ETHYLENE EVOLUTION INTENSITY AND APPLE FRUIT SETTING AFTER THINNING WITH NAA AND ETHEPHON

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A B S T R A C T

The experiment took place in 2006 and 2008. In 2007, the study did not take place due to severe damage to the buds and flowers caused by a spring frost. The subjects of the experiment were 14-year-old 'Šampion' apple trees grafted on the MM 106 rootstock. The auxin NAA, at the concentrations of 20 and 60 $mg \cdot l^{-1}$, and ethephon, at the concentrations of 200 and 600 $mg \cdot l^{-1}$, were used in the experiment. Spraying was carried out at the end of blooming, after 80% of the petals had fallen off the crown. Five days after spraying, the quantity of ethylene evolved from the fruitlets was measured. Large quantities of ethylene evolving were observed after spraying with ethephon, especially when used at 600 $mg \cdot l^{-1}$. Spraying with auxin solutions caused large quantities of ethylene to be observed only during the first year of the study, two days after spraying with the 60 $mg \cdot l^{-1}$ solution of NAA. From the third day after spraying with NAA, ethylene evolution from the fruitlets was observed to be only slightly higher than in the control. During the second year of the study, treatment with NAA caused a slight increase in ethylene evolution only during the first day after treatment. During subsequent days the evolved quantity of ethylene did not differ significantly from the control. In spite of the significant difference in the quantity of the ethylene evolved from the fruitlets, the percentage of the fruitlets was similar after using the agents at the higher concentrations: ethephon at 600 $mg \cdot l^{-1}$ and NAA at 60 $mg \cdot l^{-1}$, as well as at the lower concentrations. The treatments had only a slight influence on the reduction in the total yield. However, they were found to have a favourable influence on fruit size. The results of the study show a higher percentage of fruit with a diameter exceeding 7 cm in the total yield.

Key words: apple, auxin, yield structure

INTRODUCTION

Thinning of fruitlets of heavily-cropping apple trees is necessary in order to obtain fruit of high quality. Among the many agents used for thinning, the most frequently used are ethephon and the auxin naphtylacetic acid (NAA) (Jones et al., 2000; Webster and Spencer, 2000). The mechanism of action of ethephon is well known; however, the mechanism that causes fruitlets to fall off after the use of NAA is not thoroughly known in spite of numerous studies (Williams and Fallahi, 1999). According to the current theory, the mechanism of action of NAA is based on the stimulation of ethylene synthesis taking place in fruitlet tissue (Curry, 1991a). It has also been ascertained that the natural drop of fruitlets is always connected with an increase in ethylene synthesis and evolution (Dennis, 2000). The effectiveness of fruitlet thinning with NAA is often unsatisfactory. The efficacy of the treatment depends on the weather, which affects the intensity of the agent penetrating into leaf tissue (Schönherr et al., 2000). This can influence the intensity of ethylene synthesis and evolution, and ultimately determine the effectiveness of the treatment. The main goal of the experiment was to compare the quantities of the ethylene evolved from the fruitlets and the percentage of young fruit being formed after spraying with ethephon and the auxin NAA.

MATERIAL AND METHODS

The experiment took place in 2006 and 2008. In 2007, the study did not take place due to severe damage to the buds and flowers caused by a spring frost. The subjects of the experiment were 14-year-old 'Šampion' apple trees grafted on the MM 106 rootstock.

Two chemical agents were used in the experiment: ethephon and the auxin NAA (1-naphthalene acetic acid, triethanolamine salt). Each of them was used at two concentrations: a lower concentration – recommended by the product's manufacturer, and at a concentration three times higher than that. Ethephon was used at the concentrations of 200 and 600 $mg \cdot l^{-1}$, while the auxin at 20 and 60 $mg \cdot l^{-1}$. Thinning was conducted at the end of blooming, after 80% of the petals had fallen off the crown. The treatments were carried out before noon, on a warm and sunny day, using a knapsack-sprayer. The experiment consisted of five replications, with one tree per replication. Control trees were not treated. The collection of ethylene evolving from the fruitlets started in the morning on the next day after spraying, and was conducted at the same time of day for five consecutive days. The procedure consisted in randomly selecting seventy fruitlets along with the pedicles and enclosing every ten of them in a separate plastic vial. After one hour, a syringe was used to collect the gas from the vials to be analysed with a CHROM 5 gas chromatograph. The results were presented in nanolitres of ethylene evolved from one gram of fresh fruitlets within one hour. The fruitlets were collected from the separate groups of trees

treated with either ethephon or NAA in the same way as the trees used to examine the percentage of fruitlets forming and the quality of fruit. Apples were collected separately from each tree and divided into four size groups based on the diameter: 5-6, 6-7, 7-8 and above 8 cm. Fruit set was expressed as a percentage, assuming that the fruit set on the control trees was 100%.

