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CHEMICAL AND NON-CHEMICAL THINNING METHODS IN APPLE (*Malus domestica Borkh*)

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ABSTRACT

Thinning trials were conducted in the apple orchards of Klein Altendorf Experimental Station, Bonn, Germany using 7-year-old CV. 'Cox orange' and CV 'Elstar' apple trees in the year 2001 and 2002. The objectives were to find the effects of treatments on fruit set, yield, quality (i.e. fruit size) and to investigate how photosynthesis and transpiration are affected by one of the chemical thinners. The chemical thinning methods applied in the year 2001 were Ethrel (Flordimex) at 500ml/ha, Ethrel at 1000ml/ha, Ammonium Thiosulphate (ATS) sprayed to flowers on one year old shoots (ATS 1), Ammonium Thiosulphate (ATS) sprayed to flowers on older shoots (ATS 2), Amidthin plus Telmion, Amidthin plus Ethrel and unsprayed control. In 2002 the chemical thinning treatments applied were Azolon fluid (Urea formaldehyde), sprayed at 7.5li/ha and Ethrel (Flordimex) sprayed at 300ml/ha and unsprayed control. The non-chemical thinning method which was only applied in 2002 was partial defoliation of leaves. The experimental design used was randomized complete block design with three replications. The results showed that in the year 2001 Ethrel at 1000ml/ha had 67% thinning effect while Ethrel at 500ml/ha had 40% thinning. The other treatments had no thinning effect. Amidthin plus Ethrel had 22% yield reduction while Ethrel at 1000ml/ha had 30% yield reduction. ATS 2 had 44% increases in yield while ATS 1 had no effect. In terms of fruit size Ethrel 1000ml/ha had the best fruit quality (i.e. preferred diameter class of 70mm), followed by Amidthin plus Ethrel, Amidthin plus Telmion and Ethrel at 500ml/ha. In the year 2002 Azolon fluid resulted in 55% thinning in the first fruit set count before June drop while Ethrel had 56% and Azolon plus Ethrel 54% thinning effects which were not significantly different from defoliated treatment. Similar thinning trends were observed for fruit set counts after June drop. Transpiration and photosynthetic rates were reduced by 5% and 20%, respectively. Ethrel at 300ml/ha reduced yield significantly from 29.2kg/ha in the control to 25.5kg/tree while methylene urea (Azolon) had no effect. Thinning with methylene urea increased fruit size to 67% and Ethrel (Flordimex) to 79% of fruits larger than 70mm. It is concluded the chemical treatments thinned the fruits adequately and were not significantly ($P \leq 0.05$) different from the non-chemical methods of thinning and fruit size was improved while transpiration and photosynthesis were slightly affected after Azolon application.

Keywords: apple, thinning, chemical, non-chemical, methods, photosynthesis, transpiration, yield, fruit, size.

INTRODUCTION

Fruit trees develop many more fruits than they can support through to maturity. Hence, fruits are subjected to abscission at three stages of fruit ontogeny. The first 'early or flower drop' shortly after anthesis is followed by 'June drop' and a further drop before harvest (Dennis, 2000; Luckwill, 1953). Abiotic and biotic stresses such as late spring frosts or over cropping can disturb these regulatory mechanisms and cause biennial bearing. Fruit thinning has become a relevant management practice to produce apples of high quality including a particular fruit size, (red) coloration, firmness and soluble solids. Thinning is also a relevant measure to overcome biennial bearing in affected apple cultivars thereby securing regular harvests.

Information on photosynthesis with respect to thinning is scarce (Bangerth, 2001 and Quinlan, 1971). Chemical thinners such as Ammonium Thiosulphate (ATS) or urea caused phytotoxic effects ranging from leaf yellowing to leaf burn and reduced apple photosynthesis by 6% - 33% over 3-7 days, measured either by Warburg apparatus (Groschwska and Lubinska, 1973), porometry (Stopar *et al*, 1997) or whole canopy gas exchange (Untiedt and Blanke, 2001). Hence, the involvement of fruit thinning has been postulated, but not investigated or proven. The aim of this study was to give conclusive evidence that temporary reductions in photosynthetic rate or area cause in fruit thinning, using the alternate bearing sensitive apple trees in the year 2002 as compared to chemical thinners used in 2001. The overall objective remains to reduce the number of fruits per tree, yield and improve fruit quality.

