	=	=	=	=
Waxiness of leaves	3	3	1	5	>	>	>	=
Erectness leaves	3	3	5	3	>	>	=	=
Leaf bending	2	3	1	3	>	=	=	=
Earliness					=	=	=	>
Early bulb swelling	5	3	1	3	=	>	>	>
Earliness (Fall down)	5	4	5	3	=	=	=	>
During and after storage					=	=	=	=
Storability								
Sprout dormancy	5	4	5	5	=	>	=	=
Firmness of bulbs	5	4	5	5	=	=	=	=
Thickness of neck	5	3–4	5	3	<	=	=	=
Skin retention	5	5	5	4	=	=	=	=
Number of skins	4	4	1	4	=	=	=	=
Thickness of skins	4	3	1	4	=	=	=	=
% Rot	5	2	4	5	=	=	=	=
Bulb appearance								
Shape	5	5	5	4	<	=	=	=
Red discoloration	5	5	5	4	=	=	=	=
Uniformity	5	5	4	4	<	=	=	=
Doubling of bulbs	5	3	5	5	=	=	=	=
Bulb size	5	3	4	3	=	=	=	>
Single centre	3	3	3	5	=	=	=	=
Skin colour (yellow)	3	3	3	4	=	=	=	=
Net yield	5	5	5	4	=	=	=	=

[a] Scale 1–5, with 1 = no priority and 5 = highest priority

[b] At present none of the breeders run a separate selection programme for organic production. >, priority increases; =, priority stays the same; <, priority decreases

[c] The priority score for field traits of breeder D applies to selection among advanced populations and varieties. In the initial phases of his breeding programme he only selects among harvested bulbs after storage

mildew. Therefore besides an early fall down, also early bulb formation is important. Two breeders also take early bulb formation into account. The reason for this is not because they are interested in an escape from leaf diseases, but because they expect that early bulbing types cope better with drought.

Earliness is negatively correlated with storability, so breeders look for a balance between these traits.

Erect plant type

Three of the four breeders prefer plants with erect leaves. Breeders consider this trait important to avoid lodging of the massive crop canopy in a conventional field. Due to the lower nitrogen availability the vegetative development of an organic crop is less abundant and therefore lodging is not a problem in organic fields. Nevertheless, organic farmers also give this trait a high priority. This is because a crop with erect leaves makes mechanical weeding easier. So, although for this trait the organic and conventional objectives do not match, the end result satisfies both markets.

Disease resistance

Breeders aim at absolute resistance against the most important diseases: downy mildew and leaf blight. Only one breeder indicates that besides aiming at a high level of resistance against downy mildew by selecting in populations of interspecific crosses, he also screens for general plant health, i.e. plants with healthy green leaves, in his *Rijnsburger* populations. A breeder from another company grows his onions in a “stress” nursery, without fertilizers and fungicides, every second year. He observes that the advances in plant health he obtained are not because of selecting part of the generations in this nursery, but due to the fact that he selects for specific plant traits: waxiness and erect leaves. The relation between more wax and a lower susceptibility to downy mildew was confirmed by the other breeders. Also organic farmers point to the importance of these traits to reduce disease pressure.

Especially for organic farmers the broader way of looking at plant health, like by the two breeders mentioned above, is valuable. This is true for the current situation in which selection in the interspecific crosses has not resulted in resistant varieties yet. For downy mildew the situation may change in the near future, as in 2006 two seed companies distributed seeds for experimental use of the first resistant varieties. Results of independent variety tests were not available at the moment of writing. But also when the resistance genes from other species have been successfully crossed into commercial varieties, including general plant health remains necessary, because farmers have to deal with multiple diseases and want to diminish the reliance on purely monogenetic resistances. Therefore it is unfortunate that even the breeders, who take these traits into account, indicate that these have lower priority.

Increased root system and more vigorous growth

The same breeders, who look for early bulbing, also pay attention to drought resistance. They find that more leafy plants are less susceptible to drought stress and also relate stress resistance to a better rooting system. One of them systematically screened his plant material for the amount of roots. He attributes gains in selection for a better rooting system to his selection environment: once in every two generations of the breeding cycle he grows his onions in the earlier mentioned “stress nursery”. The influence of the environment on rooting ability is also mentioned by one of the breeders who pays less attention to selection in the field. He claims that some of his varieties are better rooting, because his main breeding nursery is situated in the south-west of the country, which is more prone to drought stress than the north-west where most of his competitors are based. Breeders argue that better rooting varieties tend to mature later, so also for this trait a balance should be sought.

Would breeders use other criteria if they would select for organic farming?

During the study breeders were also asked what they would do differently if they would select specifically for the organic market. All breeders indicate that they expect that their conventional breeding programme also yields varieties suitable for organic farming. Their argument is that the main selection criteria, storage and bulb quality traits, are determined by trader demands and these overlap. Nevertheless, Table 2 shows that three out of four breeders would give higher priority to screening traits in the field such as leafiness, waxiness, erectness of leaves and root development, while the storage and bulb quality traits, and yield would receive the same high priority. One breeder would lower the priority for bulb shape and uniformity.

