

Yield and fruit quality parameters of new early-ripening strawberry cultivars in organic growing on a highly *Verticillium*-infested site

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Abstract

For organic strawberry production the choice of cultivar is of high importance. Specific regional characteristics and farmer's preferences have to be considered. For the last decades, 'Elsanta' has been the main cultivar in European strawberry production, on organic as well as on conventional farms, although this cultivar has a high susceptibility to soilborne pathogens and sometimes a lack of flavour. The aim of this work was to find early-ripening cultivars suitable for organic growing in Eastern Austria to sell on the fresh market.

*In spring 2007, 15 cultivars were planted on an organically managed site with a high microsclerotia content of *Verticillium dahliae* in the North of Vienna. The following parameters were assessed in 2008 and 2009: plant vigour, marketable yield, percentage and categories of unmarketable fruits, incidence of the blossom weevil, fruit quality characteristics and consumer acceptance.*

*Because of the high risk for *Verticillium* wilt on the site, the differences in susceptibility of the cultivars could be well documented. Some cultivars showed a medium to high tolerance to root diseases and were also convincing regarding yield and fruit quality.*

As conclusion, some new cultivars could be found which can be recommended as alternatives or supplements to 'Elsanta' for organic production.

Keywords: *Verticillium dahliae*, strawberry, cultivar, organic farming, fruit quality

Introduction

Verticillium wilt is a progressing disease in Eastern Austria, especially on sites where the crop rotations are not arranged properly and strawberries have been grown to a high extent. Nevertheless, the cultivar 'Elsanta' which is susceptible to soilborne diseases (Barth *et al.*, 2002; Spornberger *et al.*, 2005) is still planted on many farms because of its good shelf life and its high popularity. From 2005 to 2007, a field trial on 11 sites was carried out to find alternatives to 'Elsanta' (Weissinger *et al.*, 2009). As a result, 4 early-ripening cultivars ('Alba', 'Clery', 'Daroyal' and 'Queen Elisa') with similar or better qualities in comparison to 'Elsanta' could be found. These 4 cultivars were again tested in the field trial described in this paper. Additionally several early-ripening cultivars which are already on the market in Austria, as well as not yet established cultivars which had been recommended by breeders and nurseries were included in the trial which was carried out on 11 sites in whole. The aim was to find cultivars for the fresh market which are tolerant to *Verticillium* wilt and other diseases, have a high yield and a good fruit quality which is accepted by the consumers. In this paper only the results from one organically managed site, where yield and fruit quality parameters were assessed, are shown and discussed.

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Material and Methods

Cold stored plants of 14 cultivars ('Alba', 'Antea', 'Asia', 'Betty', 'Clery', 'Daroyal', 'Elianny', 'Figaro', 'Galante', 'Gloria', 'Marianna', 'Nr. 96.46.2', 'Queen Elisa', 'Sugar Lia') and of 'Elsanta' as control were planted in April 2007 in the experimental garden of the Institute of Horticulture and Viticulture in the Northeast of Vienna (45 plants of each cultivar, 3 replications). The site (pH 7.4; humus content 4.6%, very high nutrient contents) was highly infested with *V. dahliae* (10 microsclerotia/g soil).

The symptoms of *Verticillium* wilt were evaluated 2 times per year (2008 and 2009) for every single plant: 1=plant without symptoms, 2=weak plant, 3= very weak plant, 4=dead plant. The infestation degree was calculated as following: (number of healthy plants + 2*number of weak plants + 3*number of very weak plants + 4*dead plants)/total number of plants.

In 2008 and 2009 marketable yield and average fruit weight were determined and unmarketable fruits were categorised according to the cause of damage.

Fruit quality analyses were conducted for all cultivars in 2008, but only for 9 cultivars in 2009. In 2008, these 9 cultivars were considered as recommendable ('Alba', 'Antea', 'Asia', 'Clery', 'Daroyal', 'Sugar Lia') or recommendable with reservations ('Betty', 'Elsanta', 'Queen Elisa') (Eggbauer, 2009). For the concerted statistical analysis of fruit quality data, only data of these 9 cultivars were used. To assess fruit firmness (penetrometer, M1000E, Mecmesin) and skin colour (chromameter, CR-200b, Minolta) 10 fruits in 2008 resp. 15 fruits in 2009 per replication and cultivar were measured. After extracting the juice, the following parameter were determined: soluble solids content (refractometer Palette PR-101, Atago), content of titratable acid (TitroLine alpha plus, Schott) and content of ascorbic acid (Reflektometer, RQflex, Merck).

