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Results of Multi-site Interstem Trials with Apple Trees

Erfolge mit Zwischenveredlungen bei Obstbäumen

S. J. Wertheim[1]) and O. Callesen[2])
([1]) Fruit Research Station, Randwijk, The Netherlands, [2]) Department of Fruit, Vegetable and Food Science, Årslev, Denmark

Summary

An interstem trial was planted in the spring of 1988 with the tender apple cultivars 'Elstar' and 'Jonagold' on M.9 rootstock with thirteen interstem cultivars to study their possible effects on tree hardiness and growth vigour. The interstems used were: 'Gloster', 'Golden Delicious', 'Summerred', because of their hardiness shown in an earlier Dutch trial, 'Heyer12', 'Antonovka', 'Hibernal', 'Dolgo', 'Honeygold', 'Yellow Transparent', 'Ottawa 3', 'Haralson' and 'Paulared', because of their reputed hardiness elsewhere, and 'Dubbele Zoete Aagt' as the standard interstem used in The Netherlands. Two-year-old trees directly on M.9 served as controls. The material used was free of known viruses, except for 'Hibernal' where this was not quite certain. The trees were made in one nursery and planted at one site in Denmark and three in The Netherlands in single rows at distances ranging from 3.00 x 1.20 to 3.25 x 1.50 m and raised as slender spindles. The trial lasted till winter 1994/95 with 'Jonagold'and one year longer with 'Elstar'.

No damaging frosts occurred during years that the trees were in the field, so no conclusions could be drawn with regard to the winter hardiness of the interstem cultivars involved.

Growth control was obtained, especially with 'Elstar'. With both cultivars, growth reduction occurred most consistently with 'Dolgo', 'Ottawa 3', 'Paulared' and 'Summerred'. Little growth control was obtained with 'Gloster' and 'Golden Delicious' and especially 'Antonovka'. Some, growth-reducing interstems ('Paulared', 'Summerred') had a thin trunk relative to that of the scion cultivar, for others ('Dolgo' with both cultivars and 'Ottawa 3' with 'Jonagold') the opposite was true.

Productivity per tree was not much affected by the interstems, with the exception of 'Hibernal' allowing high productions and 'Ottawa 3' lagging behind with 'Elstar'. However, compared to the controls, productivity per cm^2 scion trunk-cross sectional area (TCA) was increased in many cases, especially with 'Elstar'. With 'Elstar', interstems of 'Heyer 12', 'Hibernal', 'Paulared' and 'Summerred' especially were effective. With 'Jonagold', 'Heyer 12', 'Dolgo' and 'Ottawa 3' interstems rated high.

Fruit size was not greatly affected by the interstem and if it was there was no clear relation with productivity per cm^2 TCA. Where growth was reduced fruit colouring was improved. Except for trees on an 'Ottawa 3' interstem, where in some years lower leaf contents of N, P, K, Ca and Mg were found, no clear interstem effects were observed in the mineral content of leaves or fruits.

The results are discussed and it is concluded that where both growth control and increased hardiness are wanted, 'Summerred' is a valuable interstem. When vigour control is not the main aim, other hardy interstems are promising as well, such as 'Hibernal' with its good effect on productivity.

Given the many interactions found, it is stressed that without thorough experimentation the use of the before-mentioned interstems for other cultivars under other conditions bears risks.

Zusammenfassung

Im Frühling 1988 wurde ein Versuch mit den Sorten 'Elstar'und 'Jonagold' auf M.9 Unterlage mit dreizehn Zwischenstammsorten gepflanzt um mögliche Effekte auf Frostbeständigkeit und Wachstum zu evaluieren. Die Zwischenstammsorten waren: 'Gloster', 'Golden Delicious', 'Summerred', weil diese Sorten Frostbeständigkeit in einem früheren Versuch zeigten, 'Heyer12', 'Antonovka', 'Hibernal', 'Dolgo', 'Honeygold', 'Yellow Transparent', 'Ottawa 3', 'Haralson' und 'Paulared', in anderen Ländern als frostbeständig erwiesenermaßen und 'Dubbele Zoete Aagt' als Standardzwischenstamm. Zweijährige Bäume direkt auf M.9 dienten als Kontrolle. Das Material war frei von bekannte Viren, ausgenommen 'Hibernal' wo man nicht ganz sicher war. Die Bäume wurden in einer Baumschule angezogen und gepflanzt an einem Standort in Dänemark und an drei Stellen in den Niederlanden in Einzelreihen mit Abstände variierend zwischen 3,00 x 1,20 und 3,25 x 1,50 m und als schlanke Spindel geschnitten. Der Versuch stand bis Winter 1994/95 mit 'Jonagold' bzw. ein Jahr länger mit 'Elstar'.

Es kamen keine schädigenden Fröste während der Versuchsdauer vor. Also war es nicht möglich Folgerungen über die Frostbeständikeit der Zwischenstammsorten zu ziehen. Reduzierung des Wachstums wurde, besonders bei 'Elstar', erreicht. Bei beiden Sorten war die Reduzierung meist konsistent mit 'Dolgo', 'Ottawa 3', 'Paulared' und 'Summerred'. Wenig Wachstumsverringerung wurde erreicht mit 'Gloster' und 'Golden Delicious' und inbesondere mit 'Antonovka'. Bestimmte wachstumverminderende Sorten ('Paulared', 'Summerred') hatten einen geringeren Stammumfang verglichen mit den stammechten Bäumen. Bei anderen Sorten galt das Gegenteil ('Dolgo' mit beiden Sorten und 'Ottawa 3' mit 'Jonagold').

