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Broadening the genetic base of onion to develop better-adapted varieties for organic farming systems

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Summary

As organic farming refrains from high and chemical inputs it needs varieties better adapted to organic conditions to improve the yield stability and quality of crops. In order to make genebank accessions more accessible for the utilisation in organic breeding programmes, a participatory research project with farmers was carried out in 2002 and 2003. From the Dutch genebank collection 37 onion accessions, divided into five different groups (according to their market use), were selected and planted at a commercial organic farm. Farmer participation in characterisation and evaluation of the material resulted in including additional plant traits for genebank characterisation as well as new selection criteria for breeding. It also provided researchers insight into how organic farmers evaluate and value certain plant traits. Variation for important properties was found within and between the five groups. To establish base populations, the farmers, in collaboration with the researchers, selected the best genotypes within the five groups of onion accessions. The new base populations may be exploited in order to achieve better-adapted material for organic farming systems.

Introduction

Organic farmers depend on varieties bred for conventional high-input farming systems. Organic farmers in north-western Europe benefit from the improvements made by modern breeding activities. However, the fact that most of them use modern varieties does not imply that these are the best varieties for optimising their cropping system. As organic farming refrains from high and chemical inputs it needs reliable varieties better adapted to organic growing conditions to improve the yield stability and quality (Lammerts van Bueren et al., 2002). For this type of varieties, additional characteristics are required. Such specific variety requirements have been identified by Dutch organic onion growers during the assessment of onion variety trials under organic conditions in 2001 and 2002 (Lammerts van Bueren et al., 2003). This resulted in a crop ideotype for organic, long storable onion cultivation as given in Table 1. Most traits added by the farmers are quantitative traits indirectly supporting yield potential and stability. Farmers look for traits, such as a denser root system, that support the reduction of stress, through efficient use of organic fertilisers and moisture. But also leaf morphological traits such as leaf waxiness are considered to be necessary to reduce the risk of diseases. Next to disease resistances, also early maturing types are required to gain sufficient yield before downy mildew falls in. They also considered the appearance of dead leaf tips as an indication for sensitivity to stress conditions.

Exploiting genebank material can be valuable, as certain required properties might have disappeared by selection under modern, high input conditions. This is

Table 1. Crop ideotype for organic, long storable onions (adapted after Lammerts van Bueren et al., 2003)

Characteristics	Minimum	Ideal	Priority
Productivity	Nett after storage 30 t/ha	Nett after storage 35 t/ha with good yield stability	+++
Efficient use of organic fertilisers and moisture			
Sufficient leaf quantity[1]	6	8	+
No dead leaf tips[1]	6	8	+
Sufficient roots[1]	6	8	+
Ability to interact with mycorrhizae[1]	6	8	+
Disease and pest resistance			
Botrytis aclada	6	8	+
Botrytis squamosa	6	8	++
Fusarium	6	8	+
Peronspora destructor	6	8	+++
Thrips tabaci	6	8	+
Reducing risk of diseases			
Leaf waxiness[1]	6	8	+
Sufficient root system[1]	6	8	+
Sufficient leaf quantity[1]	6	8	+
Dead leaf tips[1]	6	8	+
Growth period	Early bulbing with a maximum of 127 growing days	Early bulbing with a maximum of 127 growing days	+++
Supporting weed management			
Erect foliage attitude	5–7	7	+
Storage quality			
Long-term storability	Yellow onion: 90% until Febr., Red onion: 90% until Jan.	Yellow onion: >95% until April, Red onion: >95% until March	+++
Neck width	Narrow to medium	Narrow	+++
Long dormancy	Few sprouting (1%)	No sprouting	+++
Hardiness	95[2]	>95[2]	+++
Number of skins	>2 dry skins	>2 dry skins	+++
Skin firmness	>96%, not below average	>96%, not below average	+++
Bulb characteristics			
Uniformity	6–7	8	++
Skin colour	Yellow, not weather-beaten	Yellow	+
Flesh colour	Even white/yellow without green venation	Even white/yellow without green venation	+

[1]For these characteristics there are no science-based selection criteria developed yet.
[2]On a scale 1–100.

confirmed by research of De Melo (2003) who found that old Dutch varieties showed a higher root density than modern varieties. Establishing base populations from old open pollinating onion varieties with a broad genetic diversity can therefore offer new gene pools for further breeding of varieties for low-input and organic farming systems.