MATERIALS AND METHODS

Thinning treatments

The thinning treatments applied during 2001 and 2002 are described as under (Tables 1 and 2):

Table-1. Thinning treatments applied in 2001.

S. No.	Treatment applied	Time and dose of application
1.	Control	Untreated or unsprayed
2.	Amidthin plus Ethrel	Full bloom: 600g/ha Amidthin + 250ml/ha Ethrel
3.	Ethrel (Flordimex)	Early flowering stage: 1000ml/ha
4.	Ammonium Thiosulphate (ATS 1)	Petal fall: 10kg/ha
5.	Ammonium Thiosulphate (ATS 2)	Full bloom: 7kg/ha
6.	Amidthin Plus Telmion	600g/ha Amidthin plus 3li/ha Telmion at 20-30% open bloom stage

Table-2. Thinning treatments applied in 2002.

S. No.	Treatment applied	Time and dose of application
1.	Azolon fluid (Urea formaldehyde)	Full bloom: 7.5li/ha
2.	Ethrel (Flordimex)	Full bloom 300ml/ha
3.	Azolon plus Ethrel (Flordimex)	Full bloom 7.5li/ha plus 300ml/ha
4.	Partial Defoliation	$^1/_3$ of primary spur leaves (i.e. non chemical method) removed at early and ½ at full bloom
5.	Control	Untreated or unsprayed

The treatments were arranged in a randomized complete block design replicated three times with three trees per replication. The experiments were carried out at the Klein Altendorf Experimental Fruit Station near Bonn, Germany. The station receives an annual rainfall of 615mm and average daily temperatures of 41^0C. The experiments were conducted on 7 year old cv 'Cox orange' apple trees in 2001 and 8 year old cv 'Elstar' apple trees in 2002 at a spacing of 3.45 X 1.50 m on M9 rootstocks. The pressure of the sprayer used to apply the chemicals was 2.5 bars and spraying was conducted on a non-windy day on 15th April 2001 between 1100 to 1200 hours. The first Ammonium Thiosulphate application (ATS 1) was carried out when the blossoms at the center of the clusters were at petal fall stage but not the outer ones (i.e. in 'Cox orange' apple trees it is the central blossoms which form good sized fruits as compared to the surrounding ones). Therefore spraying the thinners are meant to kill the latter types of blossoms. This first Ammonium Thiosulphate (ATS 1) spraying was carried out on shoots older than one year. For the current shoots, i.e. one year old the second Ammonium Thiosulphate (ATS 2) spraying was done at full bloom and they bear only small fruits Ethrel (Flordimex), Amidthin plus Ethrel and Amidthin plus Telmion treatments were applied when 20-30% blossoms were open.

In the year 2002 the treatments applied were as listed in Table-2 above and were arranged in a completely randomized block design with three tree replicates. The treatments were applied at full bloom on a non-windy day with a wind speed of 1-2m/s, temperature of 20^0C and a relative humidity of 60% resulting in a vapor pressure deficit (VPD) of 17 mbars. The treatments were applied to whole trees at 1300 hours using a tractor as described above for the 2001 experiment. In the partial defoliation treatment the primary spur leaves of the selected branches of three unsprayed apple trees were partially defoliated. Partial defoliation of these leaves was 30% from the distal end at the time of Ethrel application and then extended to one half of the leaf blade 7 days after its application.

Photosynthesis and transpiration were measured using a CIRAS –1 (PP systems, UK) on a clear, sunny day before and 1 day after Azolon (Methyl urea) application.

Data were subjected to variance analysis using a commercial package (SPSS, USA) version 9.0. Separation of means is based on a LSD test at the 5% level following Duncan's t-test.

RESULTS

In the year 2001, Ammonium Thiosulpahte (ATS 2) sprayed on to flowers of one year old shoots at petal fall, Ammonium Thiosulphate (ATS 1) sprayed to shoots older than one year, Amidthin plus Telmion and Amidthin plus Ethrel had no thinning effect as compared to the unsprayed controls (Table-4). However, Ethrel sprayed at 500ml/ha 1000ml/ha 67% thinning (Table-4).

