EFFECT OF EXOGENOUS METHYL JASMONATE ON NUMERICAL GROWTH OF THE POPULATION OF THE TWO-SPOTTED SPIDER MITE (*TETRANYCHUS URTICAE* KOCH.) ON STRAWBERRY PLANTS AND YOUNG APPLE TREES

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Abstract: Treating apple trees and strawberry plants with methyl jasmonate (JA-Me) was investigated to see how the treatment affects the population size of the two-spotted spider mite (*Tetranychus urticae* Koch.). Both apple and strawberry were represented by two cultivars: Jester, Close and Aga, Kent, respectively. Each plant was infested with mites one day after being treated with a methyl jasmonate (JA-Me) solution. The negative influence of the JA-Me plant treatment on the growth of the subsequently colonized population of the two-spotted spider mite was observed both for strawberry plants and apple trees. A significant interaction (plant treatment x cultivar), however, was observed in the experiment conducted on apple trees. The population of mites feeding on the cv. Jester was not influenced by the JA-Me treatment. This lack of influence by JA-Me treatment was in contrast to what was found with the cultivar Close.

Key words: jasmonic acid, resistance, preference, antibiosis

INTRODUCTION

Tetranychus urticae is a polyphagous mite feeding on over 200 species of plants (Boom *et al*. 2003). It is a serious pest of many crops including fruit, vegetables, field crops and ornamentals. For this reason, *T. urticae* is also regarded as one of the harmful organisms of utmost importance in apple orchards and strawberry plantations. It reproduces rapidly, which accounts for its large population numbers. Such large numbers lead to a severe damaging of the leaves and consequently, to a reduction in the crop yield. To control the pest, chemical and biological methods of plant protection are used. Up to now, application of pesticides or introduction of predatory mites have been the main methods used for this purpose. Attempts at utilizing chemical elicitors of induced resistance of plants have been undertaken recently.

Jasmonic acid (JA) is a ubiquitous and naturally occurring hormone in plants. Like other hormones, it plays a significant role during the plant's development, *e.g.* in leaves senescence, fruit development and ripening, root growth, seed germination, seedling growth, and photosynthesis (Wasternack 2007). Jasmonic acid is known for its role in plant response to different stresses. Such stresses include tissue wounds by mechanical injury or by herbivore and pathogen attack (Farmer and Ryan 1992; Creelman and Mullet 1997). It was stated that the herbivores cause an increase in the level of endogenous jasmonic acid in plant tissues. The importance of JA as the signal molecule of the defense response in plants was confirmed for many herbivore species after treating their host plants with JA or with its derivative JA-Me, the jasmonic acid methyl ester (Thaler *et al*. 1996; Thaler 1999; Baldwin 1998). It was observed that JA or JA-Me induces enzymes typical for plant defense against herbivores, in plant tissues. (Thaler 1999).

Most of the experiments were conducted on chewing insects that cause extensive damage to foliage. However, the involvement of JA in direct defense to *T. urticae* was also studied on lima bean and tomato (Omer *et al*. 2001; Li *et al*. 2002; Choh *et al*. 2004).

The goal of our study was to examine whether JA-Me treatments of young apple trees and strawberry plants influence population size of the two-spotted spider mite.

In addition, we wanted to examine whether this impact may be modified by a plant variety.

MATERIALS AND METHODS

The experiments were conducted on Close and Jester apple cultivars as well as on Aga and Kent strawberry cultivars growing in an insectary and a glasshouse, respectively. One-year-old apple trees were grown in 10 litre containers. Strawberries were planted in pots of 14 cm in diameter. The experiment began at an early phenological stage of the apple and strawberry plants; when all plants had at least three unfolded leaves. The

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apple trees and strawberry plants were divided into three experimental treatment groups, each of which was composed of 10 plants, *i.e.*:

1. Treated with a solution of 0.1% JA-Me in 0.05% Triton X-100 (wetting agent).
2. Treated with 0.05% solution of the Triton X-100.
3. Nontreated plants (check).

The application of the solutions was conducted by spraying the plants until runoff.

To study the effect of JA-Me treatment on the growth of a population of *T. urticae*, 30 adult females of the target species were introduced on each plant. The *T. urticae* females were introduced one day after spraying the plants with trial solutions. The mites used in this experiment were reared in a glasshouse on lima bean plants.

The size of the mite populations was tested 5 weeks after their introduction on apple trees, and 2 weeks after their introduction on strawberry plants.