RESULTS

Ethylene evolution from the fruitlets on the control trees during both years of the study did not exceed 10 nl of ethylene·g^{-1}·h^{-1}. As has been expected, the high concentration of ethephon (600 mg·l^{-1}) caused intense ethylene evolution during both years of the study, fluctuating around 60 nl g^{-1}·h^{-1}in 2006 and around 90 nl g^{-1}·h^{-1} in 2008 (Fig. 1, 2). During both years there were significant fluctuations in ethylene evolution observed for the combination involving ethephon. In the case of the lower concentration of ethephon, lower quantities of ethylene were recorded. During both years of the study, the quantity of ethylene fluctuated around 20 nl g^{-1}·h^{-1} over the five days of the collection. A significantly smaller effect was observed following the use of NAA. However, it was only during the first year of the study, on the second day after treatment, that intensive ethylene evolution was observed. The quantity of ethylene was then similar to the values recorded after spraying with ethephon. On the other days of the first year of the study the quantity of the gas was only slightly higher than in the control. During the second year, except on the first day after treatment, the auxin used was found to have a negligible influence on the amount of the ethylene evolved. It also turned out that there were no differences between the higher and lower concentrations of the auxin in relation to the evolved quantity of ethylene.

During the first year of the study, all the concentrations used decreased the percentage of fruit set compared with the control (Fig. 3). The more effective agent seemed to be the auxin, which, in comparison with the control, decreased fruit set to approximately 50%. There was no difference observed as regards the effectiveness of the higher and lower concentrations of the auxin. Ethephon turned out to be less effective than NAA. After spraying with ethephon, fruit set amounted to approximately 60%, compared with the control. As with the auxin, there was no difference in effectiveness between the lower and higher concentrations of ethephon. During the second year of the study, only the higher concentrations of ethephon and NAA reduced the percentage of fruit set (Fig. 4). Their effectiveness was similar, being approximately 60% of that of the control. The lower concentrations of ethephon and NAA did not have a significant influence on the reduction in the percentage of fruit set.

During the first year of the study, a slight reduction was observed in the total yield, compared with the control, only for the combination

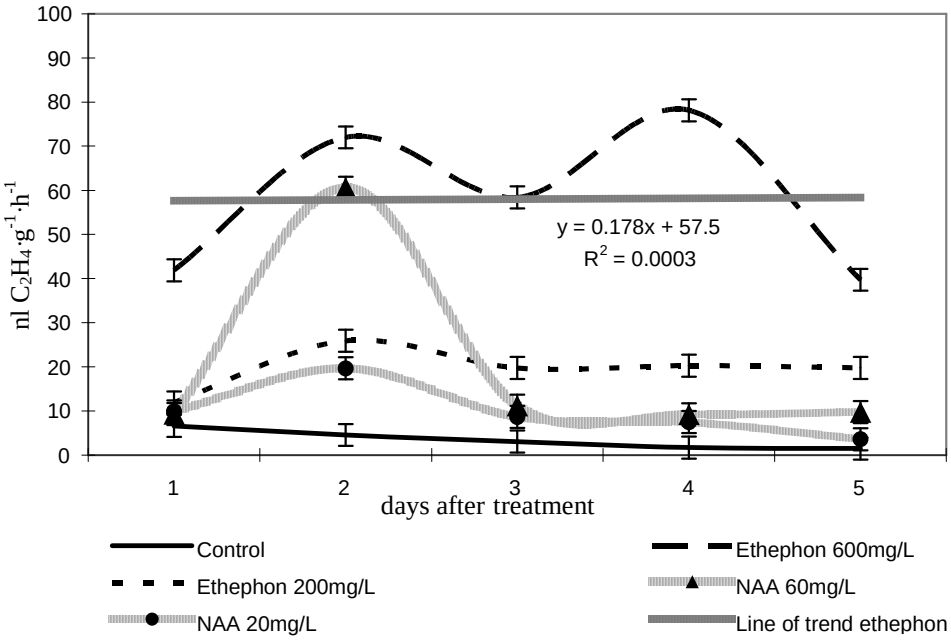

Figure 1. Ethylene evolution by fruitlets after treatment with NAA and ethephon at two concentrations in 2006

