Strategies to Control Tree Vigour and Optimise Fruit Production in 'Conference' Pears

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Abstract

The ban on the use of chlormequat (CCC) in pear orchards in 2001 forced Dutch pear growers to look for alternative methods to control tree vigour and stimulate flower bud development and fruit production. Root pruning and trunk notching have become the major growth retarding methods. In addition to the mechanical methods for controlling tree vigour, Regalis (Prohexadione-Calcium) and ethephon were tested as alternative chemical growth regulators for 'Conference' pears. In 2004, a trial was started in which six different strategies to control tree vigour and optimize fruit production in 'Conference' trees are compared. In 4 strategies root pruning was the major treatment, while in 2 strategies trunk incisions were the initial treatment to reduce tree vigour and stimulate fruit production. In 2005, no further root pruning or trunk incisions were made and ethephon and Regalis were the only treatments applied in some of the strategies. Ethephon and Regalis were also applied in 2006 in addition to root pruning in March and June or in June only. All of the strategies evaluated significantly reduced shoot growth and improved fruit production. Regular yields of 52 to more than 70 tons/ha were achieved for 3 consecutive years. So far, ethephon and Regalis have shown no or only minor additional beneficial effects compared to root pruning or trunk incision followed by root pruning in the years thereafter. Flowering, fruit yield and fruit quality of 'Conference' pears produced using the different strategies are presented and discussed.

INTRODUCTION

High density planting systems are the starting point of modern orchards. Small trees that come into production in the second year after planting are a prerequisite to achieve regular yields of high quality fruits and to economise the use of land and labour costs for pruning and picking. The use of dwarfing rootstocks, like quince MC and quince Adams, in combination with the use of the chemical growth retardant chlormequat (CCC) allowed growers to reduce shoot growth, stimulate flower bud development and to obtain regular and high production levels. However, the ban on the use of CCC in pears forced growers to look for alternative methods to reduce the growth of their trees and maintain high annual fruit yields. In the Netherlands, research has been focussed on the use of non-chemical methods of growth control, like root pruning and making an incision into the tree trunk (Maas and van der Steeg, 2001a, b). In addition, the use of ethephon (Ethrel-A) and prohexadione-calcium (Regalis), to fine tune growth control, flower bud development, fruit set and fruit quality in 'Conference' and 'Doyenne du Comice' pears were studied (Maas, 2005). This paper reports on the results of the first three years of a trial comprising six different strategies in which non-chemical and chemical methods of growth control were applied to a vigorously growing 'Conference' pear orchard with a low production level.

MATERIALS AND METHODS

Plant Materials

The trial was carried out in the experimental orchard of the fruit research station at Randwijk (5°42’08.23” East, 51°56’20.06” North). Trees were planted in 1999 in single rows in fresh soil consisting of river clay with 30% silt. Planting distances were 3.0 x 1.09 m. The trees were trained as a Y-hedge made out of trees with 4 slant, upward-growing leader branches per tree (mini-tatura or V-quad system). Trees were pruned, fertilized, irrigated and protected from pests and diseases according to local commercial practice.

Treatments

The six growth-controlling strategies compared and evaluated from 2003 to 2006 are listed in Table 1. In 2004, growth control commenced either by pruning the roots of the trees or by notching the trunk using a chain saw. Root pruning in 2004 was carried out on February 27th at the west side of the tree row at a distance of about 30 cm from the trunk to a depth of approximately 35 cm, using a curved knife (Fig. 1). Trunk incisions were made on March 29th at two places on the trunk with ca. 30 cm distance in between and from opposite sides of the trunk and to a depth of about 60% of the trunk diameter (Fig. 2). Additional treatments to the root-pruned trees were 4 sprays of Ethrel-A (480 g/L ethephon) and/or 2 sprays of Regalis (100 g/L prohexadione-calcium). Dosages and dates of application are indicated in the legend of Table 1. Half of the trees with trunk incisions also received the additional treatment with Ethrel-A. In 2005, no root pruning or notching of the trunks was carried out, but all treatments with Ethrel-A and Regalis were repeated as in 2004. In 2006, root pruning was carried out twice (in March and June at alternate sides of the tree row) in 2 of the 6 treatments and only once in the other 4 treatments, using a slant knife (Fig. 3). Each strategy-treatment was made on a plot of 8 trees of which 5 were marked as observation trees and was replicated 6 times. The trial was laid out as a randomized block design.