The experiments were arranged as a split-plot design with ten replications (plants). The results were analyzed by two-factorial ANOVA. A Tukey's HSD test was performed to analyze the significance of the difference between the means.

RESULTS

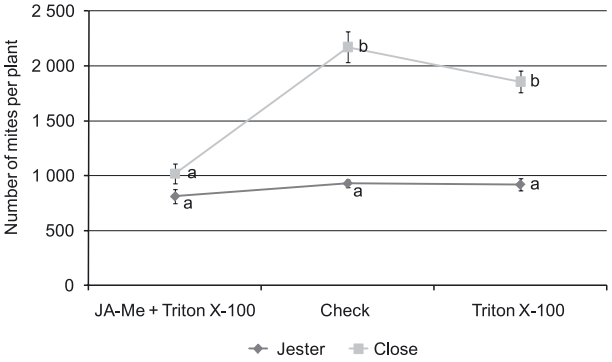
In the experiment conducted on apple trees a significant effect of the JA-Me treatment on the population size of mites was observed (Table 1). However, the interaction apple cultivar x treatment was significant and the influence of JA-Me on population size was stated only for the Close cultivar (Table 1, Fig. 1). The level of infestation of the trees with mites was higher on the Close variety. In the plants treated with JA-Me, though, no statistically significant differences between studied apple cultivars was stated (Table 1, Fig. 1).

On the other hand, JA-Me treatment of strawberry plants had a negative influence on the population growth of *T. urticae* (Table 2, Fig. 2). In this experiment no significant interaction between the two main factors (cultivar x treatment) was stated (Table 2). However, the number of mites feeding on plants depended on the strawberry cultivar (Table 2). It is worth mentioning that after JA-Me treatment of strawberry plants, the growth of the *T. urticae* population was especially low on the Kent cultivar (Fig. 2).

Table 1. Summary of ANOVA testing for the effect of the treatment (JA-Me + Triton X-100, Triton X-100, Check) and the cultivar (Jester, Close) on the total number of mites infesting apple trees

Factor	df	MS	F	p
Treatment	2	2091034	26.79	< 0.001*
Cultivar	1	9115667	116.81	< 0.001*
Interaction (treatment x cultivar)	2	1354442	17.36	< 0.001*
Residual	52	78041		

* significant at p < 0.001



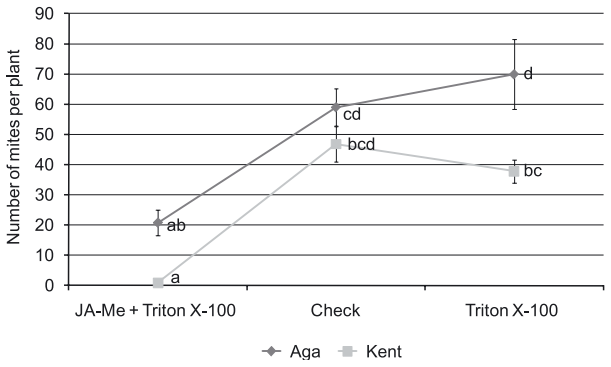
Values marked with the same letter do not differ at the significance level p = 0.05 according to Tukey's HSD test

Fig. 1. The influence of the JA-Me treatment on population size of mites feeding on trees of the Close and Jester cultivars. Plot of interaction cultivar x treatment (mean ±standard error)

Table 2. Summary of ANOVA testing for the effect of the treatment (JA-Me + Triton X-100, Triton X-100, Check) and the cultivar (Aga, Kent) on the total number of mites infesting strawberry plants

Factor	df	MS	F	p
Treatment	2	12060.35	30.40	< 0.001*
Cultivar	1	6869.40	17.31	< 0.001*
Interaction (treatment x cultivar)	2	503.45	1.27	0.289 n.s.
Residual	54	396.79		

*significant at p < 0.001, n.s. – not significant; df – number of degrees of freedom; MS – mean square; F – MS effect/MS residual; p – significance level



Values marked with the same letter do not differ at the significance level p = 0.05 according to Tukey's HSD test

Fig. 2. The influence of the JA-Me treatment of strawberries on size of the mite population feeding on the Aga and Kent cultivars. Plot of interaction cultivar x treatment (mean ±standard error)

DISCUSSION

The presented study has revealed a negative influence of exogenous JA-Me on the performance of the two-spotted spider mite feeding on apple trees and strawberry plants. These results confirmed our former research carried out in a laboratory settings for detecting the antibio-

sis resistance mechanism of apple trees and strawberry plants to mites. In the "no-choice tests", *T. urticae* females were kept separately in glass cages and demonstrated reduced fecundity on leaves treated with JA-Me as compared to females feeding on non-treated leaves. On the other hand, in the "choice test" the mites preferred to feed or oviposite on non-treated leaves. This action suggests an occurrence of the antixenosis resistance mechanism of plants to *T. urticae* (Warabieda *et al*. 2003; Warabieda *et al*. 2005).