Die Baumproduktivität wurde durch die Zwischenstämme nicht besonders beeinflusst ausgenommen 'Hibernal', der eine hohe Produktivität induzierte und 'Ottawa 3', der bei 'Elstar' zurückblieb. Die Produktivität pro cm² Stammquerschnitt von der Sorte wurde im Vergleich zur Kontrolle in vielen Fällen gefördert, besonders bei 'Elstar'. Bei 'Elstar' waren die Zwischenstämme 'Heyer 12', 'Hibernal', 'Paulared' und 'Summerred' besonders effektiv. Bei 'Jonagold' hatten 'Heyer 12', 'Dolgo' and 'Ottawa 3' hohe Produktivität.

Die Fruchtgröße wurde durch den Zwischenstamm wenig beeinflusst und ein eventueller Einfluß zeigte keinen Zusammenhang mit der Produktivtät pro cm² Stammquerschnitt. Die Fruchtfarbe wurde positiv beeinflusst, wenn das Wachstum reduziert war. Mit Ausnahme von 'Ottawa 3', wo in bestimmten Jahren niedrige Blattgehalte von N, P, K, Ca und Mg gefunden wurden, hatten die Zwischenstämme keine deutliche Effekte auf die Mineralgehalte der Blätter. Die Ergebnisse werden diskutiert und es wird gefolgert daß in Fällen, wo Frostbeständigkeit und Wachstumsreduzierung gewünscht werden, 'Summerred' ein wertvoller Zwischenstamm ist. In Fällen, in denen Wachstumsbeherrschung kein Ziel ist, sind andere winterharte Zwischenstämme vielversprechend, wie 'Hibernal' auf Grund seiner guten Effekte auf die Produktivität.

Unter Berücksichtigung der vielen Interaktionen wird betont, dass die Verwendung der genannten Zwichenstämme bei anderen Sorten und unter anderen Umständen ein Risiko beinhaltet.

Introduction

Early January 1985, after months of mild weather a sudden and severe winter frost coupled with strong winds severely damaged the Dutch apple industry. Trees were mainly damaged because scion cultivars froze, not the predominant M.9 rootstock. In an interstem trial planted in the spring of 1984 with 'Elstar' and 'Jonagold' on M.9 rootstock in the experimental garden at Numansdorp, the degree of frost damage greatly depended upon the interstem cultivar used. Trees without an interstem and with interstems of the triploids 'Belle de Boskoop' and 'Dubbele Zoete Aagt' were badly damaged or killed. Little or no frost damage occurred with trees on interstems of the diploids 'Gloster', 'Golden Delicious' or 'Summerred' [WERTHEIM, 1985]. In a duplicate trial, planted at the research station in Wilhelminadorp no frost damage was observed. Here, the 'Summerred' interstem appeared to control the vigorous growth of 'Elstar' trees in later years [VAN DE WAART & BAART, 1990]. A reduction of the growth level of this main Dutch cultivar is welcome, because growth is often excessively in later years, even on M.9. Formerly, too vigorous growth was often controlled by the growth retardant daminozide (Alar), but this chemical is now abandoned and, therefore, non-chemical means for growth control are sought. These comprise the use of more dwarfing M.9 subclones (e.g. 'Fl.56'), increased budding height, reduced planting depth, and mechanical root pruning. All these methods can cause growth reduction but may have drawbacks. 'Fl.56' is not widely available and high budding only becomes effective after a number of years and necessitates a M.9 type free of burr knots. If not, tree growth varies depending on the number of burr knots present. A reduced planting depth requires regular water supply and effects of root pruning cannot be well predicted. Of course, the use of a more dwarfing rootstock than M.9 is also a possibility, but growers are reluctant to leave the well-known M.9, because in many aspects it is an excellent rootstock. A dwarfing interstem might be another method to control growth, allowing growers to stay with trusted sub-clones of M.9, such as 'T.337'. In order to combine improved winter hardiness with growth control, a new interstem trial was set up to evaluate a range of cultivars on M.9 'T.337'. In this new trial, the three hardy interstem cultivars of the 1984 trial; 'Gloster' (Gl), 'Golden Delicious' (GD) and 'Summerred' (Su) were included. Others were added that have a good reputation of winter hardiness, such as 'Dolgo' (Do), 'Haralson' (Ha) and 'Heyer 12' (H12) [RONALD & TEMMERMAN, 1979] and 'Hibernal' (Hi) [DE HAAS, 1966; DE HAAS & HILDEBRANDT 1967]. Still other interstem cultivars were included upon recommendation by pomologists from areas where cold winters prevail, e.g. 'Antonovka' (An), 'Honeygold' (Ho), 'Ottawa 3' (O3), 'Paulared' (Pa) and 'Yellow Transparent' (YT). 'Dubbele Zoete Aagt' (DZA) was also included It is the most common interstem-cultivar in The Netherlands, because it makes a good trunk and possesses resistance to trunk rot caused by *Phythophthora cactorum*. Interstem names are further abbreviated for the sake of space.

