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The effect of virus on yield components and fruit quality in three apple cultivars

Virkning af virus på udbytte-parametre og frugtkvalitet hos tre æblesorter

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Summary

Throughout three years different components of growth and yield were compared between virus-free and virus infected trees of three apple cultivars. In 'Red Melba', where the virus infected trees were infected by the larger number of viruses, vegetative growth was restricted by virus, whereas fruit growth on a fruit number/leaf weight basis tended to be higher on the virus infected trees. In 'Golden Delicious', on the other hand, the vegetative growth was increased a little by virus, and the blossom density was reduced a little. Fruit growth on a fruit number/leaf weight basis was distinctly reduced, the concentration of dry matter was increased, and the fruits were more yellow, but heavily russeted. Virus infected 'Lobo' was found infected by a smaller number of viruses. In this cultivar no distinct differences between these trees and virus-free ones were observed.

Key words: Apple, Melba, Golden Delicious, Lobo, growth, blossom density, yield, fruit size, fruit quality, russeting, virus.

Resumé

Forskellige udbyttekomponenter blev sammenlignet hos virus-inficerede og virus-frie træer af hver af 3 æblesorter og i 3 år. Efter testningsresultaterne var 'Rød Melba' angrebet af det største antal virussygdomme, og den vegetative vækst var tydeligt reduceret sammenlignet med tilsvarende virus-frie træer. Udbyttet udtrykt pr. frugtantal/bladvægt-enhed tenderede imod at være højst i de virus-inficerede træer. Hos 'Golden Delicous' var der hos virus-inficerede træer følgende udslag sammenlignet med virus-frie træer: lidt større vegetativ vækst, lidt ringere blomstring, tydeligt lavere frugttilvækst pr. frugtantal/bladvægt-enhed, en højere tørstofprocent i frugten, og lidt mere gule, men langt mere skrubbede frugter. 'Lobo' viste ved testningen angreb af det færreste antal virussygdomme, og her var der ingen tydelig forskel på virus-inficerede og virus-frie træer.

Nøgleord: Æble, Melba, Golden Delicous, Lobo, vækst, blomstring, udbytte, frugtstørrelse, frugtkvalitet, skrub, virus.

Introduction

Different virus diseases may show various effects on vegetative growth of apple cultivars, ranging from practically no effect to a distinct restriction of growth (*Larsen*, 1977). However, a less vigorous growth is not necessarily a disadvantage in itself, as an increase in fruitfulness may be the result. In fact, depressing the vegetative growth is the main objective for the use of rootstocks. Great interest is therefore linked to information about the effect of virus on other components of yield, such as flower bud formation, fruit set, and, in particular, the fruit growth *per se*, *i.e.* the yield or fruit size when the effect of virus on tree size is taken into consideration and corrected for. Preliminary investigations using ^{14}C to illustrate the rate of translocation from leaves to fruits gave no conclusive results as to the effect of virus on fruit growth, mainly due to too large a variation of the random type. Therefore, trees found infected and with symptoms of known virus diseases were compared with corresponding trees found to be without virus symptoms. This comparison was made from trees in a pot experiment to equalize soil, water and nutrient conditions as far as possible, and where detailed observations of the various parameters of yield could be accomplished.

Material and methods

Virus-free trees were compared with spontaneously virus infected trees. Three cultivars participated and the virus infected clones were tested for virus as shown in Table 1. The virus-free clones were tested in the same way, and, in all cases sucessfully without symptoms. The virus-free clones of 'Red Melba' and 'Lobo' were produced by heat therapy (*Larsen*, 1974) from the present spontaneously virus infected clones. The virus-free 'Golden Delicious' was, however, found to be »virus-free« spontanously. So, genetic constitution of the virus-free and virus infected clones of 'Golden Delicious' may be different as well.

In the winter of 1974, graftings on virus tested rootstocks MM106 were made of virus-free and virus infected material of each cultivar. Graftings of the same clone were planted 3 together in 15 litre plastic pots in a porous soil in the spring of 1974. In the spring of 1975 the trees were replanted, but with only one tree per pot. 30 trees were planted from each clone, selecting the trees with the longest shoot growth during 1974. The trees were cut back to c. 60 cm length. The trees bloomed in 1976. On 8th July, 1976 (after June drop) all fruits were removed from 15 trees per lot. On the other 15 trees the fruits were thinned to various extents to obtain trees with different fruit/leaf-ratios within each clone. The latter trees were cut up and dried (80°C) in the autumn of 1976. The remaining 15 trees per clone were thinned, in a similar way, to various extents in 1977 and in 1978, until the trees were cut up and dried in the autumn of 1978. Due to damage by winter frost the experiment on 'Lobo' terminated after 1977.

