Carry-over Effects of CCC-applications in Pear Orchards

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Abstract

Chlormequat (CCC) has been used for many years in the Netherlands as a chemical growth retardant to restrict vegetative growth and promote flower bud development in pears. After several years of annual applications, CCC-residue levels in the fruits frequently exceeded the maximum residue limit (MRL) of 3.0 mg/kg. In 2001 the use of CCC in pears was banned and the MRL was reduced to 0.05 mg/kg. CCC is a very persistent chemical which seems to have accumulated in trees treated for many years with this growth retardant. Because of the expected carry over of these accumulated residues into fruits in the years following the last application of CCC, it was decided to transiently decrease the MRL. In 2001 and 2002 a temporary MRL of 0.5 mg/kg was in force. In 2003 a temporary MRL of 0.3 mg/kg came into force which will expire in June 2006. CCC-residue levels in pears, sampled in the final year of CCC application, varied between 6.8 and 1.1 mg/kg, depending on the dosage and number of years of CCC-treatment. During the first growing season without further CCC-applications, the CCC-residue of the fruits decreased on average by about 90%. During the following year without CCC the rates of decrease in CCC-residues varied strongly. In some trials a 60% decrease was noted in the second 'CCC-free' year, while in other trials a much lower or no further decrease was observed. In 2003 a further reduction was observed in most trees. Compared to 2002 the CCC levels had decreased by 6 to 80% and were all below the temporary MRL of 0.3 mg/kg. However, despite these decreases in CCC-residue levels in trees grown for three to six years without any further CCC application, in 2003 the CCC residue in the fruits of most trees still exceeded the future MRL of 0.05 mg/kg. Only the residue levels of the 'Doyenné du Comice' trees planted in 1997 and treated with CCC during 1998-2000 were below 0.05 mg CCC/kg. In 2004 only the fruits of one trial exceeded the MRL of 0.05 mg CCC/kg. In these trees, which received their final CCC application in 1999, an average CCC level of 0.12 mg/kg was measured. In conclusion, the data demonstrate that for trees previously treated with CCC at recommended or lower rates, at least six seasons without CCC-application are needed to reach the MRL of 0.05 mg/kg.

INTRODUCTION

Chlormequat chloride (CCC) has been used for many years as a chemical growth retardant to restrict shoot growth and promote flower bud development in pears. The use of CCC allowed growers to grow pears in high density planting systems and to quickly obtain and maintain a good balance between shoot growth and fruit production after planting. CCC is also used in other crops. For example, in grain it is applied to reduce internode elongation. Shorter stems reduce the chance of a crop being flattened by rain or wind. In floriculture it is used to grow compact and sturdy pot and bedding plants.

The mode of action of CCC in plants is the inhibition of the biosynthesis of gibberellins, a class of endogenous plant hormones involved in the control of cell elongation and flower development. CCC is a very persistent chemical in plants[1].

[1] http://www.inchem.org/documents/jmpr/jmpmono/v076pr09.htm

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Therefore, yearly applications of this growth retardant in perennial plants such as fruit trees may result in an accumulation of CCC. This stored CCC may act as a source of the chemical in future growing seasons and may be transported into the fruits. As a result CCC can be found in fruits several years after the trees have received their last CCC-treatment.

Following a number of incidents within the European Community in which the maximum residue limit (MRL) of 3.0 mg/kg was exceeded, a preliminary decision was made in 2000 to reduce the MRL for pears from 3.0 to 0.05 mg/kg fresh weight[2]. Due to the expected carry over of CCC accumulated in trees previously treated with CCC, growers were unlikely to obtain such a large reduction in MRL in only one or two years. In addition, more and more buyers were demanding CCC-free pears. Beginning in March 2001 the use of CCC in pears was no longer allowed.

In the past ten years the Fruit Research Station in Randwijk (until 1999 located in Wilheminadorp) and its former Experimental Garden Zeewolde in the Netherlands have carried out several experiments and practical trials to determine the efficacy of CCC in controlling shoot growth in pear trees. When it was announced that the use of CCC in pear orchards would be prohibited and the MRL for CCC-residue would be decreased, experiments were started to study the growth and development of the trees after termination of CCC-applications. Also, the CCC-residue levels of the fruits of these trees were monitored for several years in order to assess how many years without further CCC applications it would take to produce fruits with CCC levels no longer exceeding the MRL of 0.05 mg/kg.