Material and methods

In April 1986, uniform, virus free rooted layers of M.9 rootstock (subclone 'T.337') were table-grafted with the 13 virus free interstem cultivars, mentioned above, and planted out in one nursery block with the union at 15 cm above soil level. In August 1986, interstem shoots were budded with 'Elstar' and 'Jonagold' at 30 to 35 cm above the rootstock union. The one-year-old trees were planted in the spring of 1988 at four sites. As controls, two-year-old trees of 'Elstar' and 'Jonagold' were planted in the same season, raised in the same nursery from table grafts directly on M.9, made at the same time and in the same way as the interstem grafts. Thus, the root systems of control and interstem trees were of the same age. Both cultivars were planted at the national fruit research stations in Wilhelminadorp (W), The Netherlands (NL) and in Årslev (Å), Denmark (DK). Nearly all combinations of 'Elstar' were also planted in the Dutch regional experimental gardens in Numansdorp (N) and Zeewolde (Z) and of 'Jonagold' in Horst (H) and Geldermalsen (G). At each site, most treatments occurred in four to six replicates of three trees each. In N and G, a few interstems were missing (see later). The planting distances were 3.00 x 1.20 m (N,) 3.25 x 1.25 m (W, G) 3.25 x 1.30 (Z) and 3.25 x 1.50 m (Å). The alleys between the tree rows were grassed and the tree strips were kept weed free with herbicides. The trees were trained as slender spindles and fertigated with one dripper per tree and further managed according to local practice. At planting and at the end of the experiment (winter 1994/95 for 'Jonagold' and 1995/96 for 'Elstar', but one year earlier in N (due to closure of the garden), trunk circumference was measured of the scion cultivars at 10 cm above the interstem union and of the interstem

halfway the interstem. In W this observation was also done in the control trees at the same height. In W, the circumference of the above ground rootstock was measured at the end of the trial as well, but only with 'Jonagold'. After three growing seasons, when pruning had not yet affected tree size, and in the last winter of the trial the tree volumes were determined in the Dutch trials. In DK this was done once in May 1993. Tree volume was calculated from the average tree-head diameter and tree height using the formula for a cone volume ($^1/_3\ \pi\ r^2h$). Tree diameter was measured in two perpendicular directions, each at 45° with the tree row, at the base of the head, till the extremities of the two-year-old wood. Tree height was measured from the insertion of the lowest scaffold branch till the highest point of the two-year-old wood. Only in H, height and diameter were measured till the end of the one-year-old wood and here not the insertion of the lowest branches was taken as a base but the lowest part of the drooping branches, leading to much larger volumes. In the Dutch sites for 'Elstar', ratings were given in the summer of 1992 for vigour (scale 1 = very weak to 9 = very vigorous) and for density of the tree head (scale 1 = very dense to 9 = very thin). In some Dutch sites the number of pruning actions per tree were counted for summer or winter pruning. In late September of the last growing season in W, from the five highest shoots in each tree of 'Elstar', it was recorded whether they were still growing or had already formed a terminal bud. In W, in some years leaf health was rated according to the scale 1 = very good to 9 = very poor. In five years in NL, leaf and fruit analyses were made for N, P, K, Mg and Ca, and in leaves for Mn as well. For capacity reasons, leaf analysis was only done for the controls, An, DZA, GD, H12, Hi, O3 and Su and for fruit analysis for the same treatments except Hi. For leaf analysis, a mixed sample of 60 leaves was taken from all replicates of the third and fourth leaves from the base of long shoots positioned at breast height. For fruit analysis, a mixed sample of 25 to 35 fruits of the most common diameter was collected from all replicates shortly before picking. In W at the end of the trial, 'Elstar' trunks of some treatments were longitudinally sawn for an inside look of the two unions.

Annually, the flowering intensity was rated in W and H according to the scale 1 = no flower clusters to 9 = abundant flowering. Each year at all sites, fruits were counted and weighed per tree. As 'Elstar' in NL was spot-picked, the weight percentage of the first pick could be calculated, which is an indicator for advanced fruit colouring. Mean fruit weight (g), accumulated fruit numbers per m^3 final tree-head volume and per cm^2 final trunk cross sectional area (TCA) were calculated.

Important parameters were analysed using the statistical package Genstat 5, version 3.2. Significant F-tests ($P<0.05$) were followed by a LSD-test for pairwise comparison of the treatment means using $LSD_{0.01}$-values. Results of 'Elstar' and 'Jonagold' were analysed separately, but for each cultivar the data were combined for all sites.If there were significant interactions between interstem and site, the site data are given separately, if not, averaged for all sites. The three and two missing values in N and G respectively, were calculated by Genstat and are given in italics in the Tables. When there were significant interactions between site and interstem, no means for the sites are given. In the Tables ns means not significant, nc not calculated, and *, **, *** significant ($P<0.05$), strongly ($P<0.01$) and very strongly significant ($P<0.001$) respectively.

Results

Vegetative characters and winter hardiness

The interstem trees were well to fairly well developed and provided with feathers (sylleptic shoots), but the number differed per interstem. With both scion cultivars, trees on interstems DZA, Gl, GD and Su had a high number of feathers; averaged for the two cultivars 6.8, 7.5, 7.0 and 6.9 per tree, respectively. All other interstems gave less feathers. Control trees also had a high number of laterals; 8.2 per tree with 'Elstar' and 7.8 with 'Jonagold'). At planting, the stem of control trees was thicker than those of interstem trees (data not given). After three growing seasons, 'Elstar' trees on GD and Gl interstems had larger volumes than the controls and Ho, YT, O3, Ha and Pa had smaller ones. With 'Jonagold', none of the interstems promoted growth and only YT and O3 reduced it (Table 1, left part). So, only O3 and YT reduced tree volume in both cultivars. The growth indices given in the summer of 1992 with 'Elstar', did not show the same trends for all three sites. Only Su got the lowest rating in all places. Interactions also occurred with the rating for the density of the 'Elstar' tree heads, but again Su was the only interstem with significant thinner heads than the controls in all sites (data not given).

