Participatory plant breeding: a way to arrive at better-adapted onion varieties

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Abstract
The search for varieties that are better adapted to organic farming is a current topic in the organic sector. Breeding programmes specific for organic agriculture should solve this problem. Collaborating with organic farmers in such programmes, particularly in the selection process, can potentially result in varieties better adapted to their needs. Here, we assume that organic farmers' perceptive of plant health is broader than that of conventional breeders. Two organic onion farmers and one conventional onion breeder were monitored in their selection activities in 2004 and 2005 in order to verify whether and in which way this broader view on plant health contributes to improvement of organic varieties. They made selections by positive mass selection in three segregating populations under organic conditions. The monitoring showed that the organic farmers selected in the field for earliness and downy mildew and after storage for bulb characteristics. The conventional breeder selected only after storage. Farmers and breeder applied identical selection directions for bulb traits as a round shape, better hardness and skin firmness. This resulted in smaller bulbs in the breeders' populations, while the bulbs in the farmer populations were bigger than in the original population. In 2006 and 2007 the new onion populations will be compared with each other and the original populations to determine the selection response.

Introduction
The organic sector requires varieties that are better adapted to organic conditions to improve yield stability and quality (Lammerts van Bueren *et al*., 2002). Nowadays, organic farmers have to depend on varieties selected under conventional conditions with high nitrogen input, mineral fertilizers and other synthetic inputs. However, these varieties are not the most suitable ones for organic cropping systems. Breeding varieties specific for organic agriculture may solve this problem. The organic sector is a new niche market for public breeding companies, but these lack specific knowledge on organic agriculture and farmer demands. For this reason participatory plant breeding can be a powerful tool to meet the needs of organic agriculture appropriately. Participatory plant breeding is based on a set of methods that involve close farmer-researcher collaboration. The interaction between farmers and researchers/breeders can be various and depends on: 1, the stage of the breeding process at which farmers interact with breeders; 2, the location where selection and testing of germplasm takes place; 3, the design and management of the germplasm evaluation process (Morris and Bellon, 2004). Lammerts van Bueren, Van den Broek and Ter Berg (2003) identified specific organic onion variety requirements in collaboration with Dutch organic onion farmers during the assessment of onion variety trials under organic conditions in 2001 and 2002 and defined a crop ideotype for organic, long storable onion varieties that can be used by breeders. Soleri (2000) showed the benefits of farmer participation in selecting in segregating populations. According to some authors however, farmer involvement in the actual selection process need not be essential (Morris and Bellon, 2004; Witcombe *et al.,* 2005a). But, in some circumstances such collaboration is desirable or even essential. For instance, in the case of market failure there is no incentive to breed new varieties (Witcombe *et al,* 2005b). This is more or less the case for organic onion varieties in the Netherlands. It is not profitable for public breeding companies to run an organic onion breeding programme since the organic onion production area is too small.
Our assumption is that organic farmers perceive plant health differently than conventional breeders, because of their daily experience in organic onion cultivation. We would like to know whether and in which way their broader view will contribute to improvement of organic onion varieties. For that purpose we monitored two organic onion farmer breeders and one conventional onion breeder in their selection activities in three segregating onion populations for two years.

Material en methods

The influence of participation of organic farmers in the selection process was investigated by monitoring the selection activities and results of two onion farmer breeders and one conventional onion breeder. All three conducted their selections independently under organic growing conditions in three segregating populations, aiming at the development of an onion variety well adapted to organic conditions, including storability without sprouting inhibitors. Two of these base populations, Round Rijnsburger Group and Yellow Flat Rijnsburger Group have been developed by open pollination of several onion gene bank accessions, that were selected for good performance under organic conditions in collaboration with organic onion farmers (Lammerts van Bueren *et al.*, 2005). The third population used in this study was Balstora, an open pollinated variety. 10.000 seeds per population were used for selection. This research project runs from 2004 to 2007, which means we can select just in one generation, since onion is a biennial crop. Therefore, to gain more reliable data, we decided to select twice (in 2004 and 2005) in the original populations. In 2005 and 2006 the selected bulbs were planted for seed production. In 2006 and 2007 the selection response (R) will be determined by $R = h^2 * S$ (h^2 = narrow sense heritability, S = selection differential, the difference between the mean of the original population and the mean of the selection (Simmonds, 1979)). A field experiment will be conducted on two organic farms to compare the selections (F2) with each other and the original populations. The most important criteria to evaluate the new selections will be yield, plant health, earliness, bulb shape and storability. Figure 1 shows the time schedule of the project.