In terms of fruit yield Amidthin plus Ethrel reduced yield by 22% while Ethrel at 100ml/ha had 30% reduction in yield while Ethrel at 500ml/ha had no effect (Table-5). Ammonium Thiosulphate (ATS 2) had 44% increased in yield while Ammonium Thiosulphate (ATS 1) had no significant effect ($P \leq 0.05$). In contrast, Amidthin plus Telmion had 50% increase in yield. The treatments did not have any significant ($P \leq 0.05$) effect on the mean

fruit weight (data not shown). With respect to fruit size classification according to diameter, Ethrel 1000ml/ha, Amidthin plus Ethrel, Amidthin plus Telmion, Ammonium Thiosulphate (ATS 2) and Ammonium Thiosulphate (ATS 1), the percentages of fruit in the preferred fruit diameter (class one) i.e. 75 to 90mm were 79%, 71%, 68% and 60%, respectively (Table-3).

In the year 2002 Azolon fluid had 55% thinning while Azolon plus Ethrel had 54% thinning before June drop, which were not significantly different from the defoliation treatment. Similar thinning levels were observed after June drop but with lower levels (Table-8). The highest average yield observed was 29.2kg/tree in the untreated control trees which was not statistically different from the yield of 27.8kg/tree observed after thinning with Azolon fluid (Methylene urea). However, Ethrel (Flordimex) (300ml/ha), significantly reduced yield per tree by 3.7kg compared to the control (Table-7). The smallest fruit were found in the untreated control trees with less than 60% of the fruits larger than 70 mm. Thinning with Azolon increased fruit size to 67% and with Ethrel 300ml/ha to 79% of fruit larger than 70mm (Table-6). Transpiration and photosynthetic rates were reduced by 20% and 5%, respectively 1 day after the application of Azolon.

Table-3. Effect of treatments on apple fruit size (percentage of fruits with the preferred diameter > 70mm) in the year 2001 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Fruit size
1.	Amidthin + Ethrel	71b
2.	Amidthin + Telmion	70b
3.	ATS 2	68b
4.	ATS 1	60c
5.	Ethrel 1000ml/ha	79a
6.	Ethrel 500ml/ha	56ac
7.	Control	40d

LSD ($P \leq 0.05$) = 7.6

Table-4. Effect of treatments on the number of fruit lets per 100 blossoms before June drop in the year 2001 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Number of fruits
1.	Amidthin + Ethrel	14a
2.	Ammonium Thiosulphate (ATS 1)	14.5a
3.	Ethrel 1000ml/ha	4.1b
4.	Ethrel 500ml/ha	7.5b
5.	Ammonium Thiosulphate (ATS 2)	13.5a
6.	Amidthin + Telmion	12a
7.	Control	12.5a

L. S. D. ($P \leq 0.05$) = 5.00

Table-5. Effect of treatments on fruit yield per tree in the year 2001 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Yield (kg/tree)
1.	Amidthin + Ethrel	14.5a
2.	Ammonium Thiosulphate (ATS 1)	23.2b
3.	Ethrel 100ml/ha	13.3a
4.	Ethrel 500ml/ha	18.2a
5.	Ammonium Thiosulphate (ATS 2)	26.0ca
6.	Amidthin + Telmion	27.0cb
7.	Control	19.5

L. S. D. ($P \leq 0.05$) = 6.2

Table-6. Effect of treatments on apple fruit size (percentage of fruit with the preferred diameter > 70mm) in the year 2002 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Fruit size
1.	Ethrel (Flordimex)	77a
2.	Azolon (Methylene urea)	67b
3.	Partial defoliation	68b
4.	Unsprayed control	60c

LSD ($P \leq 0.05$) = 9.2

Table-7. Effect of treatments on fruit yield per tree in the year 2002 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Fruit yield (kg/tree)
1.	Ethrel (Flordimex)	25.5ab
2.	Azolon (Methylene urea)	27.8a
3.	Partial defoliation	22.2b
4.	Unsprayed control	29.2ac

L. S. D. ($P \leq 0.05$) = 5.5

Table-8. Effect of treatments on the initial fruit set in cv.' Elstar' apple before June drop at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Number of fruit lets per 100 fruit clusters before June drop
1.	Ethrel (Flordimex)	63a
2.	Azolon (Methylene urea)	65ab
3.	Partial defoliation	58abc
4.	Unsprayed control	147d

L. S. D. ($P \leq 0.05$) = 28.35

Table-9. Effect of treatments on final fruit set of cv 'Elstar' apples after June drop in 2002 at Klein Altendorf Station, Bonn, Germany.