In all years the trees were watered daily during the growing season with nutrient solution, so they were well supplied with water and nutrients. During the winters the trees were stored in an unheated house.

Blossom densities were evaluated on a scale where 100 equals trees totally covered with flowers. Fruit numbers and weight per tree were determined at the normal harvest times. In the autumn, every tree was enclosed in a net so that the total leaf mass could be sampled, dried at 80°C and weighed. Fruit samples were taken at harvest or during the season, either as compound samples from several trees, or from trees individually. Total dry matter at 80°C and/or soluble dry matter by refractometry and titratable acids were determined. Spur leaves were sampled on some occasions, either per tree or as compound samples. Specific leaf weights (SLW) and percentage dry matter (80°C) were determined at 18 mm discs. Soluble sugars of leaves were determined in some cases after separation on paper chromatograms (*Hansen*, 1967) and starch after enzymatic hydrolysis of the alcohol (80%)-insoluble substans (*Ryugo et al.*, 1977).

Table 1. Testing of virus infected clones

	'Red Melba'	'Golden Delicious'	'Lobo'
Lord Lambourne			
M	0	0	0
RW	+	?	0
'Virginia Crab'			
SP	+	+	0
SGr	–	–	–
GUB	+	+	0
M. cl. R 12740-7A			
CLS	+	+	+
BN	+	+	+
SP	–	0	–
M. platycarpa cl. LA 17 T2			
CLS, LP	+	+	+
ScB	+	–	+
'Spy' cl. 227			
CLS	+	+	+
BN, E	+	+	0
SP	–	0	–
M. sargentii			
E, BN	+	+	0
SP	+	+	–
SGr	+	+	–
x Pyronia veitchii			
E	–	–	0
VY	–	–	+
LP	–	–	+
Cydonia oblonga cl. 7/1			
VY	–	0	+
RS	–	0	+
M. robusta			
SL	–	0	–
'Jonathan'	–	0	–
'Gravenstein'	–	0	–
'Guldborg'	0	0	–
'Boskoop'	–	0	0
'Spartan'	–	0	0
'Cox's Orange'	–	0	–
'Golden Delicious'	–	–	–

Indexing results:
0 = Successful indexing without symptoms
\+ = Indexing with symptoms
– = No results of indexing so far
? = Inconclusive results of indexing

Symptoms:
M: Mosaic (mosaik)
RW: Rubbery wood (gummived)
SP: Stem pitting (grubet ved)
SGr: Stem grooving (rillet ved)
GUB: Graft union breakage (podningsbrud)
CLS: Chlorotic leaf spot (klorotisk bladplet)
BN: Bark necrosis (bark nekrose)
LP: Line pattern (båndmosaik)
ScB: Scarly bark (skælbark)
E: Epinasty (epinasti)
VY: Vein Yellows
RS: Ring spot
SL: Small narrow leaves (små, smalle blade)

Results

Growth

In 'Melba' the extention growth was reduced by virus and the same was the case for the dry matter accumulation in all parts of three-year old trees (Table 2). In five-year old trees only the difference in total dry matter accumulation was significant (Table 3). The leaf amount per tree was reduced by virus in all three years where it was measured (Table 4).

During the first year of growth, 1974, virus infected 'Golden Delicious' attained more feathers than virus-free ones. In 1975, when trees still were without fruits, extension growth was greater on the virus infected trees (Table 2). Also after cropping had started, virus infected trees seemed to maintain larger wood dry weights; however, lower yields here may have been partly responsible for that (Tables 2, 3, 4).

In 'Lobo', no consistent difference was found between the growth of virus-free and virus infected trees.