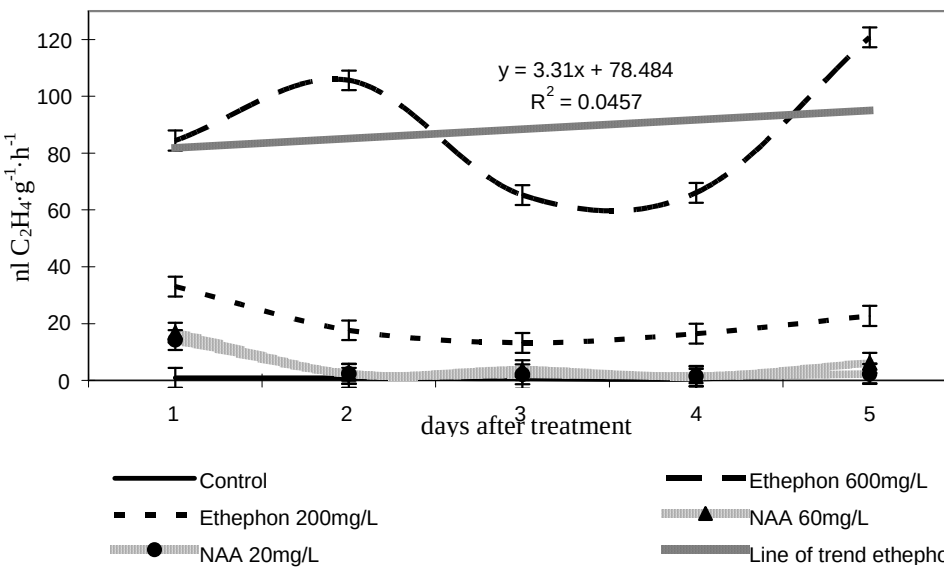

Figure 2. Ethylene evolution by fruitlets after treatment with NAA and ethephon at two concentrations in 2008

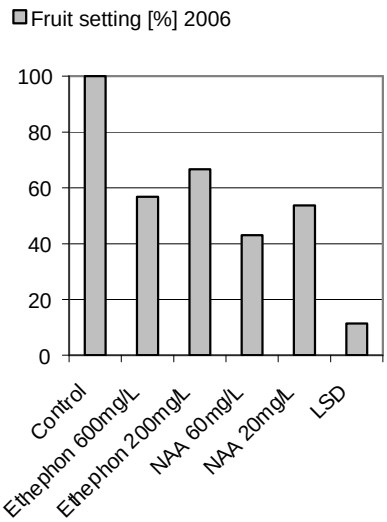

Figure 3. Fruit setting after treatment with NAA and ethephon in 2006 (control tree = 100%)

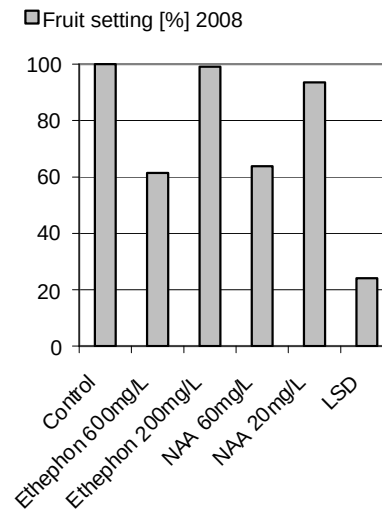

Figure 4. Fruit setting after treatment with NAA and ethephon in 2008 (control tree = 100%)

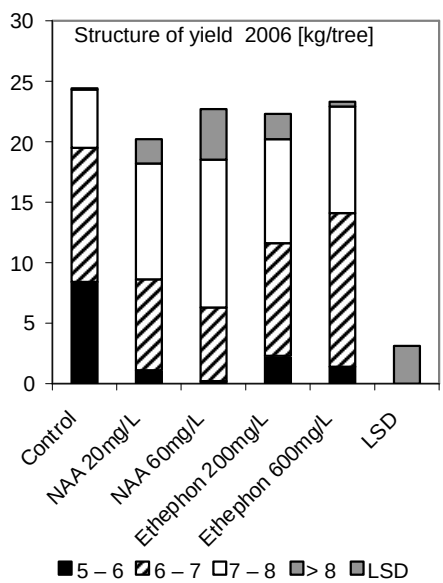

Figure 5. Structure of yield (fruit diameter) after treatment using NAA and ethephon in 2006