Statistical analysis of data was made with SPSS 12.0 (Variance analysis with post hoc S-N-K-test, $P < 0.05$).

In 2008 and in 2009 tasting sessions were carried out where appearance and taste of fruits were rated on an open scale of 0-164 mm. Because a maximum of 6 cultivars per tasting session was chosen, 3 (2008) resp. 2 (2009) sessions were necessary. 'Elsanta' as reference was included in all sessions. Due to different numbers of ratings per cultivar, no statistical analysis was made.

Results

As the site is highly infested with *V. dahliae*, first wilt symptoms occurred in July 2008. Since then, disease in susceptible cultivars progressed fast (data not shown). In July 2009 "groups" of 'tolerant' ('Daroyal', 'Asia', 'Alba') and 'highly susceptible' cultivars ('Galante', 'Figaro', 'Elianny') could be distinguished. In between gradual differences could be observed. 'Betty', 'Queen Elisa' and 'Clery' had a mean infestation degree below or similar 2 whereas the values of 'Sugar Lia', 'Marianna', 'Antea', 'Gloria', 'Elsanta' and 'Nr. 96.46.2' were between 2 and 2.5. Although 'Elsanta' is known as very susceptible to *Verticillium* wilt, it could be shown that other cultivars were even more affected than 'Elsanta'. Still, the main part of the tested cultivars showed a higher tolerance than 'Elsanta'. Especially 'Daroyal', 'Asia' and 'Alba' showed a high vitality of the plants in all 3 years (Fig. 1).

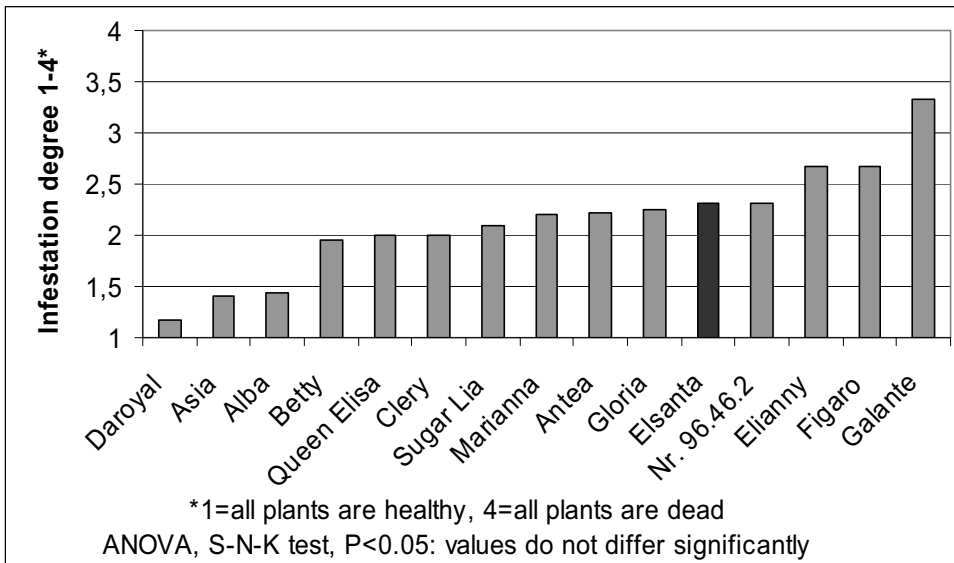


Figure 1: Infestation with *Verticillium dahliae* (2 July 2009)

In 2008, ‘Queen Elisa’, ‘Asia’, ‘Alba’ and ‘Elsanta’ were the cultivars with the highest yield. In 2009, yields were generally much lower than in 2008. ‘Alba’ had the highest yield, followed by ‘Asia’ and ‘Queen Elisa’. All other cultivars, including ‘Elsanta’, produced much less fruits. For ‘Elsanta’, the difference in yield between 2008 and 2009 was particularly high. Summing up the harvest of 2008 and 2009, ‘Alba’, ‘Queen Elisa’ and ‘Asia’ had a significantly higher yield than all other cultivars. ‘Galante’ produced very few fruits and differed significantly from ‘Betty’, ‘Marianna’, ‘Clery’, ‘Sugar Lia’, ‘Elsanta’, ‘Daroyal’, ‘Antea’, ‘Asia’, ‘Queen Elisa’ and ‘Alba’ (Fig. 2).