Table 2. Effect of virus on extension growth in 1974 and 1975, and on dry matter accumulation in different parts of the tree in October 1976. *, **, ***, significant effects of virus at 95, 99 and 99.9% level, respectively

Cultivar	Melba		Golden Delicious		Lobo	
Virus	–	+	–	+	–	+
cm shoots/tree, 1974	97***	84	116	113	85**	96
cm shoots/tree, 1975	559***	428	676**	743	510	537
g top/tree, 1976	281*	237	346	361	367	385
g trunk/tree, 1976	324***	281	322*	348	398	390
g roots/tree, 1976	224**	181	163**	215	245	225
kg total wood, tree, 1976	0.83**	0.70	0.83*	0.92	1.01	1.00
kg total wood + leaves + fruits, 1976	1.39**	1.18	1.91	1.93	1.83	1.88

Table 3. Effect of virus on dry matter accumulation. October 1978

Cultivar	Melba		Golden Delicious	
Virus	–	+	–	+
kg top/tree	0.74	0.68	0.82	0.94
kg trunk/tree	0.59	0.54	0.59	0.61
kg roots/tree	0.36	0.37	0.29	0.49
kg total wood/tree	1.69	1.59	1.69	2.04
kg total wood + leaves and fruits 1977 and 1978	5.41*	4.49	7.00	6.66

Table 4. Effect of virus on dry matter accumulation in leaves and fruit in different years

Cultivar		Melba		Golden Delicious		Lobo	
Virus		–	+	–	+	–	+
g leaves/tree	1976	124***	105	147	151	130	134
»	1977	272***	214	353	333	278	286
»	1978	503**	387	–	–	–	–
kg fruits/tree	1976	2.7	2.5	5.6	4.6	4.3	4.8
»	1977	7.1	5.9	13.6	10.6	11.0	11.0
»	1978	13.7	10.4	14.9	11.7	–	–

Table 5. Effect of virus on blossom densities in different years

Cultivar	Melba		Golden Delicious		Lobo	
Virus	–	+	–	+	–	+
1976	96	94	91**	72	76	80
1977	56	54	71	57	49	44
1978	58	59	74	63	–	–

Blossom density

In 1974 the virus-free trees of 'Golden Delicious' bloomed more abundantly than the virus infected ones (Table 5). The trend was the same in 1977 and 1978 even the differences were not significant. In the other two cultivars no distinct differences occurred. The 1976 and 1977 results were in all cases obtained on trees which were without fruits the previous year. The 1978 results originated from trees which had carried different amounts of fruits the year before, but correcting for this did not appreciably influence the results.

Yield and fruit size

In each of the years with cropping trees, 1976–1978, the fruits were thinned in order to obtain trees of various fruit/leaf-ratios. Therefore, the values of yield per tree in Table 4 are not true expressions of yielding capacity per tree. However, in 'Melba' the lower yield per tree by virus infection may, to some extent, be due to the smaller trees here, and in 'Golden Delicious' more scanty bloom may be part of the reason. To obtain true values of yielding capacity and fruit size, correction for differences in tree size and fruit number should be carried out (*Hansen*, 1977). This has been done by expressing yield on a leaf dry weight basis (in 'Golden Delicious' in 1978 branch dry weight was used, as leaves were not sampled). By this method yield and thus fruit size was a little higher in virus infected 'Red Melba' than in virus-free ones (Figure 1). This was obvious in 1976, but in 1977 and 1978 only a trend at the higher cropping levels was noticed. The difference in 1976 nearly disappears when fruit dry weights are compared, as fruits from virus infected trees had a little lower percentage of dry matter (Table 6).

In 'Golden Delicious', on the other hand, the corrected yield (or fruit size) was the lowest in the virus infected trees in all three years (Figure 2). When fruit dry weights was used, the differences were minimized but the yields of virus infected trees were still the lowest.

In 'Lobo', distinct effects of virus were not found (Tables 2, 4).

Fruit composition and quality

'Melba'. At fruit harvest in 1976 the fruits from virus infected trees had the lowest content of total dry matter and in 1977 the titrable acid was lower (Table 6). At picking in 1976 the fruits from virus infected trees were looser and less green, and also

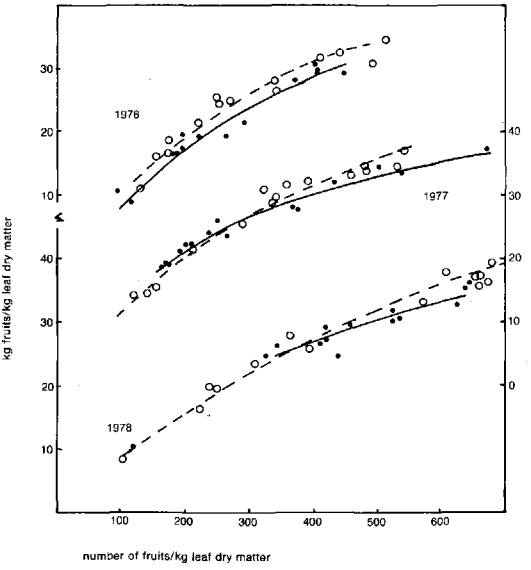

Figure 1. Yield-fruit number relationships in 'Red Melba'. o—o: virus infected trees. ●—●: virus-free trees.