The volumes determined at the end of the trial are given in Table 1 (right part). The great volumes in H were due to the different measurement method as mentioned earlier. At this time, no interstem led to larger trees than the controls, but pruning may have uniformed the volumes, masking a possible growth promoting effect. The number of interstems with significant smaller volumes than the controls differed per site and so were the interstems involved. Most reduction was caused by O3; in five out of eight cases and by Su with three out of eight. The LSD-values in Table 1 (right part) can be used for any comparison within one cultivar. Table 2 summarizes the trunk circumferences of both scion cultivars at the end of the trial. The earlier measurement in N explains the smaller figures. Significant interactions between site and interstem prohibited averaging the data of the sites. With 'Elstar', control trees had the thickest trunks; in N and Z significantly thicker than all other treatments, but in W and Å, Gl and An equalled the controls and in Å GD and Ha as well. Albeit variable, least growth occured on Pa, Su, H12, O3, Hi and Do. With 'Jonagold', too, control trees together with Gl, An, GD belonged to the most vigorous group, but Hi allowed good growth as well. Growth reduction was less than with 'Elstar' and the weakest growth occurred on O3, but also Su and Do reduced vigour.

In both cultivars, the interstem circumference at the end of the trial, was rather large for An and Gl and and the reverse was true for Su, H12 and Pa. With 'Jonagold', O3 was also rather thin (data not given). Just as an example, control 'Elstar' trunks in W, measured at

the same height as halfway the interstem, averaged 25.9 cm and An and Gl were rather large with 24.5 and 24.3 cm respectively. Their size was clearly larger than those of thinnest interstems: Pa, Su and H12 with 17.2, 17.5 and 18.4 cm respectively. With 'Jonagold', thick interstem trunks occurred with An 19.7, DZA 18.9 and Gl 18.6 cm and thin ones with Su 15.2, H12 15.5 and Pa 16.6 cm. Also, O3 scored low with 17.1 cm. O3 was the only interstem with a conspicuous rough bark.

Table 2 (right) gives the ratios between interstem and scion circumference for W. With 'Elstar' compared to the control, only Do had a thick trunk relative to the scion and many interstems had a relatively thin trunk, especially Su, H12 and Pa. With 'Jonagold', DZA, Do and O3 had a relatively thick interstem and again Su, H12 and Pa were the thinnest. The results with O3 were conspicuously contradictory for the two scion cultivars. The ratios were more or less representative for those observed in the other sites.

In W, the circumference of the M.9 rootstock at the end of the trial with 'Jonagold' was greatest for the controls (29.9 cm). Thick M.9 stems were also present under An (28.3), GD and Pa (28.1), Ha and Hi (28.0), Do (27.7), H12 (27.5), Gl (27.2). At the lower end were YT and Su (25.4) and thinnest of all O3 (19.3).

The number of pruning cuts varied between the treatments, but both in W and Z the least cuts were needed with trees on Su (data not given). In W, trees on O3, Su

Table 1. Tree volume (m^3) after three growing seasons in NL sites and at indicated seasons in all sites (A = Autumn, S = Spring)
Baumvolumen (m^3) nach drei Anbaujahren an den niederländischen Prüforten bzw. allen Prüforten.

Interstem	Elstar 3 sites A90	Jonagold 3 sites A90	Elstar W A95	N S95	Z A95	Å S93	Jonagold W A94	G A94	H A94	Å A94
Control	0.51	0.68	1.14	1.12	0.92	0.74	0.77	0.96	2.45	0.66
DZA	0.50	0.65	0.97	1.00	0.74	0.67	0.69	0.89	2.21	0.69
GD	0.58	0.66	1.02	0.93	0.82	0.72	0.96	0.92	2.31	0.82
Gl	0.57	0.67	1.23	1.03	0.82	0.74	0.94	0.96	2.38	0.80
Su	0.52	0.59	0.86	0.88	0.78	0.65	0.78	0.81	1.88	0.67
H12	0.54	0.56	1.00	0.92	0.84	0.63	0.94	0.85	2.24	0.75
An	0.53	0.67	1.19	1.11	0.83	0.78	0.78	0.87	2.45	0.73
Hi	0.50	0.66	1.01	0.97	0.86	0.70	0.92	0.90	2.35	0.75
Do	0.49	0.61	1.10	0.87	0.75	0.74	0.90	0.83	2.08	0.76
Ho	0.44	0.62	0.92	0.79	0.76	0.57	0.79	0.90	2.36	0.56
YT	0.45	0.53	1.10	0.80	0.76	0.62	0.89	0.90	2.12	0.64
O3	0.44	0.48	0.77	*0.79*	0.83	0.49	0.46	0.71	1.72	0.61
Ha	0.44	0.68	1.06	*0.96*	0.77	0.72	0.90	*0.90*	2.14	0.75
Pa	0.45	0.62	0.97	*0.89*	0.69	0.69	0.94	*0.94*	2.28	0.70
F-test	***	***			*				***	
$LSD_{0.01}$	0.05	0.11			0.19				0.26	

Table 2. Trunk circumference (cm) measured in seasons indicated and ratio circumference interstem and scion cultivar in W (A = autumn, S = spring)
Stammumfang (cm) gemessen im Herbst (A) und Frühjahr (S) und Verhältnis Umfang Stammbildner zu Edelsorte am Standort W (Wilhelminadorp).