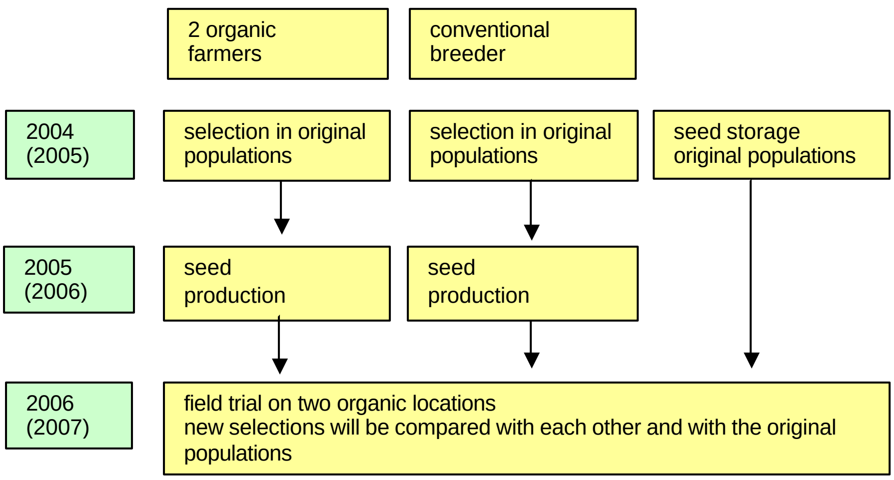

Figure 1. Time schedule of the research project.

Table 1. Evaluated characteristics of plant and bulb

Plant in the field	Bulb after harvest	Bulb after storage
foliage attitude	width of neck	intensity of basic colour of dry skin
leaf quantity	position of maximum diameter	hardness
leaf length (cm)	general shape (in longitudinal section)	number of dry skins
leaf width (cm)	shape of top	skin firmness
length of neck (cm)	shape of base	splitting (%)
foliage cranking	bulb size	percentage red onions
dead leaf tips		uniformity of the population
downy mildew		sprouting during storage
botrytis leaf blight		
earliness		

The selection differential S was determined by monitoring the selection process and the selection results in 2004 and 2005. First, the original populations were described by characterising 30 randomly chosen plants in the field and bulbs after storage for a number of selected traits (table 1) according to the UPOV standards (scoring from 1 to 9) (UPOV, 1999). Hereafter, the farmers and breeder made their selections. From these again 30 plants or bulbs were chosen randomly and characterized by the same criteria. The differences between the original populations and the new selections were evaluated using Students t-tests with statistical significance set at $P < 0{,}05$. If the difference was significant the standardized selection differential S was calculated by $((\mu 1 - \mu 2)/sed1$, whereas $\mu 1$ = mean original population, $\mu 2$ = mean new selection and sed1 = standard deviation of the original population). Expression of S in standard deviation units allows comparison of selections among populations with different amounts or types of variation (Falconer, 1989). The standardized selection differential is used to compare the selection effort of the farmers and the breeder.

Results

The selection method of both organic farmers and the breeder was followed and documented for two years. They applied positive mass selection.

