Holistic Consideration of the Inheritance and Use of the Potential of On-Farm Selection Shown on the Example of Poma Culta Apple Breeding

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Question

Can on-farm-breeding as a method contribute to improving the assortment of suitable varieties for organic fruit growing? Is it possible to obtain useful breeding results in the foreseeable future without detailed genetic testing?

Preface

Allow me to make a few brief prefaces to my remarks on the holistic view of breeding. The focus of this consideration is on the life processes that take place in our case between the apple tree and its environment with all its biotic and abiotic conditions. The history of these interactions can be found in the genome. The DNA is the basis for the life processes, whether it is the cause or only condition for it, is a philosophical question.
In accordance with the holistic view, the breeding objective is formulated in such a way that the focus in the breeding process is not on solving individual problems, but on optimally adapting the plant to its environment and thus improving the quality of the fruit, optimising the yield and reducing the cultivation risk.

Poma Culta's breeding approach is on farm breeding

As the name implies, this breeding takes place on farm, i.e. under practical conditions. This means that selection takes place under conditions that are as comparable as possible to the situation in which the new varieties later have to prove themselves.
Methodically, the focus is mainly on the selection of phenotypically detectable traits. The simple and efficient collection and processing of data is of great importance. Poma Culta works with a specially designed IT solution.

The conditions on-farm in Hessigkofen 600 m.a.s.l:

- Climate: Location with annual precipitation of around 800 - 1000 mm. Outdoor conditions with the exception of the cultivation of seedlings in unheated polytunnel.

- Soil: The apple seedlings are planted directly from the growing tray into the open field.

- Disease and pest pressure: Due to the climate, there is a high apple scab pressure in most years. Vf resistance has been broken down for 6 years. Due to weather conditions, the pressure for infections with powdery mildew, sooty blotch and *Marssonina coronaria* varies, but is usually sufficient for selection. As a result of the renunciation of direct plant protection measures in selection stage 1, there is a tendency towards increased disease pressure at the entire site. From selection stage 2, the plant protection strategy is as it could be recommended as wel for later cultivation. Poma Culta deliberately avoids the highly effective fungicides copper, net sulphur and lime sulphur, only bicarbonate products and Mycosin are sprayed. Thus selection takes place under much harsher conditions than are currently common in organic farming. No fungicides are used in selection stage 1, i.e. during the juvenile phase of the seedlings, which means that only convars with good growth and high leaf health progress.

- Parental choice: Also the parent trees used for the crossings usually grow under the conditions of the farm. This means that the decisions for the choice of crossing partners are also based on location-relevant observations.

Classical crossbreeding as a standard method

In order to achieve breeding goals, strategies are required that promise success in the foreseeable future with a rational approach. It has to be differentiated whether an improvement of monogenic or polygenic conditional traits is in the foreground. This is decisive for the choice of the method. If, for example, the goal is to additionally equip a Gala with individual resistance genes, but to leave its other traits unchanged, genetic engineering methods are now available that can be used to modify specific sequences on the genome. A great deal of work is being done in this direction around the world today.

In my opinion, classical crossbreeding is still a promising approach when it comes to improving traits that are quantitatively inherited.

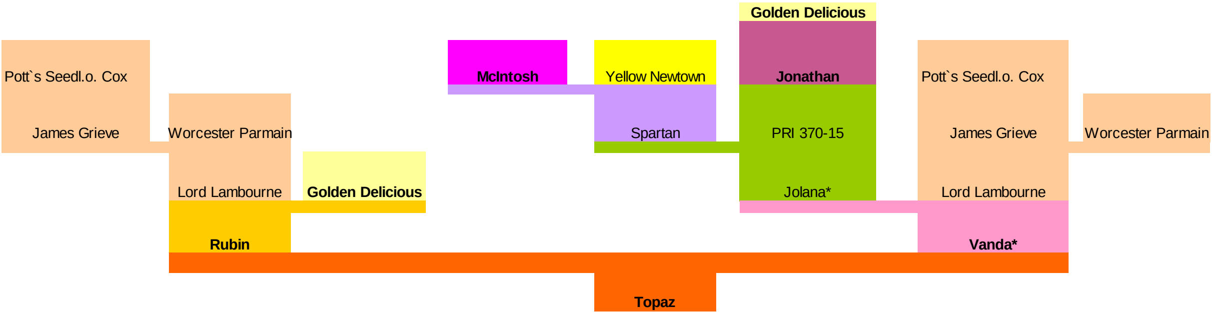
Jules Janick, the well-known American apple breeder, writes in his textbook in the Apple Breeding chapter: Quote: "*Fruit size, shape, and productivity are under polygenic control, which means that when two cultivars are intercrossed there will be a wide and continuous range of expression of all these characters in the seedlings. The range of variation is related to the expression of the characters in the parents and the progeny mean is always related to the parental mean.*" Janick *et al*. (1996)