Observations

The yearly observations made on 5 individual trees per plot were: the number of flower clusters, number of fruits thinned by hand, number of fruit at harvest, fruit weight at harvest, fruit size distribution, fruit quality at harvest and shoot growth. Fruit quality was determined on samples of 25 randomly collected fruits per plot. Shoot growth was determined after leaf drop and before winter pruning either as a figure on a scale of 1 (no shoot growth) to 9 (very excessive shoot growth) or as the number and total length of all shoots longer than 10 cm.

Statistical Analysis

The data were analysed using the Anova variance analysis of the Genstat statistical program (Lawes Agricultural Trust, Rothamsted Experimental Station, United Kingdom). In case of significant differences ($p<0.05$), LSD values were calculated and used for comparing treatment means in pairs.

RESULTS AND DISCUSSION

In 2003, the year before the trial was started, the growth of the trees of the orchard was indexed at 6.3 and the fruit production amounted to 11.4 kg/tree. Shoot growth in 2004 was strongly reduced to 4 by all treatments (Table 2). Shoot growth was almost completely inhibited in trees of which the trunk was strongly notched. Root pruning alone also reduced shoot growth in 2004, but much less than notching the trunk. Additional sprays of Ethrel-A and Regalis further reduced shoot growth of the root-pruned trees. The combination of Regalis and Ethrel-A did not result in a stronger inhibition of shoot growth in root-pruned trees than either Regalis or Ethrel-A used alone. In the case of the notched trees, Ethrel-A did not give any additional inhibition of shoot growth in 2004.

In 2005, no further root pruning and notching were carried out and only the sprayings with Regalis and Ethrel-A were repeated. Shoot growth was similar for all trees root pruned in 2004 and amounted to approx. 36 m/tree. In 2005, trees of which the trunks were incised in 2004 still showed the weakest growth, about 19 m/tree. No additional reduction in shoot growth was observed in 2005 as a result of the sprayings with Regalis and Ethrel-A.

In 2006, shoot growth was expected to become too vigorous, not only because of recovery of the root system and partial healing of the incisions in the trunks but also because of the low number of flower clusters and expected low crop loads. Therefore, the roots of trees of the first two growth-controlling strategies were already pruned before bloom at one side of the trees. In June 2006, the roots of all six treatments were pruned, those of the first 2 treatments at the opposite side of the tree as in March. As a result, shoot growth of the trees that were only root pruned remained similar to that in 2005. An additional treatment with Ethrel-A significantly further reduced shoot growth to about the same level as observed in the trees of which the trunks were incised in 2004 and the roots were pruned at one side of the trees in 2006. However, this additional reduction in shoot growth may also have been caused by a too severe root pruning of the trees in this treatment in June, which expressed itself by a temporary wilting of the shoots and shrivelling of the fruitlets.

Compared to the production of 11.4 kg/tree (34.8 ton/ha) in 2003, all growth-controlling strategies strongly increased production (Table 3). With an average production of ca. 17.5 kg/tree, the increase in production was the lowest for the trunk-incised trees and with ca. 23 kg/tree the highest for the root-pruned trees. Neither Regalis nor Ethrel-A further increased production. In 2005, all treatments gave similar high yields of ca. 23 kg/tree (70 ton/ha). Again, the additional sprayings with Regalis and Ethrel-A did not affect production. In 2006, only the trees of which the trunks were incised in 2004 and the roots were pruned in June 2006 showed similar high yields to those recorded in 2005, the other treatments showed somewhat lower yields. The lowest yield, observed for strategy 2, was most likely due to the too severe root pruning of the trees in June. Due to the dry soil conditions it was not possible to keep the pruning knife exactly parallel to the tree row in the hardened clay soil. As a result the slant knife came as close as 15 to 20 cm of the base of the trunk of many trees, pruning too much of the root system that had already been pruned at the other side of the tree in March 2006.