Field selection

The most striking difference in the selection method between the farmers and the breeder was the selection in the field. The farmers selected individual plants in the field and harvested them separately for storage. These bulbs formed about ten percent of the final number of bulbs selected after storage. The formal breeder did not select in the field at all, but only after storage of the bulbs. Both farmers said they selected actively for early and/or healthy (non affected) and vigorous plants by marking them in the field. However, implicitly they also selected for other traits such as foliage attitude (more erect), leaf length, leaf quantity and length of the neck (table 2).

Table 2 shows the standardized selection differential for several plant characteristics, combined for 2004 and 2005. Whether the difference between the selection and the original population is significant (significant t-test) depends not only on the selection effort that is made, but also on the variation for a specific trait in the original population and the mean level of this trait. In the case of little variation in the original population it is hard to select and make some progress. When, of course, the population meets already the required level for a specific trait then it is not necessary to select for this trait and the difference between the original population and the selection will not be significant. It is clear from table 2 that, according to the farmers, earliness is the most important trait to select for. Figure 2 shows that all selections were significantly earlier than the original populations.

Table 2. Mean standardized selection differentials (S) of field characteristics 2004 en 2005 and the percentage t-tests that were significant, P<0,05.

	Foliage attitude	Leaf quantity	Leaf length	Leaf width	Foliage cranking	Downy mildew	Botrytis leaf blight	Dead leaf tips	Neck length	Earliness
% significant t-test	43	57	71	14	0	43	14	0	43	100
S overall mean (n=7)*	**0.69**	**0.72**	**0.98**	**0.78**		**1.12**	**1.23**		**0.94**	**1.99**

* One organic farmer made selections in all three original populations in the two years, the other organic farmer selected only in the Round Rijnsburger Group in 2004.

The selection for downy mildew in the field was less strict. Only 43% of the selections differed significantly from the original populations. Most selections were affected more by downy mildew than the original populations as can been seen in figure 3. No significant selection was made for foliage cranking and dead leaf ends. None of the selections differed from the original populations for these two traits, because these traits meet already the required level.

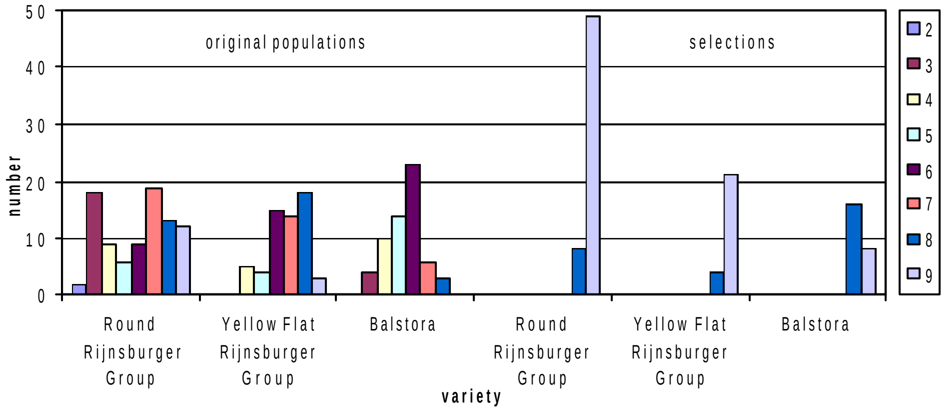

Figure 2. Distribution for earliness of the original populations and the selections of the Round Rijnsburger Group, the Yellow Flat Rijnsburger Group and Balstora, (2 = late, 9 = very early), combined for both farmers and years.