Table 6. Effect of virus on fruit contents in 'Melba'

Date Compound	18.08.1976 % total dry m.	18.08.1977 % sol. dry m.	% acid
– virus	16.0	11.3	1.31
+ virus	15.2	11.1	1.22

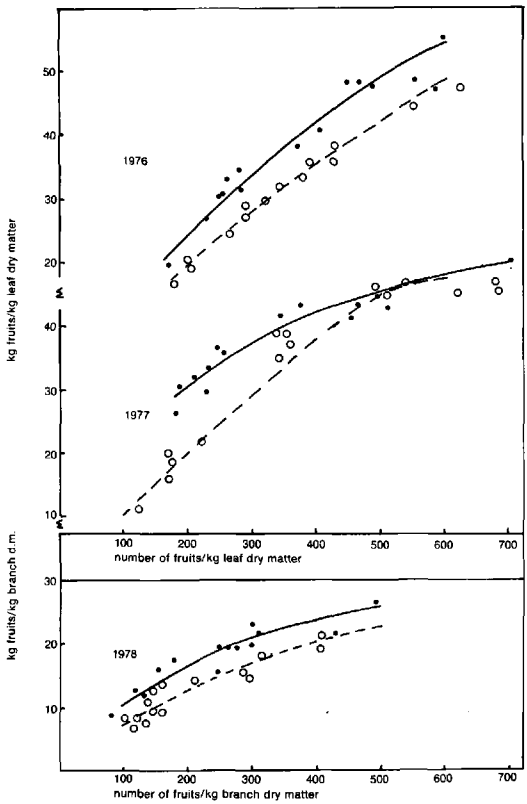

Figure 2. Yield-fruit number relationships in 'Golden Delicious': Symbols as in Figure 1.

in 1977 they were probably ripe a little earlier. At sampling on 9th and 21st August in 1978, however, fruit analysis showed no difference between trees with and without virus.

'Golden Delicious'. Fruit from virus infected trees showed higher concentrations of total dry matter, soluble dry matter and titratable acids in all three years, even the differences were not so distinct in 1977 (Table 7, Figure 3). Fruit analysis after sampling on 7th July, 23rd August and 31st October, 1978, also yielded higher contents of total and soluble dry matter and of acids from virus infected trees. These trees also had fruits of higher potassium concentrations and the colour was more yellow (Figure 3). The concentration of soluble nitrogen was similar in the two lots of trees. Fruits of virus infected trees had much more russeting in 1978 (Table 8). In 1977 the fruits were designated as russeting rather a lot and with distinct lenticels compared to smooth fruits without russeting from virus-free trees.

Also in 1976 the fruit from virus infected trees had the most distinct lenticels.

'Lobo'. Fruit analysis on 25th October 1976 and 27th September 1977 yielded no differences between treatments in soluble dry matter and titrable acids.

Table 7. Effect of virus on fruit contents in 'Golden Delicious'

Date Compound	4.11.1976 % sol. dry m.	% acid	24.10.1977 % sol. dry m.	% acid
– virus	14.7	0.70	14.4	0.71
+ virus	16.6	0.76	14.6	0.74