Taking the low number of flower buds in into account (Table 4), it can be concluded that fruit set in 2006 was much higher than in 2005, since the reduction in yield was much less than that in number of flower clusters. Fruit size in 'Conference' pears very strongly influences the market price of the fruit. As the best price is paid for pears with a diameter of 65 mm or more, it is essential for the growers that the highest possible proportion of fruit is of this size class. Fruit size distribution in the years 2004 to 2006 of the 6 strategies of this trial is summarized in Table 6. In 2004, the trees with incised trunks gave the highest percentages of fruits >55 and >65 mm in diameter. This most likely resulted from the lower crop load of these treatments (ca. 95 fruits/tree) compared to that of the root-pruned trees of the other four strategies (ca. 135 fruits/tree). Although not always statistically significant, the average size of the fruits of Ethrel-A treated was somewhat higher than that of the comparable treatment without Ethrel-A. It was observed that fruit drop in 2004 was slightly higher in trees treated with Ethrel-A and hand-thinning requirement of these trees was reduced by approx. 6 fruits/tree (Table 5). Thus, the positive effect of Ethrel-A on fruit size can also be explained by an early reduction in crop load.

In 2005, trees of all strategies showed increased flowering (Table 4), especially those of which the trunks were incised in 2004. The higher number of flowers cluster resulted in a higher number of fruits per tree and a higher requirement for hand thinning (Table 5). The data of 2005 clearly show that at similar yields (Table 5) fruit loads exceeding 100 fruits per tree negatively affected the production of fruits >65 mm (Table 6). In 2006, fruit numbers and yields were highest for the trees of strategies 3 and 4 (Table 5) but at the same time gave the lowest percentage of fruits >65 mm (Table 6).

Although strategies 1, 2, 5 and 6 showed similar numbers of fruits, the percentages of fruits >65 mm was much smaller for treatments 1 and 2 (Table 6), most likely as a consequence of the temporary water stress experienced by the trees of these treatments following the second root pruning treatment in 2006. The cumulative production over 3 years shows similar yields of about 66 kg/tree years for all six growth-controlling strategies (Table 7), but significantly lower average fruit weights for strategies 3 and 4 due to higher numbers of fruits per tree in 2005 and 2006. Another negative result of strategies 3 and 4 is the significantly higher number of fruit which had to be removed by hand thinning in order to limit the number of fruits per tree. In fact the thinning requirement for both treatments was even higher, since the fruit load at harvest of these treatments amply exceeded the target fruit load of 100 fruits per tree in two out of the three years. The cumulative production data also show that the additional treatments with Ethrel-A and/or Regalis did no further improve yield or fruit quality.

In 2004, the firmness of the fruits at harvest was significantly less and the sugar content significantly higher for trees of which the trunks had been incised (Table 8), indicating a more advanced ripening of the fruits. The lower fruit load of these trees may have contributed to this enhanced ripening. In 2005, fruit production was similar for all strategies and no significant differences were observed in firmness and sugar content of the fruits. In 2006, firmness was lowest and sugar content highest for trees of strategies 1 and 2 (2 times root pruning in 2006), indicating enhanced maturation of the fruits of these temporarily, severely water-stressed trees. However, because only one randomized sample of fruits was collected for each strategy in 2006, these results of 2006 could not be statistically analysed.

CONCLUSIONS

The results of this 3-year study clearly show that regular high yields can be obtained in a high density ‘Conference’ pear orchard by a good control of tree vigour. Of the six strategies compared in this study, cumulative production was similar for all strategies, despite the negative effect of the 2 root pruning treatment of strategies 1 and 2 in 2006. Root pruning alone gave the best overall results and less variation in fruit quality and thinning requirement than notching the trunks of the trees. When root pruning is used for growth control no or only small beneficial effects could be obtained by the use of the growth regulators Ethrel-A and Regalis.

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Tables

Table 1. Growth-controlling strategies applied to ‘Conference’ trees in 2004 to 2006.