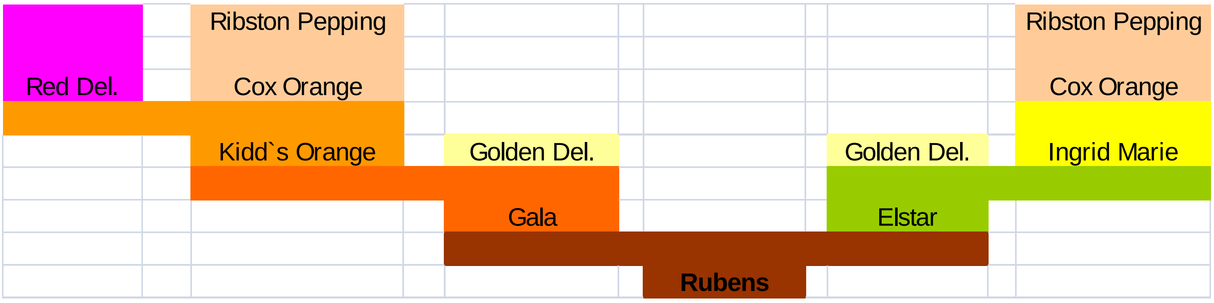
One can still extend the examples mentioned by Jules Janick. Most of the traits of the apple that are important for us are of a quantitative nature. Just think of the aroma, the texture or the shelf life. But growth traits, vitality and resistance to disease also depend on a variety of genes. The fact that there are also monogenic relationships, such as dwarfism, columnar forms etc., does not contradict this.

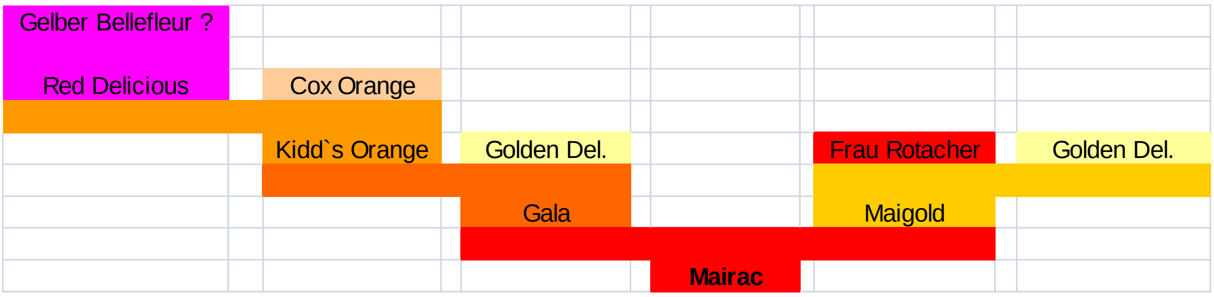
Quantitatively inherited traits cannot be improved abruptly, but only gradually over several generations. It should be noted that traits that are already at a high level, such as fruit size, are retained.

The success of a crossing depends to a large extent on the skillful selection of the parents. Their positive as well as their suboptimal characteristics must be known, especially their interaction with the location. Ideally, cross-breeding partners should be used from whom the highest possible number of valid progeny can be expected. This requires experience that can be gained from the documentation of the selection process over the years.

One difficulty that should not be underestimated is the heterozygosity of the apple caused by obligatory cross-pollination. The degree of heterozygosity could be gradually reduced by means of targeted line breeding, as it is known from animal breeding, in order to anchor genetically more firmly characteristics such as plant health or fruit quality and thus obtain more useful progeny from a crossing. Breeders generally have great respect for negative inbreeding effects. But varieties like Topaz, Rubens or Mairac show, that crossing half siblings has led to successful varieties.