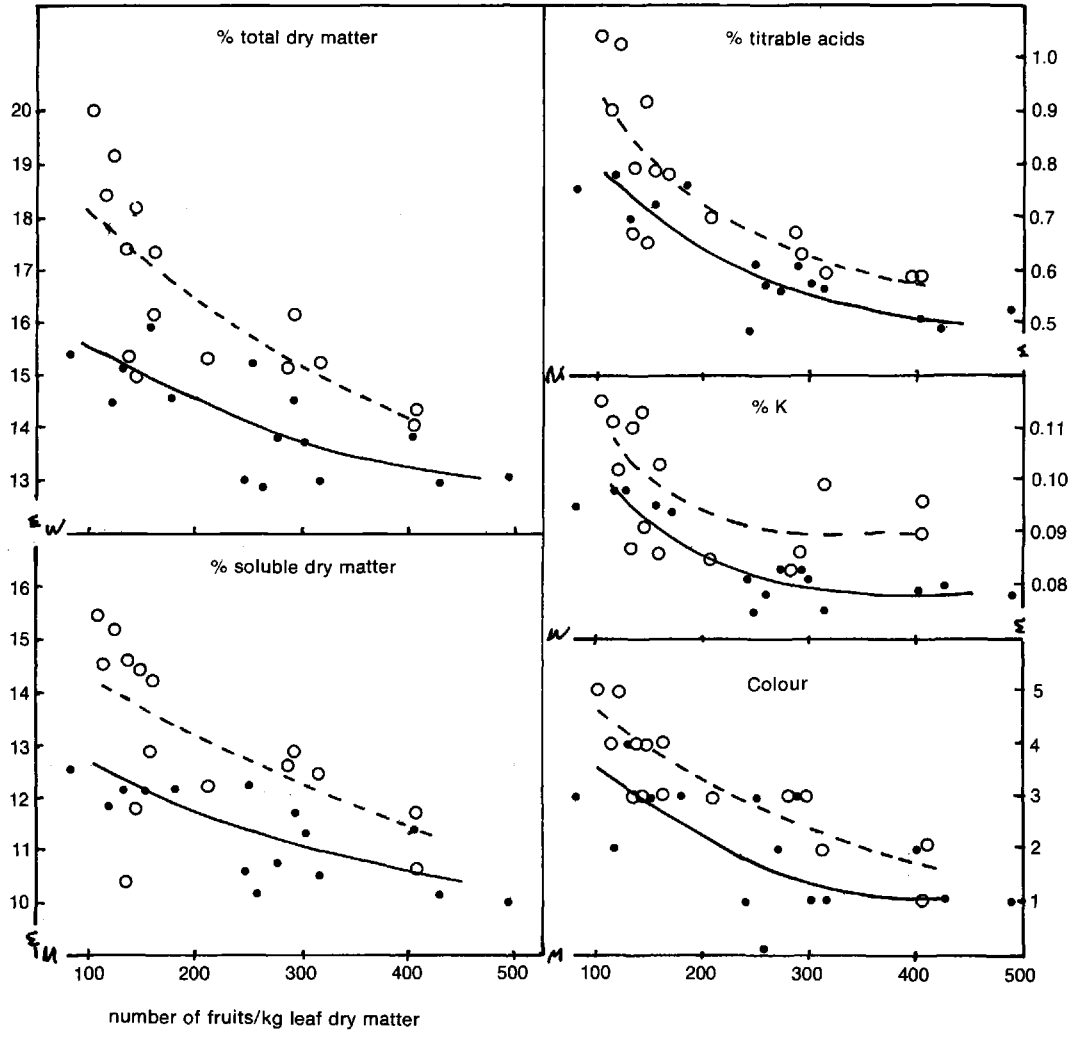

Figure 3. Composition and colour of 'Golden Delicious' fruits on October 12, 1978 as affected by virus and fruit number. Colour: 5 = all yellow, 0 = all green. Symbols as in Figure 1.

Table 8. Effect of virus on the distribution of fruits on different russeting classes. 'Golden Delicious', 31.10.1978

	Russeting class (% of skin russeting)			
	0	1–10	10–50	> 50
– virus	86	11	3	0
+ virus	0	16	33	51

Leaf contents and symptoms

Specific leaf weights (SLW), percentage dry matter, sugars and starch were determined in 1976, and again in 1978 with the exception of sugars.

No greater or significant differences between virus-free and virus infected trees were shown, except for a higher content of dry matter in the leaves of virus infected 'Golden Delicious' (40.4% than in those of virus-free trees (39.5% on 24th August, 1978.

Nitrogen, phosphorous, potassium, calcium and magnesium were determined in leaves sampled in August or early September. Consistent differences between virus-free and virus infected trees were not found.

In 'Melba', leaf spots (small, randomly distributed, necrotic spot) and premature leaf drop occurred to a greater extent in virus infected than in virus-free trees. On 9th September, 1974, virus-infected trees had dropped about 75% of their leaves and the remaining leaves had many spots, while both symptoms occurred to a much smaller extent in virus-free trees. In the middle of September 1975 yellowing leaves with darker spots around the nerves developed on virus infected trees, later, but to a smaller extent, the same occurred also in virus-free trees.