Strategy	2004	2005	2006
1. RP	Root pruning[1]	-	Root pruning[7] (2x)
2. RP+E	Root pruning + Ethrel-A[2]	- Ethrel-A[5]	Root pruning (2x) + Ethrel-A[8]
3. TI	Trunk incisions[3]	-	Root pruning[9]
4. TI+E	Trunk incisions + Ethrel-A	- Ethrel-A	Root pruning + Ethrel-A
5. RP+Re	Root pruning + Regalis[4]	- Regalis[6]	Root pruning + Regalis[10]
6. RP+Re+E	Root pruning + Regalis + Ethrel-A	- Regalis + Ethrel-A	Root pruning Regalis + Ethrel-A

[1]February 27 West side of tree row;
[2]May 4 (250 ml/ha), May 10 (125 ml/ha), May 18 (100 ml/ha), May 25 (50 ml/ha);
[3]March 29, 2 incisions, 30 cm apart at opposite sides of trunk to ca. 60% of trunk diameter;
[4]May 11 and June 1 (1.2 kg/ha);
[5]May 4 (250 ml/ha), May 10 (125 ml/ha), May 18 (100 ml/ha), May 25 (50 ml/ha);
[6]May 11 and June 7 (1.2 kg/ha);
[7]March 14 East side, June 26 West side of tree row with a slant knife;
[8]May 23 (250 ml/ha), May 31 (125 ml/ha), June 7 (100 ml/ha), June 13 (50 ml/ha);
[9]June 26, East side of tree row with a slant knife;
[10]May 11 and June 13 (1.2 kg/ha).

Table 2. Shoot growth of ‘Conference’ trees.

Strategy	2004 Growth index*	2005 ∑ shoot (m/tree)	2006 ∑ shoot (m/tree)
1. RP	4.2 c	38.7 b	37.8 b
2. RP+E	3.5 b	34.0 b	28.3 a
3. TI	2.1 a	19.6 a	25.7 a
4. TI+E	2.1 a	18.1 a	23.9 a
5. RP+Re	3.6 b	34.1 b	46.0 c
6. RP+Re+E	3.8 bc	37.1 b	43.8 bc
F-test	P<0.001	P<0.001	P<0.001
Lsd 0.05	0.5	8.0	6.5

*on scale of 1 (no growth) to 9 (very vigorous growth). Growth index in 2003 was 6.3.

Table 3. Production of ‘Conference’ trees.

Strategy	2004		2005		2006	
	kg/tree	ton/ha	kg/tree	ton/ha	kg/tree	ton/ha
1. RP	23.2 b	70.9 b	25.0	76.5	20.4 bc	62.4 bc
2. RP+E	23.0 b	70.3 b	22.4	68.4	16.9 a	51.5 a
3. TI	18.3 a	55.8 a	23.3	68.5	21.8 bc	66.8 c
4. TI+E	16.8 a	51.3 a	23.0	70.2	22.4 c	68.5 c
5. RP+Re	23.0 b	70.3 b	23.0	70.3	18.6 ab	54.7 ab
6. RP+Re+E	22.5 b	68.7 b	23.3	71.1	18.7 ab	54.9 ab
F-test	P<0.001	P<0.001	ns*	P<0.05	P<0.01	
Lsd 0.05	12.3	5.6			3.0	9.7

*ns = not significant.

Table 4. Flower buds per ‘Conference’ tree in 2004 to 2007.

Strategy	2004	2005	2006	2007
1. RP	88	161 c	62 ab	89 b
2. RP+E	89	171 c	57 ab	123 c
3. TI	86	201 d	70 bc	66 a
4. TI+E	82	223 e	79 c	72 ab
5. RP+Re	87	134 a	47 a	70 a
6. RP+Re+E	82	143 ab	61 ab	77 ab
F-test	ns	P<0.001	P<0.01	P<0.001
Lsd 0.05		20	16	18

Table 5. Number of ‘Conference’ fruits harvested and hand-thinned (June-July) per tree.

Strategy	2004		2005		2006	
	harvested	thinned	harvested	thinned	harvested	thinned
1. RP	139 b	14.3 c	127 a	14.7 a	122 ab	75 b
2. RP+E	135 b	7.8 a	114 a	15.4 a	103 a	55 a
3. TI	103 a	18.6 d	143 b	31.4 b	137 b	79 b
4. TI+E	91 a	11.8 bc	145 b	34.9 b	140 b	79 b
5. RP+Re	138 b	13.5 c	115 a	16.6 a	95 a	53 a
6. RP+Re+E	134 b	9.8 ab	116 a	14.5 a	106 a	66 ab
F-test	P<0.001	P<0.001	P<0.001	P<0.01	P<0.05	P<0.01
Lsd 0.05	12	3.5	14	13.9	28	14

Table 6. Fruit size distribution 'Conference' pears.