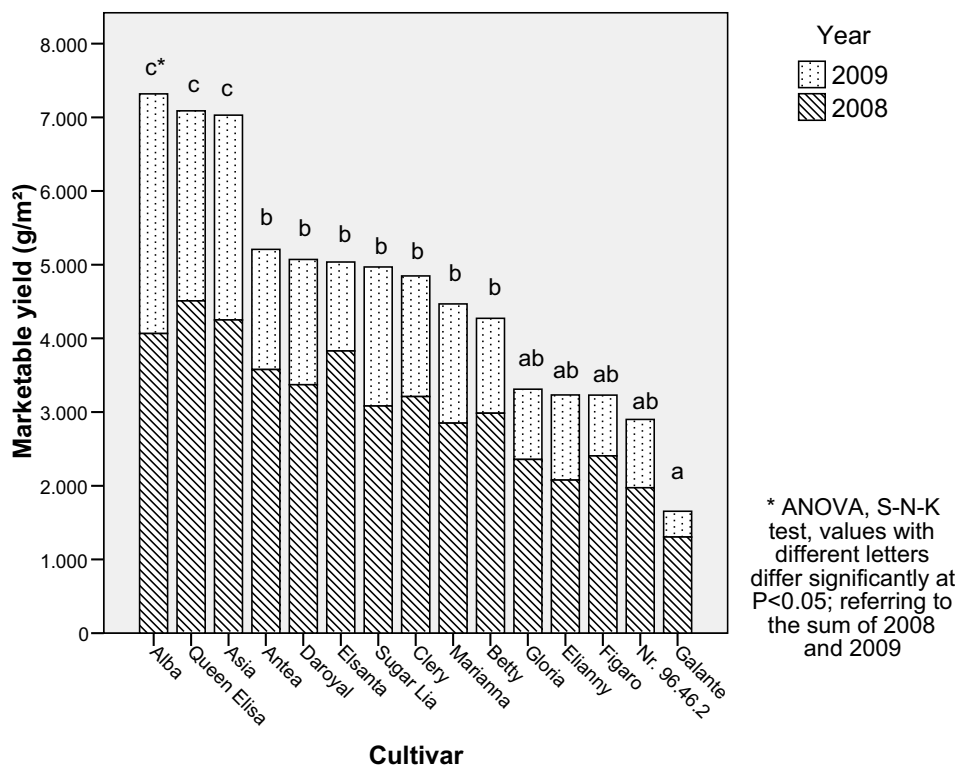


Figure 2: Marketable yield (2008 and 2009)

Depending on the cultivar, 21,84% to 47,40 % of all fruits were unmarketable. Feeding damage, fungal diseases and desiccation (=gummy fruits) were the primary causes (Fig. 3). Fungal diseases imply infestations with *Botrytis cinerea* (grey mould), *Phytophthora cactorum* (leather rot), *Sphaerotheca macularis* (mildew) and soft mould which is caused by several pathogens. Significant differences could be observed in the parameters 'fungal diseases' and 'gummy fruits' (data not shown) which accounts for the main part of the statistical differences in '% unmarketable fruits'. 'Alba', 'Elianny', 'Asia', 'Daroyal' and 'Betty' had a low percentage of unmarketable fruits and differed significantly from 'Galante'. 'Galante', 'Marianna', 'Nr. 96.46.2', 'Gloria', 'Sugar Lia' and 'Clery' had high to medium problems with fungal fruit diseases, 'Elsanta' and 'Antea' showed a very high percentage of gummy fruits.