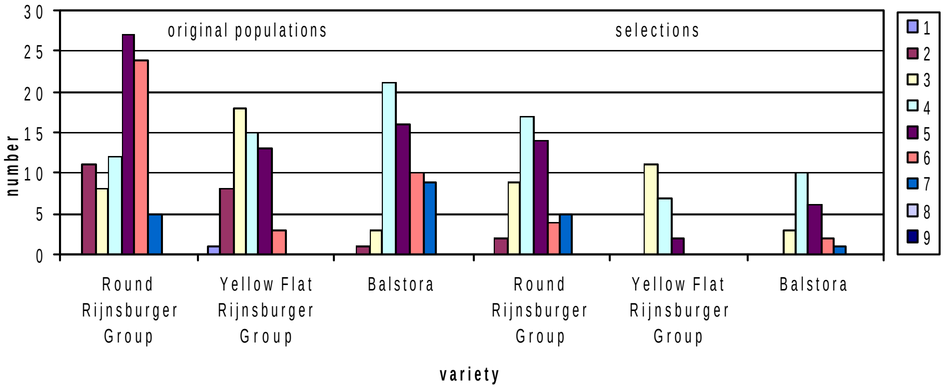

Figure 3. Distribution for susceptibility to downy mildew of the original populations and the selections of the Round Rijnsburger Group, the Yellow Flat Rijnsburger Group and Balstora, (1 = very susceptible, 9 = resistant), combined for both farmers and years.

Bulb selection

Table 3 presents the mean standardized selection differentials for the bulb characteristics. It shows that most of the breeding effort was made for bulb size, bulb shape and storability (hardness, number of skins and skin firmness).

Table 3. Mean standardized selection differentials (S) of bulb characteristics for 2004 en 2005 and the percentage of significant t-tests, P<0,05.

	Bulb size	General shape	Shape of top	Shape of base	Width of neck	Colour intensity	hardness	Number of dry skins	Skin firmness
% significant t-test	62	54	62	54	38	31	46	15	38
Selection differential Farmers (n=7)*	1.16	0.90	0.82	0.73	0.67	0.88	1.43	1.15	0.64
Breeder (n=6)*	0.51	0.64	0.51	0.43	0.48	0.48	0.54	-	0.45

* The breeder and one organic farmer made selections in all three original populations in the two years, the other organic farmer selected only in the Round Rijnsburger Group in 2004.

Bulb size was a more important selection criterion for the farmers than for the formal breeder. As can be seen from the summarized data in table 4, the farmers obviously selected for the bigger bulbs while the breeders' selection consisted of more smaller bulbs. For the other traits the farmers and the breeders selected in the same direction, namely a round bulb (score 4), with a better hardness and skin firmness.

Table 4. Mean scores (2004 and 2005) of several bulb characteristics from the original populations and the selections of both farmers and the breeder.

		Farmer 1		Farmer 2		Breeder	
population	**characteristic**	**original**	**selection**	**original**	**selection**	**original**	**selection**
Round	bulb size	5.3	6.5	5.5	6.6	5.4	4.9
Rijnsburger	bulb shape	5.0	4.3	4.5	4.1	5.3	4.7
Group	hardness	6.7	7.5	7.8	8.0	7.0	7.6
	skin firmness	6.8	7.1	7.2	7.3	6.5	6.5
Yellow Flat	bulb size	5.0	5.3			4.6	3.8
Rijnsburger	bulb shape	6.6	4.7			6.0	5.1
Group	hardness	6.4	7.4			7.2	7.2
	skin firmness	6.8	7.3			6.1	6.5
Balstora	bulb size	4.3	6.1			5.0	4.7
	bulb shape	3.7	4.1			5.1	4.8
	hardness	6.5	7.6			7.2	7.5
	skin firmness	7.4	7.7			7.1	7.5

Note: Explanation of the scores: Bulb size: 3 = small, 5 = medium, 7 = large, 9 = very large, Bulb shape: 1= elliptic, 2 = ovate, 3 = broad elliptic, 4 = round, 5 = broad ovate, 6 = broad obovate, 7 = rhombic, 8 transverse elliptic, 9 = transverse narrow elliptic (flat), Hardness: 5 = not sufficient, 6 = sufficient, 7 = highly sufficient, 8 = good, Skin firmness: 5 = not sufficient, 6 = sufficient, 7 = highly sufficient, 8 = good.