There were similar results received, in an experiment conducted on cotton infested with the two-spotted spider mite (Omer *et al*. 2001). Application of JA on leaves of cotton plants caused the mites to prefer the non-treated leaves. The application did not affect the survival of spider mites. A significant reduction in egg numbers, though, was observed in comparison to the controls.

The influence of jasmonic acid or methyl jasmonate on the mechanisms of plant resistance to arthropods is associated with the products of induced expression of numerous genes (Schenk *et al*. 2000; Pena-Cortès *et al*. 2005). On the other hand, methyl jasmonate has not been found to be directly toxic to herbivores (Avdiushko *et al*. 1997). This thesis was indirectly confirmed in our experiment, as the level of mite infestation of trees of the Jester cv. treated with JA-Me was comparable to that of non treated plants.

In our study, mites feeding on apple trees or strawberry plants reacted in different ways to the JA-Me treatment. The reaction of the mites depended on the cultivar. This differentiation was especially clear in the experiment on apple trees and was confirmed statistically by a significant interaction (treatment x cultivar).

As for strawberry, after spraying the plants with JA-Me, we found a decrease in the number of mites on both strawberry cultivars. The decrease was especially significant on the Kent cv.

In the experiment with apple trees, we stated that the mite infestation on non-treated trees of the Close cv. was twice as high as the mite infestation on the Jester cv. The probable reason may be that the cultivar Jester possesses a higher level of constitutive resistance to mites as compared to the Close cultivar. In our former experiment conducted in field conditions, the trees of Jester revealed a lower level of mite infestation than the trees of Close. In that former study we stated that both of the cultivars varied in the anatomical and morphological traits of their leaves as well as in the level of their phenolic compounds (Warabieda *et al*. 1997).

On the other hand, after JA-Me treatment, the population size of the mites feeding on the Close cv. decreased to a level comparable to the population feeding on the Jester cv. This population decrease suggests the possible involvement of an induced mechanism of resistance to mites triggered by JA-Me treatment on the Close cv.

The question is: why did the trees of the Close cultivar reveal such an unequivocally induced resistance to mites after JA-Me treatment in contrast to the Jester cultivar? To explain the phenomenon of the different reaction of Close and Jester cultivars to the exogenous JA-Me treatment, an analysis of the level of endogenous jasmonic acid or its derivatives in the leaves of both apple cultivars should be done. An account for this thesis may be in the statement resulting from an experiment made by other authors on wild-type and jasmonate-deficient mutant tomato plants (def1). In the study mentioned, researchers proved that treating the def1 tomato plants with JA-Me elevates the resistance of the plants to *T. urticae* and reduces the fecundity of female mites (Li *et al*. 2002). Taking into account the results of our study, it should be interesting to check the influence of JA-Me on the activity of some enzymes involved in a resistance mechanism to herbivores like polyphenol oxidase, peroxidase, or accumulation of proteinase inhibitors.

Our paper has demonstrated that methyl jasmonate could be an effective compound against the two-spotted spider mite feeding on apple and strawberry foliage. It should be underlined, that before practical application of JA-Me, the influence of this compound on the growth and development of the plants will have to be taken into account. Another question involved is, how JA-Me treatment influences the sensitivity of plants to other pests and pathogens.

CONCLUSIONS

1. Application of the exogenous JA-Me increased the resistance of both the Aga and Kent strawberry cultivars to *T. urticae*.
2. Of the two varieties of apple trees, the negative impact of JA-Me plant treatments on the development of the spider mite population were found only in the case of the Close cultivar.
3. On the Jester cultivar there was no effect of exogenous JA-Me on the population of the two-spotted spider mite. However, the population size of this pest was at a low level compared to the population size of this pest on the Close cultivar. It is possible that in the case of the Jester cultivar, we were dealing with constitutive resistance to *T. urticae.*
4. To explain the phenomenon of different apple cultivar response to JA-Me, further study should be performed. Particular emphasis should be placed on the impact of this elicitor on the activation of enzymes typical for plant defense against herbivores.