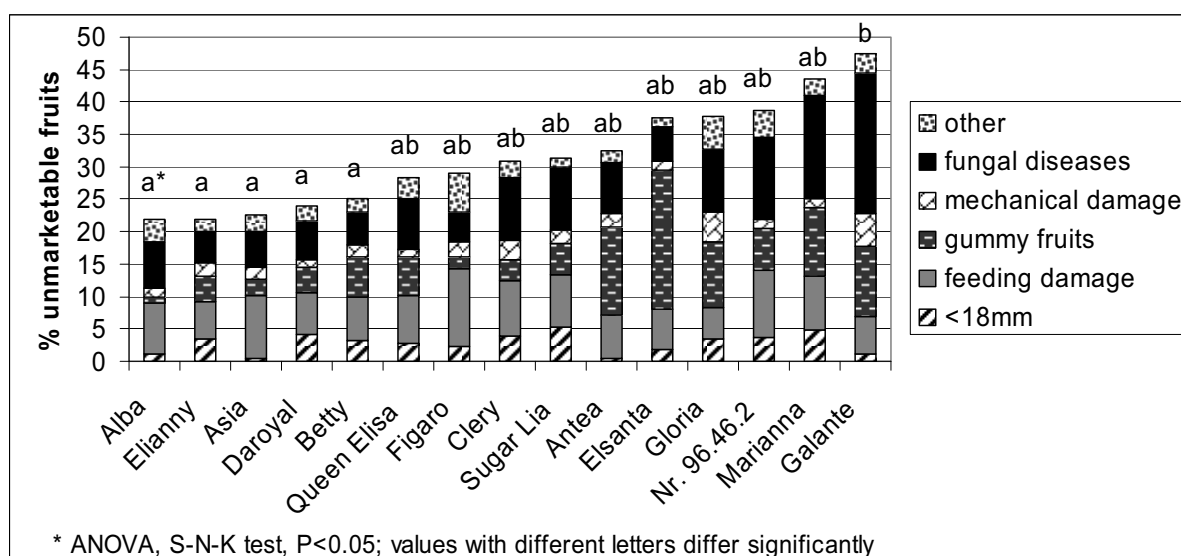


Figure 3: Percentage and components of unmarketable fruits (mean values of 2008 and 2009)

'Asia' had the highest mean fruit weight, followed by 'Alba', 'Queen Elisa', 'Sugar Lia' and 'Antea', whereas 'Elsanta' and 'Betty' had the smallest fruits. 'Daroyal' offered the highest content of soluble solids and differed significantly from 'Alba', 'Betty' and 'Asia'. When related to the amount of titratable acid, 'Clery' and 'Daroyal' had a significantly higher sugar:acid ratio than 'Alba'. Regarding the ascorbic acid content, 'Antea' showed a very high mean value, 'Daroyal' a very low one, in both cases with significant difference to all other cultivars. The fruits of 'Queen Elisa' and 'Antea' were very firm, in contrast to the fruits of 'Daroyal', 'Asia' and 'Elsanta'. Concerning the colour of the skin, fruits of 'Queen Elisa' had the highest values for brightness and colour intensity, whereas 'Daroyal' had the significantly darkest and least colour intense fruits, compared with all other cultivars (Tab.1).

Table 1: Selected fruit quality parameters (mean values of 2008 and 2009)

Cultivar	Fruit weight		Soluble solids		Sugar:Acid ratio		Ascorbic acid		Firmness		Brightness		Colour intensity	
	g/fruit	*	°Brix	*		*	mg/l	*	kg/cm ²	*	L*	*	C*	*
Alba	15,87	cd	6,18	a	7,03	a	587	ab	0,85	b	37,30	bcde	42,67	de
Antea	13,58	bc	7,65	bc	8,92	ab	929	c	1,27	c	37,71	cde	41,65	cd
Asia	16,72	d	6,57	ab	7,99	ab	528	ab	0,66	a	36,79	bcd	40,31	bc
Betty	10,80	a	6,56	ab	8,31	ab	524	ab	0,89	b	35,92	b	38,94	b
Clery	12,76	ab	7,50	bc	9,66	b	628	b	0,89	b	36,20	bc	40,36	bc
Daroyal	12,20	ab	8,23	c	9,26	b	473	a	0,64	a	33,44	a	36,71	a
Elsanta	10,43	a	7,68	bc	8,01	ab	654	b	0,71	a	36,73	bcd	38,58	b
Queen Elisa	14,26	bc	7,40	bc	8,82	ab	594	ab	1,33	c	38,49	e	44,27	e
Sugar Lia	13,86	bc	7,45	bc	8,21	ab	607	ab	0,91	b	37,98	de	42,17	cd

* ANOVA, S-N-K test, values with different letters differ significantly at P<0.05

There were only minor differences in the results obtained from the tasting sessions. As an overall result, appearance was rated higher than taste with exception of 'Daroyal'. Regarding the appearance of fruits, 'Alba' and 'Asia' were appreciated most whereas the rating of taste was lowest in these cultivars. The test people liked the taste of 'Clery' and 'Daroyal' best. 'Elsanta' was neither appreciated for its appearance nor for its taste. By trend, similar values could be assessed in 2008 and 2009 (data not shown). In 2009 all values were slightly lower which can be explained by the lower vitality of the plants and the moist weather conditions during the harvest.