Interstem	Elstar W A95	N S95	Z A95	Å S96	Jonagold W A94	G A94	H A94	Å A94	Ratio Elstar A95	Ratio Jonagold A94
Control	25.1	24.3	26.2	25.0	19.5	19.7	22.5	18.6	1.02	1.00
DZA	22.1	20.3	23.5	22.0	17.7	18.2	21.3	17.6	1.06	1.06
GD	23.5	19.6	21.5	23.5	19.1	18.2	22.6	19.5	0.94	0.95
Gl	25.2	20.2	22.3	25.7	19.0	20.4	22.5	20.2	0.96	0.98
Su	21.4	18.4	18.1	21.3	17.5	17.5	20.5	17.5	0.82	0.86
H12	21.9	18.3	18.0	21.6	18.1	17.8	20.7	17.9	0.84	0.86
An	25.0	19.6	24.0	25.2	19.2	18.9	23.3	19.2	0.98	1.02
Hi	21.3	18.5	20.4	21.9	18.6	18.8	22.4	18.2	0.95	1.00
Do	21.4	17.4	22.3	21.4	16.8	17.2	19.7	17.3	1.11	1.06
Ho	21.9	19.2	21.1	23.0	16.7	20.1	22.9	16.7	0.99	1.02
YT	22.6	20.2	22.0	21.3	17.9	18.6	19.7	18.3	1.02	0.98
O3	21.2	*17.8*	21.0	19.9	14.8	15.8	17.3	16.3	0.94	1.10
Ha	22.2	*19.0*	19.1	24.1	18.3	*18.6*	21.5	18.0	0.92	0.94
Pa	20.9	*16.9*	16.9	20.9	18.0	*17.8*	19.5	18.0	0.82	0.88
F-test		***					***		***	***
$LSD_{0.01}$		1.8					2.0		0.06	0.04

and Ho were the first to end shoot growth in late summer (data not given). The index for leaf health of 'Elstar' only showed that Su and O3 looked slightly paler than the other treatments. With 'Jonagold', too, O3 and less so Ho showed the least healthy leaves, but Su did not differ from the other treatments (data not given). Of the treatments analysed, O3 showed the lowest contents of nutrients in leaves. With 'Elstar', the percentage of N on a dry weight basis averaged for seven year-site combinations was 2,16 for O3 as against 2,24-2,32 for five other treatments, including the control. For P the figures were 0.16 against 0.19-0.20, for K 1.06 against 1.34-1.39, for Ca 1.77 against 1.91-2.02, for Mg 0.24 against 0.25-0.26 and for Mn 44 ppm against 50-59 ppm respectively. With 'Jonagold', only O3 differed slightly for K (1.21 against 1.26-1.37) and Ca (1.62 against 1.67-1.71).

In NL, tree losses due to fruit-tree canker (*Nectria galligena*) during the trial were only conspicuous with Ho and Ha. In the summer of 1997, vertical trunk fissures were counted in 'Elstar' in W, but the numbers of both closed and new fissures were low (on average less than one per tree). Burr knots and root suckers hardly occurred.

Internally, the connection between 'Elstar' and the interstems DZA, GD, Gl, Hi, O3, Pa and Su all looked well and the same held for the union of these interstems with M.9; no brown lines were visible. During the trial period, no winter-frost damage occurred in NL or in DK.

Generative characters

From 1989 onward, the trees flowered well and no clear differences occurred between the treatments. Trees also cropped well and increasingly so with increasing tree size during the years, except for 'Elstar' in 1993 when at all sites, due to a too large crop in 1992, production fell back. However, no clear effect of the interstem could be detected. For 'Jonagold', the 1993 drop only occurred in Ho. Table 3 gives the accumulated production in fruits and kg per tree per site; interactions did not allow averaging. On the whole, no spectacular differences occurred between the treatments, possibly with the exception of Hi inducing high productions per tree in most sites with both cultivars and of O3 lagging behind in two 'Elstar' sites. With 'Jonagold' in Å, control trees were less productive than interstem trees. Productions in kg showed the same trends. As tree size is confounded with production per tree, Tables 4 and 5 give the productions per m^3 tree volume and cm^2 TCA per site respectively, for again interactions did not allow averaging. Table 4 shows that in some cases only, especially in Z, interstem trees cropped significantly more than control trees. Further, O3 proved to be a productive interstem per unit of tree volume. In not any case, interstem trees had lower numbers of fruit per m^3 than the controls. Further, no general lines are visible. Table 5 shows that in many more cases interstem trees were more fertile than control trees, especially for 'Elstar'. With 'Elstar', Z stood out. Here, except for DZA, all interstems enhanced productivity. Most productive interstems for 'Elstar' were H12, Hi, O3 and Pa all with significantly higher productions compared to the control at all four sites. Su, Ho, and Ha came close at three sites. Especially, Hi and Pa had high numbers of fruit per unit of TCA. With 'Jonagold', Do and O3 trees produced significantly more than the controls at all four sites but for all other interstems there was no consistent pattern. When both cultivars are considered, O3 was the only interstem that gave significantly higher numbers of fruit per cm^2 in all eight cases. H12, Do and Pa followed with six and Hi, Ho and Ha with five.

In NL, fruits of both cultivars were of good size in all years in all treatments. In DK, fruits were clearly smaller, especially when the trees got older, which will in part have been due to the higher latitude. Table 6 gives the fruit weights averaged over all years, separately for each site. There were no clear interstem effects holding for all sites, except with O3 that induced smaller fruit in four out of eight cases. In both cultivars, O3 stood out in percentage first pick, hence in fruit colour. Averaged for W and Z (where all interstems were present)

Table 3. Fruits number and kg (as exponents) per tree accumulated till the indicated year
Fruchtanzahl und Gesamternte (kg) pro Baum bis zum angegebenen Erntejahr.