MATERIALS AND METHODS

Legal Directives for the Use of CCC in Pear Orchards

Until March 2001 fruit growers were allowed to use CCC for controlling shoot growth and promoting flower bud development in pear. The latest date for legal application of the product was set at 3 months before harvest. Recommended dosages were 150 to 250 ml/100 l spray volume, using a product containing 750 g CCC/l. According to the instructions of the manufacturer, the first application should be given when the young shoots have developed 5 to 8 leaves, followed by a second application two to three weeks later, if necessary. The maximum residue limit (MRL) for CCC in fruits was, at this time, 3.0 mg/kg fresh weight. Based on EU regulations this MRL is currently reduced to 0.05 mg/kg. In 2001 and 2002 a 2-year transition period was in force, during which the maximum CCC-level for pears was 0.5 mg/kg. From August 1, 2003 till July 31, 2006, a second transition period is in force with a maximum CCC residue level of 0.3 mg/kg fresh weight.

CCC-applications in the trials described in this paper were carried out by means of a knapsack sprayer. Trees were sprayed till runoff, equivalent to a total volume of approximately 1000 l/ha.

Experiments

1. Trial 1. In spring 1989 two-year old ‘Conference’ trees on quince MC rootstocks were planted in the Experimental Garden Zeewolde at a distance of 3.25 x 1.30 m (2367 trees/ha). From 1991 to 1997 the trees were sprayed annually with 2.3 kg CCC (two times 2.5 l/ha each year) using a product containing 460 g/l CCC. The treatment was carried out on plots of two trees and replicated four times. In 1998 the trees received 2.25 kg CCC (two times, 1.5 l/ha on May 12 and May 20) using a product containing 750 g/l CCC. In 1998 fruits were harvested on September 15. On February 19, 1999 a sample of these fruits was taken for CCC-residue analysis. Samples of fruits were taken directly from the trees on September 22, 1999, August 29, 2000, September 5, 2001, September 2, 2002,

[2] http://europa.eu.int/comm/food/fs/inspections/fnaoi/reports/pesticides/netherlands/fnaoi_rep_neth_1139-2000_en.pdf

September 8, 2003, and September 11, 2004.

2. Trial 2. In spring 1989 two-year old ‘Conference’ trees on quince MC rootstocks were planted in the Experimental Garden Zeewolde at a distance of 3.25 x 1.30 m (2367 trees/ha). Each treatment was replicated eight times and contained one tree each. The treatments sampled for CCC-residue analysis were: 1) CCC-treatment from 1994 -1997, no CCC from 1998 onwards, 2) CCC-treatment from 1994-1998, no CCC-application from 1999 onwards. From 1994 to 1997 both treatments were sprayed annually with 3.0 kg/ha CCC, using a product containing 460 g/l CCC. The dates on which CCC was sprayed in treatment 2 in 1998 were May 11 (2 l/ha), May 25 (1 l/ha), and June 8 (1 l/ha) with a product containing 750 g/l CCC, again up to a total amount of 3.0 kg/ha. In 1998 fruits were harvested on September 14 and stored. On January 29 and February 19, 1999 samples were taken for CCC-residue analysis. In 1999 the trees of treatment 2 received a total amount of 3.75 kg/ha CCC, which was sprayed over 4 applications on May 3 (2 l/ha), May 17 (1 l/ha), May 31 (1 l/ha), and on June 11 (1 l/ha) using a product containing 750 g/l CCC. Fruits for CCC-residue analysis were sampled on September 22, 1999, August 29, 2000, September 5, 2001, September 2, 2002, September 8, 2003, and September 11, 2004.

3. Trial 3. In spring 1992 eight-year old ‘Conference’ trees on quince MC rootstocks were planted in the Experimental Garden Zeewolde at a distance of 3.25 x 1.20 m (2564 trees/ha). Each treatment consisted of plots of four trees planted in four replicates. The treatments sampled for CCC-residue analysis were: 1) Untreated control trees, 2) Trees treated twice with 0.5 l/ha CCC, 3) Trees treated twice with 1 l/ha CCC, and 4) Trees treated twice with 1.5 l/ha CCC. These CCC-treatments were carried out in 1999 only and took place on May 4 and 17, using a product containing 750 g/l CCC and giving total dosages of 0.75, 1.5, and 2.25 kg/ha, respectively. Fruits were sampled on September 22, 1999, August 29, 2000, September 5, 2001, September 2, 2002, September 8, 2003, and September 11, 2004.