Discussion and conclusions

For this study we hypothesized that organic farmers apply a broader view on plant health when they select the best onions for organic agriculture than conventional breeders and that this will contribute to the development of better adapted varieties to organic conditions. The most striking difference in the approach of the farmers and the breeder appeared during the field season. The farmers selected the most early and healthy plants in the field by marking them and harvesting them separately. The breeder did not select in the field, only during storage. Though the farmers tried to select for healthy plants, most new selections were affected more by downy mildew than the original populations. This is not surprising, because early maturing plants are more susceptible and therefore have a bigger chance to become affected by downy mildew than plants that mature later. On the other hand, early varieties can achieve suitable yields before the crop is destroyed by downy mildew.

So, earliness is a very important trait for both farmers and breeder. Selection in the field at the time of beginning of bolting and foliage fall-over is not the only approach to select for early varieties. According to the farmers and the breeder a longer neck length and a thinner neck also contribute to earliness because then the plant falls over more easily which stimulates ripening. Good ripening is an important condition for storability. This is why both farmers selected for a longer and a thinner neck. Selecting for a thinner neck was the only way for the conventional breeder to select indirectly for earliness after storage, which he did.

Farmers as well as the breeder made selections after storage of the bulbs. The new selections of the farmers and the breeder differed most evidently in bulb size. The farmers selected the largest bulbs while the breeders' selections consisted of more smaller bulbs, due to the higher priority the breeder gave to other traits as shape and storability. The organic farmers believe that larger bulbs have a higher yield potential. The selection direction for the other traits with a relatively high selection effort being bulb shape, hardness and skin firmness, was the same for both farmers and breeder. A round bulb is demanded by the market. Storability is enhanced by a hard bulb with a good skin firmness.

To show the selection response in the field, the original populations and all selections will be sown in two field trials under organic conditions. It should then become clear whether and in which way the selection effort of the farmers and the breeder will have contributed to improvements towards varieties better adapted to organic conditions. We expect that the selection response will be most different for earliness as part of a broader plant health strategy, because of the field selection approach of the farmer breeders. They selected directly for earliness, whereas the conventional breeder only selected indirectly for this criterion.

References

Falconer, D.S., 1989. Introduction to Quantitative Genetics. Third ed. Longman Scientific & Technical, Essex, UK.

Lammerts van Bueren, E.T., Struik, P.C. and E. Jacobsen, 2002. Ecological concepts in organic farming and their consequences for an organic ideotype. Neth J Agric Sci 50:1-26.

Lammerts van Bueren, E.T., van den Broek, R., and C. ter Berg, 2003. Passende Rassen: uien-rassenonderzoek voor biologische bedrijfs-systemen 2001-2002, pp. 60. Louis Bolk Instituut, Driebergen/Praktijkonderzoek Plant en Omgeving-AGV, Lelystad.

Lammerts van Bueren, E.T., van Soest, L.J.M., de Groot, E.C., Boukema, I.W. and A.M. Osman, 2005. Broadening the genetic base of onion to develop better-adapted varieties for organic farming systems. Euphytica 146:125-132.

Morris, M.L. and M.R. Bellon, 2004. Participatory plant breeding research: Opportunities and challenges for the international crop improvement system.

Simmonds, N.W., 1979. Principles of crop improvement. Longman Group Ltd, London, UK.

UPOV, 1999. Guidelines for the conduct of tests for distinctness, uniformity and stability. www.upov.int/en/publications/

Witcombe, J.R., Joshi, K.D., Gyawali, S., Musa, A.M., Johansen, C., Virk, D.S. and B.R. Sthapit, 2005a. Participatory plant breeding is better described as highly client-oriented plant breeding. I. Four indicators of client-orientation in plant breeding. Expl Agric. 41:299-319.

Witcombe, J.R., Gyawali, S., Sunwar, S., Sthapit, B.R. and K.D. Joshi, 2005b. Participatory plant breeding is better described as highly client-oriented plant breeding. II. Optional farmer collaboration in the segregating generations.