Interstem	Elstar				Jonagold			
	W	N	Z	Å	W	G	H	Å
	1995	1994	1995	1995	1994	1994	1994	1994
Control	808^{134}	537^{96}	958^{147}	827^{116}	502^{124}	543^{121}	555^{141}	527^{100}
DZA	741^{126}	501^{90}	894^{136}	811^{113}	519^{121}	531^{108}	567^{136}	625^{110}
GD	816^{138}	541^{97}	970^{149}	737^{111}	548^{131}	580^{119}	589^{145}	575^{109}
Gl	847^{155}	539^{93}	1014^{160}	797^{122}	529^{129}	631^{132}	565^{142}	636^{120}
Su	680^{116}	511^{85}	902^{136}	763^{103}	508^{120}	525^{104}	578^{132}	581^{105}
H12	760^{128}	485^{88}	978^{147}	783^{118}	549^{132}	587^{122}	553^{135}	639^{116}
An	788^{143}	526^{95}	977^{154}	757^{117}	501^{124}	560^{119}	573^{146}	656^{124}
Hi	824^{141}	559^{98}	1094^{166}	948^{134}	545^{130}	578^{120}	542^{137}	689^{128}
Do	765^{128}	451^{81}	861^{135}	718^{107}	485^{119}	572^{119}	607^{143}	646^{120}
Ho	825^{135}	446^{78}	996^{146}	893^{117}	520^{124}	546^{117}	550^{138}	592^{106}
YT	717^{119}	506^{91}	993^{148}	669^{93}	463^{112}	546^{118}	579^{136}	598^{114}
O3	759^{124}	*474^{70}*	944^{138}	731^{98}	468^{104}	511^{104}	529^{124}	552^{95}
Ha	779^{134}	*568^{99}*	1035^{160}	900^{127}	514^{125}	*594^{126}*	644^{158}	634^{117}
Pa	779^{128}	*563^{94}*	1053^{159}	868^{120}	518^{125}	*578^{124}*	627^{156}	599^{113}
F-test		*** ***				*** ***		
$LSD_{0.01}$		112^{16}				78^{17}		

Table 4. Accumulated number of fruits per m³ final tree volume till indicated year
Gesamtanzahl Früchte pro Baumvolumen (m³) bis zum angegebenen Jahr.

Interstem	Elstar				Jonagold			
	W	N	Z	Å	W	G	H	Å
	1995	1994	1995	1995	1994	1994	1994	1994
Control	793	503	1054	1133	666	580	240	849
DZA	791	576	1222	1235	845	602	266	866
GD	796	682	1201	1052	625	623	265	686
Gl	732	571	1276	1099	613	659	246	829
Su	825	598	1182	1181	755	657	314	940
H12	802	563	1188	1124	625	693	259	838
An	687	555	1204	1016	692	644	241	883
Hi	872	666	1262	1407	652	632	236	869
Do	749	560	1167	981	615	682	290	879
Ho	909	656	1371	1266	716	621	250	862
YT	683	691	1293	984	592	570	279	768
O3	1027	*741*	1152	1377	1121	727	310	912
Ha	776	*631*	1280	1171	645	*638*	293	877
Pa	811	*733*	1423	1300	596	*620*	279	886
F-test			***				***	
$LSD_{0.01}$			205				172	

Table 5. Accumulated number of fruits per cm² final scion TCA till indicated year
Gesamtanzahl Früchte pro cm² Stammquerschnitt (TCA) bis zum angegebenen Jahr.

Interstem	Elstar				Jonagold			
	W	N	Z	Å	W	G	H	Å
	1995	1994	1995	1995	1994	1994	1994	1994
Control	16.3	11.8	17.6	16.7	16.5	16.8	14.3	19.2
DZA	19.3	15.3	20.4	21.2	20.7	20.3	16.0	25.4
GD	18.6	17.8	26.3	17.0	18.7	21.4	14.7	19.2
Gl	16.9	16.8	25.9	15.2	18.3	19.4	14.3	19.7
Su	18.7	19.1	34.6	21.1	20.8	21.5	17.9	23.3
H12	20.1	18.5	38.2	21.4	20.7	23.3	16.7	25.8
An	16.0	17.3	22.0	15.1	17.0	19.8	13.5	22.4
Hi	23.1	21.0	33.0	24.9	19.7	20.3	13.8	26.1
Do	21.0	18.7	21.6	19.7	21.5	24.0	19.6	27.7
Ho	21.8	15.2	28.2	21.2	23.2	17.4	14.0	27.0
YT	17.7	15.9	26.1	19.0	18.2	18.6	19.0	22.4
O3	21.3	*19.5*	26.9	24.1	26.5	25.9	21.9	26.0
Ha	20,0	*20.2*	35.2	19.3	19.3	*21.3*	17.5	25.0
Pa	22.4	*26.4*	45.2	25.6	20.1	*21.9*	20.2	23.3
F-test			***				***	
$LSD_{0.01}$			4.0				4.3	

comprising 6 or 5 years respectively, 72% of the 'Elstar' fruit of O3 trees was harvested during the first pick. The lowest value occurred with Gl (57%). Su, YT and Do also ranked rather high with 63%. For 'Jonagold', averaged for six years in W and Z, O3 had the highest score with 46%. Here, the lowest figures were 36% (Hi, Pa) and 37% (Gl, An). 'Jonagold' colour grading in G during three years resulted in a range in weight percentage of fruit with more than 33% red blush from 55 (Hi) to 61 (Su). In H, grading was done in five years and weight percentages of fruit with more than 50% red colour ranged from 36 (Hi) to 47 (Su). So in both places, Hi scored low and Su high.

Averaged for five analyses, the calcium content of 'Elstar' fruit ranged between 5.1 (GD) and 5.4 (control and O3) mg/100 g fresh weight and for 'Jonagold', average of four analyses, between 3.8 (control) and 4.4 (Su). In both cultivars, the differences for the other minerals (N, P, K, Mg) and the dry matter content were also small (data not given).