4. Trial 4. In spring 1996 two-year old ‘Conference’ trees on quince MC rootstocks were planted in the Experimental Garden Randwijk at a distance of 3 x 1.25 m (2667 trees/ha). Each treatment consisted of plots of three trees planted in four replicates. CCC-treated trees received CCC-applications from 1997 to 2000. In 1997 trees were given 2.63 kg/ha CCC divided over two applications, the first one on May 5 (2 l/ha) and a second one on May 23 (1.5 l/ha) using a product containing750 g/l CCC. In 1998 six applications of CCC were made (1, 13, 20 and 28 May, 5 and 10 June) which resulted in a total amount of 4 kg/ha. In 1999 and 2000 two applications of 1 l/ha of a product containing 750 g/l CCC were carried out each year (1.5 kg CCC/ha). Dates of application were May 4 and 14 in 1999, and May 3 and 11 in 2000. In 2001 none of the trees received any CCC and the CCC-treatments were replaced by root pruning. In 1999 fruits were harvested on September 4 and sampled for CCC-residue analysis around November 15. Fruits were sampled directly from the trees on September 5, 2001, and September 2, 2002. After the harvest in 2002 the trial was finished because part of the orchard, including the trees used in this trial, was grubbed.

5. Trial 5. In March 1997 two-year old ‘Doyenné du Comice’ trees on quince MC rootstocks were planted in the Experimental Garden Randwijk at a distance of 3.5 x 1 m (2857 trees/ha). The trial was carried out to evaluate the growth retarding effect of a new chemical as an alternative to growth control by CCC. Each treatment consisted of plots of three trees planted in six replicates. The treatments sampled for CCC-residue analysis were: 1) Untreated control trees, 2) Trees treated annually with 2.63 kg/ha CCC (1 x 1.5 l/ha and 2 x 1 l/ha of a product containing 750 g/l CCC) in 1999 and 2000. Fruits were sampled directly from the trees on September 5, 2001, September 2, 2002, September 16, 2003, and October 4, 2004.

CCC-residue Analysis

For each sample 10 to 20 randomly harvested fruits from a single treatment were homogenised. In 1998, 1999, 2001, 2002, 2003, and 2004 the CCC-residue analyses were carried out by the Soil, Crop, and Environmental Laboratory "Zeeuws Vlaanderen BV" in Graauw (Netherlands). The samples taken in 2000 were analysed by TNO Nutrition in Zeist (Netherlands). Both laboratories use similar procedures for extraction, purification, detection and quantification of the CCC-content of the fruits (LC-MSMS, combined liquid chromatography and mass spectrometry). The analytic method (European standard NEN 15055) warrants a very sensitive and reproducible determination of CCC. Since 2002 the sensitivity of the CCC-analysis method has been improved. The detection limit of the method has been reduced from 0.05 to 0.01 mg CCC/kg fresh product.

Growth and Production

The growth and production of the trees was determined in 1998 (trials 1 and 2), 1999 (trial 1 to 5) and 2000 (trial 4 and 5). Shoot growth was determined either as total shoot length (m/tree) or by a growth index based on visual judgement on a scale of 1 (no growth) to 9 (excessive growth). Production was measured by weighing of all fruits of the observation trees at harvest.

RESULTS

CCC Residues. Tables 1 to 4 summarize the results of the CCC-residue analyses carried out in the years CCC was applied to the trees, as well as up to six years after the final CCC application to the trees.

1. Trial 1. In 1998, the year in which the trees of trial 1 received their last CCC-treatment, the average CCC-residue content of the fruits was 6.8 mg/kg fruit (Table 1). This residue level was more than two times the maximum residue limit for CCC of 3 mg/kg fruit (MRL valid up to March 2001). Fruits sampled from the same trees in 1999 and 2000 contained significantly less CCC. In 1999, one year after the last CCC-application, the average CCC-residue level had decreased to 0.5 mg/kg. In 2000 the average residue level had further decreased to 0.17 mg/kg. Thus, during the first growing season after termination of the CCC-applications, the CCC-residue level decreased by more than 92%, followed by another 66% decrease in the following growing season. Surprisingly, in 2001 no further decrease in the CCC-residue was observed. On the contrary, the average residue level of 0.27 mg/kg in fruits grown in 2001 was even higher than the level of 0.17 mg/kg in 2000. From 2002 to 2004 the average CCC-level in the fruits of the treated trees steadily decreased from 0.19 to 0.04 mg/kg.