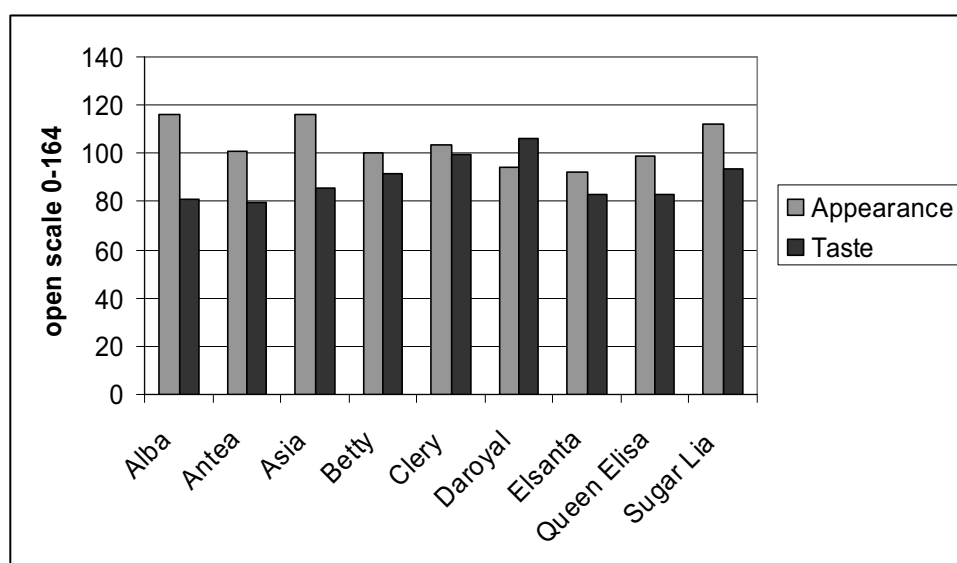


Figure 4: Consumer approval (mean values of 2008 and 2009; a total of 5 tasting sessions)

Discussion

'Alba' and 'Queen Elisa' had much higher yields than 'Elsanta', in contrast to the trial 2005-2007 where their yields were lower than those of 'Elsanta'. The higher productivity of 'Alba' and 'Queen Elisa' in this trial in comparison to 'Elsanta' corresponds to a higher plant vitality of those cultivars. This is the same for 'Asia', 'Antea' and 'Daroyal' which all had a higher yield and a lower infestation with *V. dahliae* than 'Elsanta'. In contrast, 'Galante' had the highest number of plant losses and by far the lowest yield. To sum up, the low marketable yield of susceptible cultivars in 2009 was on the one hand due to the loss or weakness of plants, on the other hand due to a high number of gummy fruits which results from the mycelium of *V. dahliae* in the rhizome blocking the water transport from the roots to the fruits.

To conclude, cultivars which were considered as the most interesting in the field trial 2005-2007 ('Alba', 'Clery', 'Daroyal' and 'Queen Elisa') proved their worth again, taking into account yield, vitality and fruit quality. 'Alba' turned out to be most convincing when summarizing important characteristics as tolerance to *Verticillium* wilt, yield, high percentage of marketable fruits and appearance of fruits. One drawback is the low sugar:acid ratio which relates to a low acceptance of the consumers. 'Clery' and 'Daroyal' proved to have the best taste of the tested cultivars. Despite the good fruit quality characteristics, 'Clery' had some problems with grey mould and fruit mildew. One drawback of 'Daroyal' are the dark and soft fruits which get overripe and therewith unattractive quickly, one big advantage are the outstandingly robust and vigorous plants. 'Asia' had very similar characteristics to 'Alba' and can therefore be recommended for organic farming and *Verticillium*-infested soils so far. 'Asia' produced slightly larger, softer and darker fruits than 'Alba'. 'Queen Elisa' had a high yield in this trial in contrast to the results of the trial 2005-2007 when the yield of 'Queen Elisa' was rather low. In 2006 and 2007 'Queen Elisa' appeared to be extremely susceptible to grey mould, an observation which could not be confirmed in the trial described in this paper because the percentage of *Botrytis*-infested fruits was average in comparison to the other tested cultivars. In terms of appearance of fruits, 'Queen Elisa' is a very recommendable cultivar, not so in terms of taste. In addition to the already mentioned cultivars, 'Betty', 'Sugar Lia' and 'Antea' appeared to be possible alternatives for 'Elsanta', but have some larger disadvantages. 'Galante' performed very poorly, not much better did 'Figaro', 'Nr. 96.46.2', 'Gloria' and 'Marianna', what was the reason for being excluded from the fruit quality analyses in 2009. Many plants of 'Galante' and 'Figaro' died off after the harvest in 2008. 'Marianna' and 'Nr. 96.46.2' showed a slightly higher tolerance to *V. dahliae* than 'Galante', but had big problems with fruit rots, especially with grey mould, and are therefore not recommendable for organic farming. 'Elsanta' is still recommendable for not-infested soils, regarding yield, whereas for infested soils other cultivars should be favoured. But also on healthy soils, 'Elsanta' could be replaced by cultivars with tastier and larger fruits. For further conclusions, the results from the other sites have to be included which will be done in a different publication.

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