Example for illustration

Convar PoC_3988 comes from the offspring of a cross between the variety Braeburn (favoured fruit quality) and Rewena (progenitor of robustness). In the first step the plant health could be improved significantly. Only the spots known from Rewena (Elsinoe) still occur. The flesh firmness is very good and therefore also the shelf life. The aroma and sugar content proved to be insufficient.

In the following years PoC_3988 was crossed with high quality varieties (Topaz, Rajka, Otava and others). In these offspring convars with good or improved tolerance characteristics were found. Further progress has been made with regard to fruit quality. They are now in the range of older standard varieties. In order to meet the quality requirements of a future top variety, further crossings are necessary.

(See tables in appendix)

Status of breeding and prospects

Over the past 20 years, the breeding of Poma Culta has been successively expanded and has reached a professional level in recent years. Currently there are about 20 valuable convars with partly very good fruit and resistance characteristics, which are used for further crossbreeding. At six locations in various important fruit-growing areas in Europe, trial cultivation is carried out for the internal preliminary clarification of the variety suitability. Eight convars undergo official variety testing at various state stations.

As final remark I would like to invite all colleagues, who are interested in a bigger diversity on apple varieties on the market to get in contact with me, in order to find ways to realise this under the current leagal conditions of the European Community.

Thank you for your attention.

Reference

Jules Janick, James N. Cummins, Susan K. Brown, and Minou Hemmat (1996). Apples. In: J. Janick and J.N. Moore. Fruit Breeding Vol. I. *Tree and Tropical Fruits*, pp. 1 – 77. Wiley, New York.

Appendix

Convar	Parents	Year of Cross	Crispiness	Aroma	Gloeosp.	Elsinoe-Spots	Scab, resist. breaking	Mars.	Sooty Blotch
1. Generation									
Braeburn			++	+++			--	-	---
Rewena			--	--		--	++	-	--
PoC_3988	**Braeburn x Rewena**	**2001**	++	--	+++	--	++	++	+

Convar	Parents	Year of Cross	Crispiness	Aroma	Gloeosp.	Elsinoe-Spots	Scab, resist. breaking	Mars.	Sooty Blotch
2. Generation	**Example 1**								
Otava			+	+++	-		--	---	---
PoC_3988	Braeburn x Rewena	2001	++	--	+++	--	++	++	+
PoC_0700	**Otava x PoC_3988**	**2011**	+	++	++	+	++	++	++

Convar	Parents	Year of Cross	Crispiness	Aroma	Gloeosp.	Elsinoe-Spots	Scab, resist. breaking	Mars.	Sooty Blotch
2. Generation	**Example 2**								
Rajka			+/-	++	+		+/-	---	+/-
PoC_3988	Braeburn x Rewena	2001	++	--	+++	--	++	++	+
PoC_0321	**PoC_3988 x Rajka**	**2011**	++	++	++	+++	+	++	++

Convar	Parents	Year of Cross	Crispiness	Aroma	Gloeosp.	Elsinoe-Spots	Scab, resist. breaking	Mars.	Sooty Blotch
2. Generation	**Example 3**								
Topaz			+	+++	--	-	-	--	--
PoC_3988	Braeburn x Rewena	2001	++	--	+++	--	++	++	+
PoC-1329	**PoC_3988 x Topaz**	**2008**	+++	+	+++	+	+	++	+++

Convar	Parents	Year of Cross	Crispi-ness	Aroma	Gloeo-sporium	Elsinoe-Spots	Scab, resist. br.	M. Co-ronaria	Sooty Blotch
3. Generation	**Fiction**								
PoC-1329	**PoC_3988 x Topaz**	**2008**	**+++**	**+**	**+++**	**+**	**+**	**++**	**+++**
PoC_0321	**PoC_3988 x Rajka**	**2011**	**++**	**++**	**++**	**+++**	**+**	**++**	**++**
PoC_GOAL			**+++**	**+++**	**+++**	**+++**	**++**	**++**	**++**