Discussion

Due to lack of severe frosts no conclusions can be drawn with regard to the winter hardiness of the interstems used for 'Elstar' and 'Jonagold', except for Su, GD and Gl present in an earlier trial (see Introduction). Hi can be mentioned as well given the established positive experiences in Germany, albeit with other scion cultivars [DE HAAS, 1966]. One can only speculate on the cause of hardiness increase of scion cultivars by an interstem. If trees are to be well prepared for the coming winter, terminal shoot buds should be formed rather early. Under Dutch conditions, when the weath-

Table 6. Mean fruit weight (g) averaged for all production years
Mittleres Fruchtgewicht (g) über alle Produktionsjahre.

Interstem	Elstar				Jonagold			
	W	N	Z	Å	W	G	H	Å
	1995	1994	1995	1995	1994	1994	1994	1994
Control	169	180	161	149	253	236	255	190
DZA	169	182	162	158	242	225	240	175
GD	172	181	162	156	246	215	248	191
Gl	181	173	164	159	252	228	251	189
Su	167	167	163	147	244	224	228	181
H12	174	182	163	161	246	228	245	182
An	179	184	165	161	250	227	254	188
Hi	173	177	160	154	247	222	253	187
Do	173	184	172	155	255	224	236	186
Ho	168	177	158	146	241	244	253	179
YT	169	182	159	149	248	231	234	191
O3	163	*169*	156	141	228	225	235	174
Ha	172	*180*	162	159	247	*220*	246	185
Pa	164	*176*	162	154	252	*233*	250	189
F-test			**				***	
$LSD_{0.01}$			10				15	

er is mild 'Elstar' and 'Jonagold' continue to grow till late in autumn and this might explain their tenderness. In the current trial the few observations on the termination of shoot growth showed that Su led to earlier terminal bud formation than control trees, whereas Gl and GD did not. Still, in the former interstem trial all were hardy. The same holds for Hi, no early bud formation, but a good reputation as a hardy interstem. O3 and Ho also led to early cessation of shoot growth, but without more detailed observations no prediction on hardiness can be given and this also holds for all others not yet mentioned. It is known that the lower trunk is the last part to harden [PALONEN & BUSZARD, 1997], which may explain why a hardy cultivar as trunk lowers frost risks. Given the complexity of dormancy [DENNIS, 1994], it is uncertain whether the positive effects of the three interstems in the 1984 trial, will have a more general validity.

The second aim of the trial, growth control, was achieved. Several interstems caused some growth reduction as seen in Table 1 for final tree volume, but especially in Table 2 for the final circumference of the central leader. The latter is more accurate, as tree volume is more affected by pruning. O3 was the most consistent growth-controlling interstem; in all eight cases trunks remained significantly thinner than those of the controls. Do and Su followed closely with seven cases; the data for all other interstems were less consistent (Table 2). Since growth reduction is of more importance for 'Elstar' than for 'Jonagold', it should be noted that in addition to the three interstems mentioned, DZA, H12, Hi, Ho, YT and Pa also significantly reduced trunk size of 'Elstar' in all four sites (Table 2). KÖKSAL [1973], too, found many interactions between cultivar and interstem. However, his material was probably not virus free and because viruses may moderate growth [VAN OOSTEN et al, 1982], it is not possible to distinguish between virus and interstem effects. O3 was not only the most consistent interstem in growth reduction, but also the one that slightly reduced the content of some minerals in the leaves and did not look as healthy as the other combinations. Apparently, O3 formed a barrier for upward transport. It has been suggested that O3 may be not well compatible with 'Jonagold' [AUTIO et al.,1997]. So, our 'Jonagold' effects may have been due to the poor growing together. Alas, no observations were made with regard to the internal quality of the unions. As in our trial, O3 also induced low mineral contents in 'Elstar' leaves, this cultivar, too, may be not well compatible with O3. However, internally the unions of O3 with 'Elstar' or M.9 did not show any sign of poor compatibility. The growth reducing interstems Su, H12 and Pa had relatively thin trunks, but for Do just the opposite was true (Tables 2 and 3). With 'Jonagold', the growth reducing Su had a relatively thin trunk as well, but here both the O3 and Do interstems were relatively thick (Table 1 and Table 2, right). Dwarfing interstems on vigorous rootstocks reduce vigour and have a larger diameter relative to that of the scion cultivar [PARRY & ROGERS, 1968; CARLSON & OH, 1975]. It is not clear what role the diameter of interstem and scion plays in growth reduction. Size differences have been explained by different degrees of uptake and utilization of minerals by the interstem tissues. It has been found that differences exist in the nutrient levels of the ascending sap above and below interstems. Dwarfing interstems might 'keep' more nutrients and as a result show more radial growth than either the scion or the rootstock, whereas invigorating interstems remain thinner, because more nutrients may pass allowing more radial growth of scion and rootstock cultivars [JONES, 1971; 1976]. This reasoning may be in line with our results of 'Jonagold' on O3 and Do, but certainly not with those of Su, H12 and Pa (Table 2). Indeed, most of the weakening interstems in our trial remained thinner in relation to the scion cultivar compared to non-dwarfing ones. In case of a thin interstem, one is inclined to think that growth reduction is the result of a mechanical restriction in acropetal and basipetal transport. It has been found, as mentioned earlier, that interstems restrict upward movement of nutrients [JONES, 1971] and of gibberellins