In order to make genebank accessions of onions better accessible to organic breeding programmes, an initial participatory breeding project was conducted in 2002 and 2003 to characterise, evaluate, select promising material and to produce base populations (Lammerts van Bueren et al., 2004). The partners in this project were the Centre for Genetic Resources, The Netherlands (CGN), Louis Bolk Institute (LBI, specialised in research for organic farming) and three experienced organic farmers, specialised in the cultivation and selection of onion.

Materials and methods

To characterise, evaluate and select promising material, and to produce base populations, 37 old open pollinated onion accessions were selected, nearly all orginating from the CGN collection (Boukema, 1999). These were divided into five different groups according to their market use: Round Rijnsburger Group (13), Flat Rijnsburger Group (7), Red Flat Onion Group (4), Zeeuwse Bruine Group (3) and a Group of old Eastern-European varieties (12). More information is included in Table 2. The main criterion for selecting the accessions for this experiment was to use broad variation. The choice was based on the experiences of three previous projects. First of all the experience of the EU project Allium GENRES-CT95-20 'Protecting future European Community crops: a programme to conserve, characterise, evaluate and collect Allium crops and wild species.' In this project, CGN compared old open pollinated varieties to detect near duplicated accessions. Secondly, the results of the participatory project 'Suitable Varieties for Organic Farming' conducted by the Louis Bolk Institute (Lammerts van Bueren et al., 2003). Thirdly, the experiences obtained in the research on root systems of onions by De Melo (2003) were taken into account. Important properties such as leaf quantity, disease tolerance and storability of the bulbs were taken into consideration during the evaluation of the germplasm. The focus was mainly to make use of the variation in old Dutch open pollinated varieties of the yellow round type, following the main interest of the current organic sector. The organic sector has also interest in red types, and therefore a small group of red types was included. Flat types were included because of the experience of their good root systems. A group of Eastern European onion accessions was added because of their potential tolerance against diseases, such as downy mildew. Finally the groups were completed with a number of standard, open pollinated varieties, which are currently cultivated by organic farmers (e.g. Red Barron, Promo, Balstora and Balusta).

In the first year (2002) the selected accessions were evaluated under organic farming conditions based on criteria important for organic onion growers. Therefore, the accessions were sown and seedlings were planted on a commercial organic farm. The farmer carried out all cultural practices and after harvest managed the storage of the onions. Researchers of CGN characterised the populations in the field at the full leaf stage (early August) and shortly after harvest (early September) using their internal standard descriptor list based on the IPGRI Descriptors for *Allium* (IPGRI et al., 2001). The participating farmers assessed these accessions at the same time as the CGN researchers. The assessment of the storability was conducted at the end of February 2003. Based on the ideotype for the organic onion crop, developed by the farmers in an earlier research project (Table 1), additional plant traits were added to the descriptor list of the CGN-researchers, see Table 3.

In 2003 the establishment of several new base populations as a start for low-input or organic breeding programmes was conducted. To establish such base populations, the group selected the best genotypes within the five groups of onion accessions, particularly based on the field performance and the bulb and storage properties. The farmers started the first round of selection in August 2002 by marking the selected plants. These selected plants were harvested and stored separately. The final selection took place in February after assessment of the bulb and storage properties of the preselected plants, but also among the other stored bulbs. The farmers have not only related the selection criteria to their own farming requirements but focussed on a broader view of requirements for the organic sector.

To produce seeds of the base populations, selected bulbs of six separate groups were planted in isolation cages in the greenhouse facilities of CGN and pollination was carried out by blow flies. Included were the best selected genotypes of each of the five original groups and an extra group selected from the most promising Round Rijnsburger accessions. Just before flowering, the farmers excluded those plants that produced flowering stems too late, or those that formed five or more flowering stems or none at all.

Results

Characterisation

The result of the characterisation of the accessions is given in Table 4. The joint characterisation and evaluation provides researchers insight into how farmers evaluate and value certain plant traits. As a number of traits, such as foliage attitude, leaf quantity and bulb uniformity, were assessed both by the farmers and the researchers of the gene bank, the results could be compared, see Table 4. Obviously, the focus of the two groups was somewhat different. CGN characterised the accessions according to their standard descriptor list of onion using a number of standard varieties as

Table 2. List of selected accessions for evaluation under organic conditions, Swifterbant (2002)