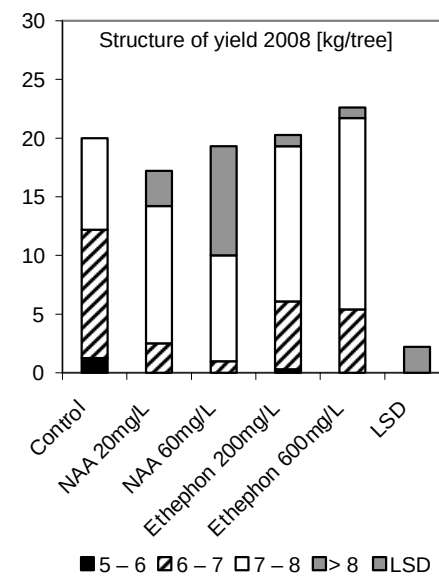

Figure 6. Structure of yield (fruit diameter) after treatment using NAA and ethephon in 2008

involving treatment with NAA at the higher concentration (Fig. 5). In the case of the other combinations, the total yield did not differ significantly from the control. A significant decrease in the share in the total yield was observed in the case of fruit smaller than 6 cm in diameter. The thinning treatments caused an increase in the share in the total yield for fruit whose diameter was 6-7 cm, and particularly those with a diameter exceeding 7 cm. Similar results were obtained during the second year of the study. A decrease in the total yield, in comparison with the control, was observed only after treating the trees with NAA at the higher concentration (Fig. 6). In the case of the trees treated with the lower concentration of ethephon, a slight increase in the total yield was observed. All the agents used improved fruit quality. They had an influence on the increase in the share in the total yield of the fruit whose diameter exceeded 7 cm. The most pronounced influence was that of NAA, because after using this agent a significant increase in the share in the total yield was observed for very big fruit, the diameter of which exceeded 8 cm.

DISCUSSION

An increase in ethylene evolution after treatment with ethephon could be expected. Ethephon (2-chloroethylphosphonic acid) is a stable compound in an acidic environment with a pH below 4.1. In an environment with an alkaline pH, ethephon decomposes into ethylene, Cl^- and HPO_3^{2-} (Dobromilska and Kujath, 2006). On this basis, an assumption can be made that the mechanism of fruitlet abscission after treatment with ethephon is dependent on the action of ethylene. A similar theory applies to the mechanism of action of NAA (Curry, 1991ab). After the application of NAA, an instantaneous increase in ethylene evolution from the fruitlets has been observed (Guardiola and Garcia-Luis, 2000; Gonkiewicz and Nosal, 2006a). A conclusion can thus be drawn that fruitlet abscission after the use of NAA is also connected with the action of ethylene (Wertheim, 2000) and the activation of the abscission zone (Bangerth, 2000).

The experiment revealed significant differences in the intensity of ethylene evolution depending on the agent and the concentrations used. The use of ethephon at a concentration of 600 $mg \cdot l^{-1}$ caused a seventeen-fold increase in ethylene evolution during the first year of the study and an eighty-fold increase during the second year of the study in comparison with the control (Tab. 1). During both years, the increase in ethylene evolution caused a related decrease in fruit set to approximately 40% in comparison with the untreated trees. The three times lower concentration of ethephon caused correspondingly lower ethylene evolution. The agent used at a concentration of 200 $mg \cdot l^{-1}$ caused three times lower ethylene evolution during the first year, and four times lower evolution during the second year, than it did at the higher concentration. However, during the first year of the study, ethephon was as effective in fruitlet thinning at the

Table 1. Average amount of ethylene evolved during five days after treatment [nL $C_2H_4 \cdot g^{-1} \cdot h^{-1}$]

Year	Control	Ethephon 600 mg·l^{-1}	Ethephon 200 mg·l^{-1}	NAA 60 mg·l^{-1}	NAA 20 mg·l^{-1}
2006	3.5	58.0	19.5	20.0	9.9
2008	1.1	88.4	20.6	6.0	4.5

lower concentration as it was at the higher concentration. Unfortunately, during the second year of the study it was found to be completely ineffective when used at the lower concentration. The auxin NAA did not cause the same intensity of ethylene evolution as ethephon did, yet during the first year of the study it was more effective in thinning fruitlets (Fig. 3). During the second year of the study, a slight increase in ethylene evolution was observed only on the first day after treatment. During the subsequent days, the results did not differ statistically from the control. In spite of such significant differences in the intensity of ethylene evolution after the use of ethephon and the auxin, both agents showed similar effectiveness in the thinning of fruitlets in relation to the concentrations used (Fig. 4). The obtained results do not confirm the theory according to which ethylene is a factor directly responsible for causing fruitlet abscission after the use of NAA.