The breeding system

The case of onion is illustrative for the objections of the organic sector against non fertile hybrids. The CMS used by Dutch breeders is derived from the *Rijnsburger* populations and prevents seed setting for almost 100%. Although in theory skilled breeders can try to produce seeds from these hybrids by pollinating these with their own set of lines with different restorer genes, two of the three hybrid breeders found that in practice chances to successfully obtain fertile inbred lines in this way were so small that they did not even bother to attempt this. As a result, the CMS-system slows down genetic development, as advances made by one company for a certain plant trait (e.g. storability) are not rapidly combined with advances of another breeder on another trait (e.g. mildew resistance). This favours the breeding company with the leading varieties, but not (organic) farmers who need varieties, which perform well for all priority traits.

Another disadvantage of onion hybrids is the multiplication costs, because seed yields of hybrid onions are generally lower than seed yields of OPs. The difference in seed price between hybrids and OPs becomes even larger when seeds are multiplied organically. Seed company Hoza sells its organic seed of OPs at twice the price of conventional seed of the same variety (Hoza 2007), while seed company Bejo calculates that organically multiplied hybrid seeds cost three times more than conventionally multiplied hybrid seeds (van der Zeijden 2003). Farmers consider the high costs of organically multiplied hybrid seeds a problem. The price difference also motivated a small group of organic farmers to get involved in the organic multiplication of OP varieties. However, because most breeding companies focus on hybrids, variety choice within the group of OPs is limited.

Conclusions and perspectives

Do breeders' selection traits match organic farmers' priorities?

Although breeders develop varieties for the conventional market, the bulb and storage traits they select for coincide with organic farmers' priority traits. This is because traders mainly export organic onions to conventional supermarkets and their quality standards for organic onions are similar to their conventional standards. Due to the strong influence of traders there are also only minor differences between breeders in priorities for bulb and storage traits.

Besides the importance of bulb quality, organic farmers also need a good field performance under organic growing conditions. However, for all breeders selection in the field has a low priority. Yet, breeders differ in their approach in the field: two of the interviewed breeders make very few or no field observations, while the other two screened their plants under a conventional cropping regime, as well as under sub-optimal growing conditions (one with less fungicides, the other with no fungicides and fertilizers at all).

Despite the limited attention to the field not all farmers' priority field traits are neglected by breeders. Most breeders and organic farmers share a preference for an erect plant type, but for different reasons. For organic farmers this plant type makes mechanical weeding easier, while breeders want to prevent lodging of the crop. So, remarkably, a similar plant type is required to address two different problems that both are unique to either only the organic or only the conventional cropping system.

Also breeders aim at downy mildew and leaf blight resistance that are among the top priorities of organic farmers. The breeders' approach is strongly focused on resistance genes of related *Allium* species, because only these have been reported to confer the high level of resistance that is required by the conventional market. Field resistance, that is present in *Rijnsburger* populations, and other traits such as more wax and early bulbing that may help to diminish problems with diseases, do not receive priority. This is because they expect that the effect will be too limited to allow for a significant reduction of fungicide use. Organic farmers also prefer a high level of resistance, but they do not want to rely solely on monogenic resistances to single diseases. To avoid the risk of a break-down of such resistance genes, other traits that contribute to general plant health remain important. But even the two breeders who claim to pay more attention to observations in the field, state that field results receive low priority in decision making.

Finally, farmers wish to have varieties that show a good vegetative development. They think that better rooting varieties with an enhanced symbiosis with

AMF may contribute to this. Breeders do not observe AMF. Two breeders did evaluate the rooting systems, but again they gave this trait a low priority in their selection.

The selection environment

The selection environment may also influence the results of a breeding programme. Empirical evidence of the Dutch breeders shows that selection progress towards an improved root system is better in a drought or nitrogen stress environment. A larger root system is also thought to be an advantage for an organic crop, because nitrogen is scarce early in the season. As the breeders' experience implicates that material selected in stress environments may already be an improvement for organic farmers, selecting in an organic environment may even enhance the chance to find better adapted varieties. A shift in selection environment, during a part of the breeding programme, seems more feasible for breeding companies than a shift in priority traits. This is because conventional companies are not interested in varieties with traits that are only interesting for a specific niche market.

Perspectives of obtaining varieties for the organic sector through conventional breeding programmes

From the above it becomes clear that for bulb quality traits the conventional seed sector can supply organic farmers with varieties that fulfil their requirements. The reason for this is that the Dutch organic sector mainly supplies a market that employs conventional quality standards. However, for a targeted improvement of the required field traits a shift in priority traits is required. Breeders themselves also indicate that they would dedicate more time in the field, if they would aim at breeding for the organic sector. However, as long as the organic seed market remains limited, private breeding companies will not make this shift.

The majority of conventional breeding companies have decided to abandon OP onion breeding for the Dutch market and since a decade new varieties are mainly hybrids. To produce these hybrids, breeders use cytoplasmic male sterility. As the fertility restorer genes are not publicly available, this breeding methodology conflicts with the organic principles of the world umbrella organization for organic farming IFOAM.

If in the future the organic seed market will grow, conventional breeders might consider taking organic preferences for key traits into account. However, it is less likely that seed companies that currently use CMS-hybridisation methodology will be prepared to adapt this methodology to the organic principles, by e.g. making restorer genes publicly available. The latter would require a change in company policy, while adapting to the needs of new promising markets is part of the existing policies.

At present conventional breeders can provide varieties that comply with organic farmers' demands for storability and quality traits, but are not giving priority to the required field traits. If in the future the organic seed market will grow, breeders may also pay more attention to field selection. However, if the organic sector wants both varieties that perform well in their production system as well as varieties that are developed according to their principles, it should either set up its own onion breeding programme or seek alliances with breeding companies that are prepared to harmonize their breeding methodology with the organic principles.

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