Seed source/ANR[1]	Name[2]	Origin	Number of plants at the start[3]	General impression	Number of bulbs selected[4]	Percentage of selected bulbs (%)[5]
	Round Rijnsburger Group					
CGN14754	Rijnsb. Noordhollandse Bolronde-Group 1	NLD	110	8	18	9.1
CGN14739	Rijnsburger-sel.Maelstede Group 1	NLD	111	8	13	6.6
CGN18737	Early Rijnsburger-Group 1	NLD	109	7/8	24	12.1
CGN873540	Rijnsburger-Pikeur	NLD	109	7/8	19	9.6
HRI5521	Rijnsburger-Luctor	NLD	37	6/7	8	4.1
CGN16354	Rijnsburger-Krano	NLD	100	7/8	9	4.5
CGN14729	Rijnsburger-Sublima	NLD	124	8/9	21	10.6
HRI4128	Rijnsburger-Bola	NLD	42	6/7	9	4.5
CGN14722	Selection Spalding	GBR	96	5	14	7.1
CGN16367	Compas	NLD	61	5/7	9	4.5
CGN14721	Selection Westerloo	NLD	107	5/6	2	1.0
Standard	Promo/Nickerson Zwaan	NLD	95	7	32	16.2
Standard	Balstora/Bejo Seeds	NLD			30[6]	15.1
	Total				198	100
	Yellow Flat Rijnsburger Group					
CGN14745	Noordhollandse Strogele-Group 1	NLD	103	7	21	12.5
CGN14741	Stuttgarter-Group 1	NLD	106	6	21	12.5
CGN16355	Zefa	CHE	105	6/7	23	13.7
CGN14742	Zittauer-Group 1	NLD	86	6/7	16	9.6
CGN16361	Bronze Kugel	DEU	109	5/6	20	12.0
CGN14743	Zwijndrechtse Poot-Group 1	NLD	105	8	37	22.2
CGN16357	Gelber Wiener	NLD	105	6/7	29	17.3
	Total				167	100
	Red Flat Onion Group					
CGN14744	Noordhollandse Bloedrode-Group 1	NLD	95	8	8	22.0
CGN010601	Rouge Fonce	FRA	92	7	12	19.0
CGN14733	Red Wethersfield	NLD	108	7	3	4.7
CGN16363	Danilovsky 301 Elite 180	SUN	92	5	0	0
Standard	Red Baron/Bejo Seeds	NLD			40[6]	63.5
	Total				63	100
	Zeeuwse Bruine group					
CGN14756	Rijnsburger Zeeuwen-Group 1	NLD	125	8	40	45.5
HRI132	Rijnsburger-Enormus	NLD	68	6/7	15	17.0
Standard	Balusta/Bakker Brothers	NLD	105	7	33	37.5
	Total				88	100
	Eastern-Europe Group					
CGN14726	Wolska Type From Poland	POL	85	3	17	15.9
CGN14740	Wolska-Group 1	NLD	105	6	28	26.2
HRI8428	Wolska	POL	38	3	6	5.6
CGN16366	Vsetatska	CSK	84	2	12	11.2
CGN14755	Strigunovskii-Group 1	NLD	99	4/5	14	13.1
CGN16362	Zolotoj	SUN	101	4	4	3.7
CGN14731	Markovskii	BGR	98	3/4	7	6.5

(*Continued on next page*)

Table 2. (*Continued*)

Seed source/ANR[1]	Name[2]	Origin	Number of plants at the start[3]	General impression	Number of bulbs selected[4]	Percentage of selected bulbs (%)[5]
CGN16376		BGR	90	1	0	0
CGN14753	Ptujski-Group 1	NLD	95	3/4	0	0
CGN14752	Skwirskii-Group 1	NLD	90	2	0	0
CGN14757	Kasticka-Group 1	NLD	85	5	20	18.7
	Total				107	100

[1]HRI = Horticultural Research Institute, UK; CGN = Centre for Genetic Resources, The Netherlands.
[2]Groups formed by CGN by bulking closely related accessions of one type together as one population during regeneration.
[3]Present at 13 June 2002.
[4]Minus the number of plants removed before flowering which were too late in flowering or had more than five flowering stems.
[5]Percentage of selected bulbs with respect to the total number of bulbs selected in the group.
[6]Added from a production field.