In the spring of 1978 virus infected 'Golden Delicious' had larger branch sections without leaves and spurs (assessed value 26% of total branch length) than virus-free trees (17%). In October, bare sections of branches were measured to be 8.1 and 11.5% of total branch length for virus-free and virus infected trees, respectively.

Discussion

A reduction in the vegetative growth of apple trees by virus infection has been demonstrated in several cases, but the size of the reduction may depend on the extent of infection as well as on the cultivar, nutrition level etc. (*Larsen,* 1977; *Lüdders,* 1980). Testing gave symptoms of the larger number of viruses, including rubbery wood, in virus infected *'Red Melba'*. This was the only of the present cultivars where growth was clearly restricted by virus infection as it was already shown in this cultivar (*Hassing & Larsen,* 1976). Yield was reduced by virus in consequence of the smaller trees, but when tree size (leaf area) was considered, fruit growth itself tended ot be a little greater in the virus infected trees. This was probably related to a promotion of the maturity of the fruits. The inhibition of vegetative growth and the promotion of fruit growth by virus in this cultivar may be similar to the effects of a weak rootstock.

Contrary to 'Red Melba', evidence of a direct effect of virus on yield parameters was found in 'Golden Delicious'. Firstly, blossom density may decrease in virus infected trees (*Cambell,* 1973). Consequently, flower bud formation must have been reduced by virus. In the present investigation this can not be explained via the well-known relationships between flower bud formation and crop load or growth (*Hansen& Grauslund,* 1980). Secondly, fruit growth itself is depressed in the virus infected trees of 'Golden Delicious'. Relative fruitfulness, expressed as crop per unit trunk girth or trunk sectional area has in several cases been reduced by virus, even the contrary has been found as well (*Campbell,* 1973; *Sampson & Johnstone,* 1974; *Meijneke et al.,* 1975). The present result indicates a direct inhibitory effect on fruit growth in the virus infected 'Golden Delicious'. This is further supported by the increased accumulation of dry matter in the fruits and in one case in the leaves as well. According to previous results, restricted fruit growth and a contemporary increased accumulation of dry matter in fruit and leaves are evidence of a reduced sink activity of the fruits i.e. a lower potential growth rate of fruits, established through an effect acting on the fruits directly and not via the leaves or other parts of the tree.

The question arises whether the restricted fruit growth in virus infected 'Golden Delicious' compared to the virus free clone is solely due to virus. As mentioned, the virus infected and virus-free 'Golden Delicious' were different clones, so genetic differences may exist as well. Also, the more vigorous vegetative growth in the virus infected trees is not likely to be an effect of virus. Fruits on the virus infected trees russeted heavi-

ly. *Meijneke et al.* (1975) also found more russeting on virus infected clones, but in comparisons of different virus-free clones of 'Golden Delicious' russeting may occur to various extent, the heavier russeting occurring in low-yielding clones (*Meijneke et al.*, 1975; *Larsen*, 1978).

No clear differences were demonstrated between virus-free and virus infected 'Lobo', where also the smallest number of virus diseases were found.

Conclusion

Depending on the extent of virus infection and the cultivar, the following reactions have been found:

No clear effect of virus on vegetative growth or yield.

A distinct depression of vegetative growth by virus, which may influence fruit growth and maturity similar to other types of growth restriction such as by a weak root-stock.

A clear growth inhibiting effect of virus directly upon fruits. Still, genetic variation between clones may be part of the reason in this case.

Inhibition of fruit growth itself by virus would be an obvious disadvantage . Even restriction of vegetative growth normally is included in cultural practices, the results do not suggest the inhibitory effect of virus on vegetative growth to be of any advantage to the normal procedures of growth regulation as done by rootstocks etc. Furthermore, virus would be an extremely difficult growth regulator to handle due to the interaction between cultivar and different virus diseases. Also, in this case a large number of interactions should be defined including those where direct negative effects on fruit growth or quality may be expected. So the use of virus-free material and other methods of growth regulation than virus infection is recommended. On the other hand it should be stressed that virus infection does not have negative effects in all cases.

The distinct differences in fruit growth potential and fruit quality of the two clones of 'Golden Delicious', whether caused exclusively by virus or by other factors as well, give credit to the importance of clonal selective work within individual cultivars.

Acknowledgement

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