Strategy	2004		2005		2006	
	>55 mm	>65 mm	>55 mm	>65 mm	>55 mm	>65 mm
1. RP	81.8 a	23.7 a	96.8 d	56.8 b	94.1	43.1 a
2. RP+E	86.8 bc	27.4 a	93.7 bc	52.9 b	92.8	35.1 a
3. TI	89.4 c	46.4 b	92.1 ab	23.8 a	91.3	29.9 a
4. TI+E	94.1 d	52.4 b	91.5 a	19.3 a	93.9	32.3 a
5. RP+Re	83.7 ab	24.6 a	95.8 cd	59.3 b	96.6	65.5 b
6. RP+Re+E	85.2 ac	27.5 a	96.1 cd	57.5 b	95.2	58.7 b
F-test	P<0.001	P<0.001	ns	P<0.001	ns	P<0.001
Lsd 0.05	4.4	9.7	2.7	7.5		15.1

Table 7. Cumulative yield, fruit weight and thinning requirement of 'Conference' in 2004 to 2006.

Strategy	Production			Fruits/tree thinned by hand
	fruits/tree	kg/tree	g/fruit	
1. RP	381.4 b	70.9	187 a	107 b
2. RP+E	330.1 a	62.0	188 a	80 a
3. TI	408.0 bc	67.3	206 b	134 c
4. TI+E	424.8 c	67.5	207 b	134 c
5. RP+Re	331.2 a	64.5	196 a	88 ab
6. RP+Re+E	337.8 a	64.8	195 a	93 ab
F-test	P<0.001	ns	P<0.001	P<0.001
Lsd 0.05	41.1		10	23

Table 8. Fruit firmness* (kg/0.5 cm^2) and sugar content (°Brix) 'Conference' at harvest.

Strategy	2004		2005		2006	
	firmness	sugar	firmness	sugar	firmness	sugar
1. RP	5.2 b	12.2 a	5.1	12.5	5.2	13.5
2. RP+E	5.2 b	12.2 a	5.1	12.2	5.1	14.1
3. TI	4.9 a	12.5 ab	5.0	12.5	5.3	13.3
4. TI+E	4.9 a	12.8 b	5.0	12.4	5.4	12.7
5. RP+Re	5.2 b	12.2 a	5.1	12.3	5.4	13.1
6. RP+Re+E	5.2 b	12.4 a	5.1	12.5	5.4	13.3
F-test	P<0.001	P<0.01	ns	ns	na**	na
Lsd 0.05	0.2	0.3				

*determined with an Instron penetrometer equipped with an 8-mm diameter plunger.

**not statistically analyzed as quality measurements were made on only a single sample of 25 randomly collected fruits per treatment.

Figures

Fig. 1. Root pruning with a curved knife blade.

Fig. 2. Trunk incisions made with a chain saw.

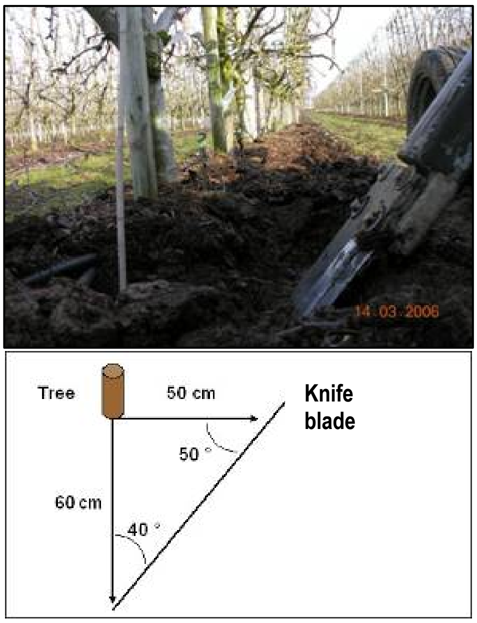

Fig. 3. Root pruning with a slant knife blade.