2. Trial 2. Despite the higher amounts of CCC applied in this trial, the CCC-residue levels in the fruits were lower than those in trial 1. In this second trial the residue-levels in 1998 in treatment 10 remained below 3.0 mg/kg (Table 2). Continuation of the CCC-treatments in 1999 increased the residue levels in this year to an average value of 3.2 mg/kg. In 2000 CCC was no longer applied, which resulted in residue levels that were only about 10% of those in the previous year. In 2001 no further decrease in CCC-residue levels was observed, but in 2002 they showed a further decrease to 0.24 mg/kg for the trees of treatment 10. However, in 2003 the residue level remained almost similar to that in 2002 and amounted to 0.23 mg/kg. In 2004 a further decrease in the level of CCC to 0.12 mg/kg was noted. The trees of treatment 1 received their last CCC application in 1997. In 1998 the CCC-residue level in their fruits was 0.4 mg/kg. In 2000, after 3 years without CCC applications this level had decreased to 0.10 mg/kg. As observed in treatment 2 a slightly higher level of 0.14 mg/kg was observed in 2001. In 2002, 5 years after the last application of CCC in this treatment, the average level of CCC in the fruits was still 0.10 mg/kg. One year later, in 2003, again a residue level of 0.10 mg/kg was measured. However, in 2004 this level had decreased to 0.03 mg/kg.

3. Trial 3. This trial was conducted to examine whether a satisfactory degree of growth control in pear trees could be achieved by applying lower dosages of CCC and how this would affect the residue levels in the fruits. The CCC-residue data listed in Table 3 clearly demonstrate that lowering the dosage of CCC reduces the CCC-residue in the fruits. In the year of application, CCC-residue levels in fruits of trees treated with 0.75,

1.5 or 2.25 kg/ha CCC were 1.1, 1.7 and 2.0 mg/kg, respectively. In 2001 and 2002, two and three years after the final CCC-treatment, these residue levels had decreased to 0.15, 0.20 and 0.22 mg/kg and to 0.08, 0.12 and 0.17 mg/kg, respectively. Despite these large decreases in residue levels of 88% or more, the future maximum residue limit of 0.05 m/kg was still exceeded in all treatments. In 2003 and 2004 a further decrease in CCC-levels was noted to 0.06, 0.10 and 0.05 mg/kg and to 0.03, 0.02 and 0.02 mg/kg, respectively. Unfortunately, in 2000 only trees treated with 2.25 kg/ha CCC in 1999 were sampled for CCC-residue analysis. Comparing the residue levels of 2000 to 2002 of fruits from this treatment shows that the greatest reduction in residue level took place during the first growing season without CCC-application, and that the decrease continued at a much slower pace during the following growing seasons.
4. Trial 4. The CCC-residue level of fruits of 'Conference' trees in trial 4, treated with 2.63 kg CCC/ha in 1997, 4.0 kg/ha in 1998 and 1.5 kg/ha in 1999, was 0.9 mg/kg in 1999 (Table 4). In 2000 the use of CCC in this trial ended, with a last application of 1.5 kg/ha CCC. In 2001, after one year without CCC-treatment, a CCC-residue level of 0.09 mg was found, i.e. only 10% of the level observed in 1999. One year later, in 2002, the CCC-residue level had further decreased to 0.05 mg/kg.
5. Trial 5. Fruits of the 'Doyenné du Comice' trees of this trial, which were treated with 2.63 kg CCC/ha from 1998 to 2000, contained 0.19 mg CCC/kg in 2001 (Table 5). In 2002 this level was still as high as 0.17 mg/kg. Further decreases to 0.03 mg/kg and to 0.01 mg/kg were observed in 2003 and 2004, respectively.
At Randwijk parts of the pear orchard were never treated with CCC. CCC-levels in fruits sampled from these trees were below the detection limits of the applied analytical method (0.05 mg/kg in 1999-2001 and 0.01 mg/kg in 2002-2004).

Growth and Production

The growth of the trees was significantly inhibited by the amounts of CCC applied to the trees (Table 6). In trial 1 tree growth in 1998, the last year of CCC-treatment, was reduced by more than 75% as compared with untreated trees. In 1999, the first year without further CCC-application, growth of the CCC treated trees was still strongly reduced although the extent of growth reduction had decreased to 40%. Fruit production was slightly higher in the CCC-treated trees. In trial 2 growth of the trees of treatment 1 (last CCC-application in 1997) was stronger than that of the trees of treatment 2 (last CCC-application in 1999) in both 1998 and 1999. However, in the same years only very small differences in fruit production were observed between both treatments.