Table 3. Descriptor list for characterisation and evaluation used by CGN and the farmers/LBI

Growth phase	Traits used by CGN	Traits used by both CGN and farmers	Traits used by farmers
Leaf	Leaf length	Leaf quantity	Dead leaf tips
	Leaf width	Foliage attitude	*Botrytis squamosa*
	Leaf cranking	Leaf colour	*Peronospora destructor*
	Leaf waxiness		Crop uniformity
			Maturity type
Harvest	Bulb size	Bulb colour	Ideal farmer's onion type[1]
	Bulb shape	Bulb uniformity	Yield potential[2]
	Bulb length		Bulb hardiness
	Bulb top shape		Neck thickness
	Bulb base shape		General impression
	Bulb skin colour intensity		
	Bulb splitting tendency		
	Bulb root disk position		
Storage	–	–	Bulb hardiness
			Number of skins
			Skin firmness

[1]Ideal farmer's onion type means a combination of form and size compatible to the current market requirements.
[2]Yield potential includes bulb size, bulb uniformity and grading.

a point of reference. The farmers focussed particularly on traits to be used for further selection and not merely characterised the accessions, but also assessed the traits on usefulness for cultivation from a farmer's point of view. Farmers tended to maximise differences in scores, and the differences in minimum and maximum scores were therefore greater than those of the CGN scores (e.g. foliage attitude). With a trait such as leaf quantity, the scores of the farmers were sometimes lower than values given by the researchers, because the farmers were more critical on the quantity of leaves which is acceptable under organic conditions. The same applies for leaf colour. Also farmers assessed the criterion bulb uniformity less precisely, because they were merely interested in the uniformity of size, shape and the occurrence of deviations, such as thick-necked onions or double centres. Although the accessions in the Eastern-Europe Group performed better in leaf healthiness traits and showed less dead leaf tips, the overall scores for general impression of these accessions was lower than that of the other groups, see Table 2. This was mostly due to a larger variation within some of the accessions of the Eastern-Europe Group for yield potential. This group, however, scored better for

Table 4. Results of the characterisation of onion accessions under organic conditions by farmers and CGN-researchers, Swifterbant 2002/2003

		Evaluation by																			
		Farmers							Farmers	CGN	Farmers	CGN	Farmers	CGN	CGN						
Group		Dead leaf tips	*Peronospora destructor*	*Botrytis squamosa*	Maturrity type	Crop unifomrity	Yield potential	Thick necks	Foliage attitude	Foliage attitude	Leaf quantity	Leaf quantity	Bulb uniformity	Bulb uniformity	Leaf colour	Leaf cranking	Leaf waxiness	Bulb size	Bulb length	Bulb skin colour	Bulb splitting tendency
Round Rijnsburger Group	Mean	5,8	5,6	6,1	6,2	6,4	7,0	6,5	4,1	6,9	6,1	6,1	7,1	5,3	5,8	1,8	5,8	5,2	5,7	3,0	1,2
	Min	4	4	6	5	5	5	4	3	6	4	4	5	4	5	1	5	4	5	3	1
	Max	7	7	7	8	8	9	8	6	7	7,5	7	9	6	6	3	6	6	6	3	3
Yellow Flat Rijnsburger Group	Mean	6,2	6,1	6,4	6,3	6,1	6,7	6,9	3,7	6,7	6,2	6,6	6,5	5,6	5,9	2,0	5,9	5,4	6,6	3,0	1,1
	Min	6	5	5	4	4	4	5	3	6	4	4	4	5	5	1	5	5	5	3	1
	Max	7	7	7	7	8	8	9	4	7	7	8	8	6	6	3	6	6	8	3	2
Red Flat Onion Group	Mean	6,3	6,5	6,2	7,2	6,1	6,3	8,2	5,0	7,0	6,3	5,3	8,0	6,0	6,7	1,3	6,3	5,0	7,7	4,0	1,0
	Min	6	6	5	7	5	6	8	4	7	6	5	8	5	6	1	6	5	7	4	1
	Max	7	7	7	7,5	7	7	9	7	7	7	6	8	7	7	2	7	5	8	4	1
Zeeuwse bruine Group	Mean	7,0	6,8	7,2	5,8	6,3	7,8	6,3	3,7	6,7	7,3	7,3	6,5	5,3	6,0	1,3	6,0	5,7	5,7	3,0	1,0
	Min	6	6	6	4	6	7	5	3	6	7	6	5	5	5	1	6	5	5	3	1
	Max	8	8	8	7	7	9	8	5	7	8	9	8	6	6	2	6	6	6	3	1
Eastern- Europe Group	Mean	6,8	7,0	6,0	5,5	4,6	3,3	4,3	5,2	6,8	5,1	5,3	5,0	5,2	6,0	1,3	6,5	4,5	6,3	3,2	1,0
	Min	6	5	4	4	3	1	1	3	6	3	4	4	4	5	1	6	4	5	3	1
	Max	8	8	8	7	6	8	8	7	7	8	7	7	6	7	3	7	6	8	4	1