[RICHARDS et al., 1986]. It has also been found that the interstem bark may reduce the downward transport of assimilates [DICKSON & SAMUELS, 1956]. Why various interstems clasped between the same partners, can grow differently in radial direction, is unclear. It appears as if an interstem still can express some of its own features. The conclusions of the extensive work of LOCKARD & SCHNEIDER [1981] are relevant here. They ascribe the dwarfing effect of an interstem to reduction of the downward flow of auxin passing through the bark. The bark of different cultivars will permit different amounts of auxin to pass. This will affect root growth and as a consequence cytokinin formation in the roots and these root hormones in turn influence shoot growth. Bark phenolic compounds may be involved in the effect on auxin transfer. In this reasoning, in our trial the bark of the growth-reducing interstems apparently provides the M.9 rootstock with less auxin than non-growth controlling interstems. It would be interesting to know more about the auxin-transport capacity of the bark of the various interstems used. Compared to the control trees more interstems reduced growth with 'Elstar' than with 'Jonagold' for which no explanation can be offered. KÖKSAL [1973] found that the influence of an interstem increases with the vigour of the rootstock and the scion cultivar. As stated already, 'Elstar' is a more vigorous cultivar than 'Jonagold'. In a study with various rootstocks used as interstems on two rootstocks it was found that the interstems made trees intermediate in vigour between that of the two rootstock parts used separately [PARRY & ROGERS, 1968]. In our trial, the vigour of the used cultivars 'on their own roots' is not known, so it cannot be said whether 'Elstar' and 'Jonagold' were subject to a 'blending' of the influence of the two components as stated by PARRY & ROGERS [1968].

Productivity per tree (Table 3) is as usual confounded with tree size and is thus, not of great value in distinguishing an interstem effect. Only Hi allowed a high tree production with both cultivars and with 'Elstar' O3 lagged behind. Tables 4 and 5 both show that compared to the controls interstems never had a negative effect on productivity. Often, the reverse was true. In Z, production per cm^2 was raised more often than elsewhere, which may have been due to the greater vigour whereby a reduction sooner leads to an increase in productivity. Still, although control 'Elstar' trees in Z had thicker trunks than in W or Å, the effect was not significant (Table 2).

Anyhow, as both Table 4 and 5 show, interstems bear no risk for tree productivity, which is in line with results of other studies [PARRY & ROGERS, 1968; CARLSON & OH, 1975, CZYNCZYK, 1981]. However, the positive effects of some interstems on cropping efficiency do not fit in the findings of PARRY & ROGERS [1968], who found that interstem trees were neither more nor less productive for their size than single-worked trees. Only in a few cases Table 5 agrees with Table 4, for example in the positive effects of Hi. This means that the two parameters do not give similar impressions on tree productivity. Fruits per cm^2 TCA is probably the better parameter and as such widely used. In the most cases were growth was significantly reduced compared to the control, productivity per cm^2 TCA was enhanced and the same held for the cases where growth was not reduced and fertility not promoted (Tables 2 and 5). In spite of the effects on growth and cropping, the interstems had no great effect on fruit size. With 'Elstar', only Su and O3 in N gave smaller fruit compared to the controls which is not in line with the many more cases where productivity was enhanced. For 'Elstar', there were also six cases where significantly larger fruits were obtained, independent of an increase in productivity (Tables 5 and 6). With 'Jonagold', fruit size was never enhanced and in nine cases a reduction occurred compared to the controls and except for Su in H this was always coupled with an increase in fruit number per unit of TCA. Still, in other cases, increases in productivity did not lead to a decrease in fruit size (Tables 5 and 6). As fruit size of 'Jonagold' often tends to be too large a small negative effect may be acceptable. As expected, fruit colour was advanced by those interstems that reduced vigour and induced less dense tree heads. Reduced shoot growth will leave more assimilates for fruit colour formation and in a smaller tree head more fruit will be exposed to direct radiation. For Su, this effect was recorded earlier [VAN DE WAART & BAART, 1990], and is also known of other cultivars [HILKENBÄUMER, 1975]. However, the colour effect was too small to choose an interstem for that reason only. The interstems, except O3, did not clearly affect fruit mineral composition. Thus, it is not expected that fruit quality or storability will be negatively affected by the interstem, but no observations were made.

In our trial, several interstems induced growth control with 'Elstar' without disadvantages for productivity or fruit size (Tables 2, 5 and 6). Of these, Ho and Ha cannot be recommended because tree losses due to fruit tree canker were unacceptable. O3 must be discarded, because of possible compatibility problems [AUTIO et al., 1997] and because it affects the nutrient status of the tree negatively. That leaves DZA, Su, H12, Hi, Do, YT and Pa. Of these, only Su did also prove to be winter hardy in an earlier study under Dutch conditions as mentioned in the Introduction. Although the others may have a similar hardiness, such as Hi with its good reputation in neighbouring Germany, the choice for Su is more obvious. In The Netherlands, Su is currently used increasingly as an interstem for the tender and vigorous 'Elstar'. Hi is another interstem that looks promising given its good reputation on hardiness in Germany and its good effect on productivity (Table 3 and 5). If for the less vigorous 'Jonagold', growth control is also wanted, Su can be used as well. Given the many interactions found here and elsewhere [KÖKSAL, 1973], it is emphasised that without thorough experimentation the use of the before-mentioned interstems for other cultivars under other conditions bears risks.

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Dr. Ir. S.J. Wertheim, Fruit Research Station, Lingewal 1, 6668 LA, Randwijk, The Netherlands. Dr. O. Callesen, Danish Institute of Agricultural Sciences, Department of Fruit, Vegetable and Food Science, DK 5792, Årslev, Denmark.