During the first year of treatment, two applications of 1.5 l/ha (2.25 kg/ha) of CCC reduced the shoot growth of the trees in trial 3 by almost 40% without any effect on fruit production. Growth of the trees of trial 4 in 2000 was only visually judged. In 1999 and 2000 only a limited amount of 1.5 kg CCC/ha was applied, which did not significantly affect either growth or production. In 1999, one year after the trees had received 4 kg CCC/ha, the CCC-treated trees produced 80% more than the trees that were root pruned to control their growth. Unfortunately growth of these trees was not assessed in 1999. The production of 'Doyenne du Comice' in trial 5 was very low in 1999 and the growth in this year was only slightly reduced in the CCC-treated trees. In 2000 the production was much higher. The CCC-treated trees produced on average 1.7 kg/tree more than the untreated trees while at the same time shoot growth was reduced by 38%. No observations on growth and fruit production of the trees were made in the years 2001-2004.

DISCUSSION

A number of the observations which were made in this study are difficult to explain. In 1998 almost three times less CCC was found in the fruits of trial 2, which had received 3 kg CCC /ha, than in the fruits of trial 3, which had received a lower dosage of CCC of 2.3 kg/ha. The most logical factors that may explain this discrepancy in CCC-residue levels are differences in tree vigour and number of years of CCC-treatment. The trees of trial 3 which showed the highest levels of CCC-residue in 1998 had been sprayed with CCC for 8 years, while those of trial 2 had only received CCC for 5 years in 1998. A comparison of the residue levels in trial 2 for 1998 and 1999 strongly suggests an accumulation of CCC-residue during the years of CCC-treatment. In 1999, after 6 years of CCC-application, the residue level had increased from 2.3 mg/kg in 1998 to 3.2 mg/kg in 1999. Similar observations, based on analyses of retail samples of pears in the UK between 1997 and 2002, have been reported recently (Reynolds, 2004).

The degree of shoot growth decreases with the number of years of CCC-treatment. The data on shoot growth presented in Table 3 clearly show that the growth of the trees in trial 3 was significantly less than that of the trees in trial 2. Consequently, more of the CCC may be transported into the fruits of the trees with the weaker growth instead of being diluted into new shoot growth. Finally, it cannot be excluded that differences in climatic conditions between the dates of CCC-application in both trials may have resulted in differences in the rates of CCC-uptake and subsequently have led to differences in CCC-residue in the fruits.

The slightly higher CCC residues in 2001 as compared to 2000 may be related to the much lower fruit load in 2001 as opposed to 2000, resulting in a relatively higher availability of the remaining CCC in the tree per fruit.

CONCLUSIONS

The results of the CCC-residue analyses of pears harvested in the year of CCC-application and in the years thereafter clearly demonstrate that it may take at least six years of cultivation without CCC-applications to produce fruits with a CCC-residue level below the maximum residue limit of 0.05 mg/kg. In all trials used for this study, a very large initial decrease in CCC-residue level was observed in fruits grown in the first years after ending the CCC-applications. Compared to the residue levels in the last year of CCC-treatment, the levels after one year without any further application of CCC had decreased by about 90%. In the second year without CCC-application, CCC-residues decreased by 66% and 42% in the trials 1 and 4, respectively. However, no further or only a very small decrease was observed in the second year without CCC in the other trials. Despite these large initial decreases, the CCC-residue levels in most of the trials sampled after two to five years without further CCC-treatments still exceeded the value of 0.05 mg/kg, but were below the temporary MRL of 0.3 mg/kg. Even after six years without CCC, some trees produced fruits containing 0.12 mg CCC/kg.

Therefore, it can be concluded that for orchards which have been treated for many years with CCC more than six growing seasons without CCC-applications are needed to obtain fruit with a CCC-residue level below 0.05 mg/kg. The exact number of years required to reach this maximum residue limit of 0.05 mg/kg most likely depends on the amount of CCC that has been accumulated in the trees during the years that their growth was controlled by CCC and on the rate at which the accumulated CCC is transported into fruits and shoots that will be removed during harvesting and pruning of the trees.

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Literature Cited

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Tables

Table 1. CCC residues detected in 'Conference' pear fruits (mg chlormequat/kg fresh weight) in trial 1.

Treatment CCC 1990-1998	Replicates A	B	C	Average
1998	6.4	6.7	7.4	6.8
1999	0.5	0.4	0.5	0.5
2000	0.19	0.15	0.17	0.17
2001	0.19	0.43	0.19	0.27
2002	0.12	0.25	0.20	0.19
2003	0.07	0.12	0.14	0.11
2004	0.02	0.05	0.04	0.04

Table 2. CCC residues detected in 'Conference' pear fruits (mg chlormequat/kg fresh weight) in trial 2.