The process of fruitlet abscission might be connected with a decrease in the intensity of photosynthesis (Stopar et al., 1997; Untiedt and Blanke, 2001) or the stopping of compounds from reaching the fruitlets (Ward and Marini, 1999). It has been noted that exogenous ethylene activates the abscission zone (Dennis, 2000). However, no proof has been found that the activity of the enzymes responsible for the activation of the abscission zone (Bonghi et al., 1992) is responsible for a reduction in the compounds reaching the fruitlets (Ward and Marini, 1999). It is also difficult to explain the difference in the effectiveness of the agents to be a result of different sensibility of the abscission zone to ethylene (Bonghi et al., 2000). Explanation is also needed for the part played by callose saturation of the chalaza in the process of fruitlet abscission and the stopping of endosperm evolution and embryo degeneration , which have been observed during the first days after spraying with the auxin NAA (Gonkiewicz and Nosal, 2006b).

Regardless of the agent used and its concentration there was an improvement in the size of apples. The same conclusion has been reported by other authors (Basak and Niezborala, 1991; Jones et al., 1992; Poniedziałek et al., 2002). A particularly marked effect was observed in the combinations involving treatment with NAA. It is likely that the increase in fruit size was caused not only by the reduced number of fruitlets, but also by the agent itself.

CONCLUSIONS

1. The results regarding ethylene evolution and fruit setting did not show that ethylene was a factor directly responsible for fruitlet abscission after the use of the auxin NAA.
2. The influence of the auxin NAA on the size of apples is more positive than the influence of ethephon.

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INTENSYWNOŚĆ WYDZIELANIA ETYLENU ORAZ ZAWIĄZANIA OWOCÓW PO PRZERZEDZANIU ZAWIĄZKÓW JABŁONI NAA I ETEFONEM

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S T R E S Z C Z E N I E

Doświadczenie przeprowadzono w latach 2006 i 2008. W 2007 roku nie prowadzono badań z powodu znacznych uszkodzeń pąków i kwiatów przez przymrozki wiosenne. Obiektem badań były 14-letnie drzewa jabłoni 'Szampion' na podkładce MM 106. W doświadczeniu zastosowano auksynę NAA w stężeniu 20 i 60 $mg \cdot l^{-1}$ oraz etefon w stężeniu 200 i 600 $mg \cdot l^{-1}$. Oprysk wykonano pod koniec kwitnienia, gdy opadło 80% płatków korony. Przez pięć dni po zbiegu badano ilość etylenu wydzielanego przez zawiązki owocowe. Bardzo duże ilości wydzielanego etylenu zaobserwowano po zabiegu etefonem, szczególnie w stężeniu 600 $mg \cdot l^{-1}$. Po zabiegu roztworem auksyny dużą ilość etylenu zaobserwowano tylko w pierwszym roku badań dwa dni po zastosowaniu 60 $mg \cdot l^{-1}$. Od trzeciego dnia po zabiegu NAA ilość wydzielanego etylenu przez zawiązki owocowe była nieznacznie wyższa niż w kontroli. Auksyna zastosowana w drugim roku badań spowodowała nieznaczny wzrost wydzielanego etylenu tylko w pierwszym dniu badań. W pozostałych dniach ilość wydzielanego etylenu nie różniła się statystycznie od kontroli. Pomimo dużych różnic w ilości wydzielanego etylenu przez zawiązki owocowe, procent zawiązanych owoców był po-

dobny po zastosowaniu preparatów w wyższych stężeniach: etefonu w stężeniu 600 $mg \cdot l^{-1}$ i NAA 60 $mg \cdot l^{-1}$, jak również w niższych stężeniach etefonu i NAA. Wykonane zabiegi miały niewielki wpływ na obniżenie wielkości plonu ogólnego. Zaobserwowano jednak bardzo korzystny wpływ na wielkość owoców. Zanotowano większy procentowy udział w plonie ogólnym owoców o średnicy powyżej 7 cm.

Słowa kluczowe: jabłonie, auksyna, struktura plonu