Note. Explanation of the scores: Dead leaf tips: 1 = large amount, 9 = very few; *Peronospora destr.*: 1 = large amount, 9 = very few; *Botrytis squamosa*: 1 = large amount, 9 = very few; Maturity type: 1 = very late, 9 = very early; Crop uniformity: 1 = very low, 9 = very high; Yield potential: 1 = very low, 9 = very high; Thick necks: 1 = large amount, 9 = very few; Foliage attitude: 3 = horizontal, 5 = semi erect, 7 = erect; Leaf quantity: 1 = very few, 9 = large amount; Bulb uniformity: 1 = very low, 9 = very high; Leaf colour: 3 = light green, 5 = medium, 7 = dark; Leaf cranking: 3 = weak, 5 = medium, 7 = strong; Leaf waxiness: 3 = weak, 5 = medium, 7 = strong; Bulb size: 3 = small, 5 = medium, 7 = large, 9 = very large; Bulb length: 3 = broad elliptic, 5 = broad ovate, 7 = rhombic; Bulb skin colour: 3 = yellow to brown, 4 = red, 5 = violet, 6 = green; Bulb splitting tendency: 1 = absent, 3 = weak, 5 = medium, 7 = strong.

aspects such as leaf waxiness, which the farmers also considered to be of interest to support tolerance against diseases.

Selection and production of the base populations

With respect to the purpose of evaluating the accessions for further exploitation for organic farming systems, it was noticed that within the studied open pollinated varieties substantial diversity was observed, see Table 4. Variation for important properties was found within and between the five groups. In Table 2 an overview is given of the individual accessions and of the total percentages of selected bulbs per accession. The healthiness of the leaves in the Eastern-European Group was notable. However, some of the accessions of the Eastern-European Group were performing very poorly and no plants of such accessions were selected. In the five best performing accessions of the Round Rijnsburger Group additional bulbs were selected to establish an extra base population. This base population may be used for selecting rapidly a marketable variety for organic farming systems. The farmers were mostly focussed on the Round Rijnsburger types, and will look for interesting parent plants out of the other populations to add useful traits for further breeding for organic agriculture.

Seeds of six new base onion populations are now available for organic breeding programmes, and will be used for further selection. In 2004, a new selection program started in two of the created base populations (Round Rijnsburger Group and Yellow Flat Rijnsburger Group). The group also defined six high performing accessions with a score on the general impression of 8 or higher, which may also be exploited on their own in order to achieve improved genotypes for organic farming systems. It includes three accessions from the Round Rijnsburger Group and one each of the other groups with the exception of the Eastern-European Group.

Conclusions

We learned from this project that participation of organic farmers in the evaluation of the accessions is a useful method to make genebank accessions of onions better accessible for the utilisation in organic breeding programmes. Farmer participation in characterisation and evaluation of the material resulted in including additional plant traits for genebank characterisation as well as new selection criteria for breeding. It also provided researchers insight into how organic farmers evaluate and value certain plant traits. However, it should be noted that not all traits important for organic farming are easy to evaluate by genebanks within their normal programmes. This is because genebanks usually combine characterisations with regeneration and multiplication of the collection. The conditions to be able to characterise some of the important traits compete with conditions for merely multiplication. The standard procedure includes the use of agro-chemicals against pests and diseases and therefore disease resistance cannot be evaluated. Usually storage ability is not assessed because of lack of storage facilities. Without extra financing a genebank cannot provide the extra information on accessions which is important for the organic sector.

Variation for important properties was found within and between the five groups of accessions. This research project resulted therefore in the selection of germplasm for six base populations with traits that are appropriate for starting a breeding programme for organic agriculture. The first group of Rijnsburger types has a genetic background that is closely related to the current modern cultivars. But it offers the possibility to select anew from the original broad genetic base for the organic sector without the risk that important traits might have disappeared during selection under high-input conditions.

So far CGN has not established base populations. It may be possible that in the future the demand from breeding companies for genetic base broadening will increase and that the establishment and maintenance of base populations will fulfil this need. It certainly serves the needs of the organic agriculture to select better-adapted varieties from a broad genetic base.

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