Treatment CCC 1994-1997	Replicates A+B	C+D	E+F	Average	Treatment CCC 1994-1999	Replicates A+B	C+D	E+F	Average
1998	0.4	0.5	0.3	0.4	1998	2.5	2.2	2.2	2.3
1999	0.3	0.3	0.2	0.3	1999	3.6	3.6	2.5	3.2
2000	0.09	0.12	0.09	0.10	2000	0.38	0.27	0.41	0.35
2001	0.11	0.09	0.21	0.14	2001	0.44	0.25	0.53	0.41
2002	0.16	0.11	0.04	0.10	2002	0.28	0.21	0.22	0.24
2003	0.12	0.10	0.07	0.10	2003	0.19	0.19	0.31	0.23
2004	0.04	0.03	0.03	0.03	2004	0.14	0.09	0.14	0.12

Table 3. CCC residues detected in 'Conference' pear fruits (mg chlormequat/kg fresh weight) in trial 3.

Treatment 1999	Residue in year	Replicates A	B	C	Average
2 x 0.5 l/ha	1999	-	-	-	1.1
2 x 1.0 l/ha		-	-	-	1.7
2 x 1.5 l/ha		-	-	-	2.0
2 x 0.5 l/ha	2000	-	-	-	-
2 x 1.0 l/ha		-	-	-	-
2 x 1.5 l/ha		0.18	0.21	0.21	0.20
2 x 0.5 l/ha	2001	0.18	0.09	0.17	0.15
2 x 1.0 l/ha		0.26	0.17	0.18	0.20
2 x 1.5 l/ha		0.32	0.23	0.10	0.22
2 x 0.5 l/ha	2002	0.07	0.06	0.11	0.08
2 x 1.0 l/ha		0.08	0.14	0.13	0.12
2 x 1.5 l/ha		0.22	0.10	0.18	0.17
2 x 0.5 l/ha	2003	0.01	0.09	0.07	0.06
2 x 1.0 l/ha		0.09	0.11	0.09	0.10
2 x 1.5 l/ha		0.05	0.04	0.07	0.05
2 x 0.5 l/ha	2004	0.02	0.0 (<0.01)	0.04	0.03
2 x 1.0 l/ha		0.0 (<0.01)	0.02	0.0 (<0.01)	0.02
2 x 1.5 l/ha		0.03	0.02	0.02	0.02

Table 4. CCC residues (mg chlormequat/kg fresh weight) in 'Conference' (trial 4) and 'Doyenné du Comice' (trial 5).

Treatment	Residue in year	Replicates A	B	C	D	Average
Conference	1999	-	-	-	-	0.9
CCC 1997-2000	2001	0.1	0.08	0.06	0.11	0.09
	2002	0.04	0.04	0.04	0.06	0.05
Doyenné du Comice	2001	0.23	0.14	0.14	0.24	0.19
CCC 1998-2000	2002	0.15	0.14	0.16	0.21	0.17
	2003	0.03	0.04	0.04	0.02	0.03
	2004	0.01	0.02	< 0.01	0.02	0.01

Table 5. Growth and production of untreated and CCC-treated 'Conference' trees in the Experimental Garden at Zeewolde.

Treatment	Trial	1998 Production (kg/tree)	1998 Growth (m/tree)	1999 Production (kg/tree)	1999 Growth (m/tree)
Untreated	1	18.4	29	25.7	43
CCC 1990-1998		20.0	7	27.3	26
CCC 1994-1997	2	30.3	36	20.6	46
CCC 1994-1999		29.4	21	21.4	17
Untreated	3	-	-	22.3	31
CCC 1999		-	-	22.0	19

Table 6. Growth and production of root-pruned and CCC-treated 'Conference' (trial 4) and untreated and CCC-treated 'Doyenné du Comice' (trial 5) in the Experimental Garden at Randwijk.

Treatment	Trial	1999 Production (kg/tree)	1999 Growth (m/tree)	2000 Production (kg/tree)	2000 Growth[1]
Root pruning 1999	4	8.8	-	19.3	7.1
CCC 1990-1998		15.8	-	18.7	6.8
Untreated	5	2.9	18.3	11.3	45.1
CCC 1999		1.5	16.2	13.0	28.0

[1]Growth in trial 4 in 2000 estimated by a growth index on a scale of 1 (no growth) to 9 (excessive growth); growth in trial 5 in 2000 determined as cumulative shoot length in m/tree.