S. #	Treatment	Number of fruits per 100 flower clusters after June drop
1.	Ethrel (Flordimex)	14a
2.	Azolon (Methylene urea)	16ab
3.	Partial defoliation	15abc
4.	Unsprayed control	49d

L. S. D. ($P \leq 0.05$) = 7.57

Table-10. Photosynthesis and transpiration of cv 'Elstar' apple leaves before and one week after Azolon (Methylene urea) application under measuring conditions of PAR of 1400 umol, temperature of 24^0C and VPD of 1.8kPa.

Parameter	Day 0	Day 7
Photosynthesis ($umolCO_2M^{-2}S^{-1}$)	21.7	18.2
Transpiration ($ummolH_2OM^{-2}S^{-1}$)	1.5	1.2

DISCUSSION

In the year 2001, the treatments amidthin plus Ethrel, Ammonium Thiosulphate (ATS 1), Amidthin plus Telmion and Ammonium Thiosulphate (ATS 2) were not statistically different ($P \leq 0.05$). This may have been due to environmental factors, cultivar effects, time of application factor and concentration used. (Weaver and Pool 1971a; Weaver and Pool 1971b). The weather conditions during the time of spraying and immediately after, particularly temperature, humidity and wind velocity have an effect on the efficacy of the chemical thinners. Cultivar effect can influence thinning because there are some apple cultivars, which are difficult to thin and therefore need higher concentrations of the chemicals. The mode of action of nitrogen fertilizers used in this study i.e. Azolon and Ammonium Thiosulphate seems to be scorching of blossoms and leaves, a resulting into ethylene shock (Handschack, 1994). Whether scorching is strictly necessary for their thinning or not is controversial (Handschack, 1994; Link, 1994). The fact that the thinning effect is well correlated with the degree of leaf and blossom scorching induced by higher treatment concentration and higher spray volume could have affected the present results, i.e. the concentrations could have been too low to trigger the above mentioned effects. Ethrel at the two rates used thinned the fruits well at the two rates of 500ml/ha and 1000ml/ha. This can be attributed to increased ethylene biosynthesis and reduced basipetal auxin transport to the separation zone (Untiedt and Blanke, 2001). At the Ethrel (Flordimex) concentration of 1000ml/ha the tendency for the above conversion increased many-fold.

Most of the treatments applied in 2001 particularly the nitrogen fertilizers increased yield. This may be due to their fertilizing effect, which could have increased vegetative growth of the apple trees. The Ammonium Thiosulphate sprayed to shoots older than 1 year had no effect on yield due to their slower growth rates as compared to current shoots. The treatments increased the fruit diameter classes due to their thinning effects, which lowered fruit counts thus reducing competition for metabolites among the remaining fruit (Quinlan and Preston, 1968). The nitrogen fertilizers did not thin but increased fruit diameter because of their fertilizing effect.

In the year 2002 all the chemical and defoliation treatments thinned the fruits equally but more than the unsprayed control. Following petal fall, fruit growth, leaf area, and shoot growth increases rapidly. There is a high demand for energy produced at these multiple centers of metabolic activity (Quinlan and Preston, 1971). Leaf photosynthesis is the main source of carbohydrates for developing fruit. Apple fruit abscission after fertilization and during June drop has been attributed to competition for essential metabolites, including photosynthesis, among individual fruit lets and between fruit lets and vegetative shoots (Abbott, 1960; Knight, 1980; Quinlan and Preston, 1971). Shading or application of photosynthetic inhibitors such as chemical thinners or leaf defoliation as in the present study, during this critical time, which reduces photosynthesis and thus the carbohydrates available is the primary factor responsible for early apple fruit abscission (Arthey and Wilkinson, 1964; Ferree and Palmer, 1982; Proctor and Palmer, 1991. Byers *et al,* 1990, 1991, Schneider, 1978). Carbon balance models indicate a potential limitation of carbon availability during the first 5 weeks after bloom, a critical period for fruit set and fruit cell division (Lakso and Grappadelli, 1992).

CONCLUSIONS

It can be concluded that:

The chemical treatments thinned the fruits adequately and were not significantly different from non-chemical methods, fruit size was improved and photosynthetic and

transpiration rates were slightly affected after Azolon application.

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