REFERENCES

Avdiushko S.A., Brown G.C., Dahlman D.L. Hildebrand D.F. 1997. Methyl jasmonate exposure induced insect resistance in cabbage and tobacco. Environ. Entomol. 26 (3): 642–654.

Baldwin I.T., 1998. Jasmonate-induced responses are costly but benefit plants under attack in native populations. Proc. Natl. Acad. Sci. USA 95: 8113–8118

Boom van den C.E.M., Beek T.A., Dicke M. 2003. Differences among plant species in acceptance by the spider mite *Tetranychus urticae* Koch. J. Appl. Entomol. 127 (3): 177–183.

Choh Y., Ozawa R., Takabayashi J. 2004. Effects of exogenous Jasmonic acid and benzo (1,2,3) thiadiazole-7carbothioic acid S-methyl ester (BTH), a functional analogue of salicylic acid, on the egg production of herbivorous mite *Tetranychus urticae* (Acari: Tetranychidae). Appl. Entomol. Zool. 39 (2): 311–314.

Creelman R.A., Mullet J.E. 1997. Biosynthesis and action of Jasmonates in plants. Ann. Rev. Plant Physiol. Plant Mol. Biol. 48: 355–381

Farmer E.E., Ryan C.A. 1992. Octadecanoid precursors of jasmonic acid activate the synthesis of wound-inducible proteinase inhibitors. Plant Cell 4 (2): 129–134.

Li C., Williams M.M., Loh Ying-Tsu., Lee G.I., Howe G.A. 2002. Resistance of cultivated tomato to cell content-feeding herbivores is regulated by the Octadecanoid - signaling pathway. Plant Physiol. 130 (1): 494–503.

Omer A.D., Granett J., Karban R., Villa E.M. 2001. Chemically-induced resistance against multiple pests in cotton. Int. J. Pest Manage. 47 (1): 49–54.

Pena-Cortès H., Barrios P., Dorta F., Polanco V., Sanchez C., Sanchez E., Ramirez I. 2005. Involvement of Jasmonic acid and derivatives in plant responses to pathogens and insects and in fruit ripening. J. Plant Growth Regul. 23 (3)**:** 246–260.

Schenk P.M., Kazan K., Wilson I., Anderson J.P., Richmond T., Somerville S.C., Manners J.M. 2000. Coordinated plant defense responses in Arabidopsis revealed by microarray analysis. Proc. Natl. Acad. Sci. USA. 97: 11655–11660.

Thaler J.S., Stout M.J., Karban R., Duffey S.S. 1996. Exogenous jasmonates simulate insect wounding in tomato plants (*Lycopersicon esculentum*) in the laboratory and field. J. Chem. Ecol. 22 (10): 1767–1781.

Thaler J.S. 1999. Induced resistance in agricultural crops: effects of Jasmonic acid on herbivory and yield in tomato plants. Environ. Entomol. 28 (1): 30–37.

Warabieda W., Miszczak A., Olszak R.W. 2003. The influence of methyl jasmonate and β-glucosidase on induction of apple tree resistance mechanisms to two-spotted spider mite – (*Tetranychus urticae* Koch.). p. 265–270. In: Proc. 55th Int. Symposium on Crop Protection. Gent, 6 May 2003, Vol. 68 (4a): 1–456.

Warabieda W., Miszczak A., Olszak R.W. 2005. The influence of metyl jasmonate (JA-Me) and β-glucosidase on induction of resistance mechanisms of strawberry 'Aga' inst two-spotted spider mite (*Tetranychus urticae* Koch.). p. 829–836. In: Communications in Appl. Biol. Sci. "Proc. 57th Int. Symposium on Crop Protection". Gent, 10 May 2005, Vol. 70 (4): 515–1092.

Warabieda W., Olszak R.W., Dyki B. 1997. Some aspects of tolerance of apple cultivars to two-spotted spider mite (*Tetranychus urticae*). In: Workshop on Arthropod Pest Problems in Pome Fruit Productions. Einsiedeln, Switzerland. Bull. IOBC/WPRS 22 (7): 211–215.

Wasternack C. 2007. Jasmonates, an update on biosynthesis, signal transduction and action in plant stress response, growth and development. Ann. Bot. 100 (4): 681–697.

POLISH SUMMARY

WPŁYW EGZOGENNEGO ESTRU METYLOWEGO KWASU JASMONOWEGO, NA ROZWÓJ POPULACJI PRZĘDZIORKA CHMIELOWCA (*TETRANYCHUS URTICAE* KOCH.) NA JABŁONI I TRUSKAWCE

W dwóch doświadczeniach, przeprowadzonych na jabłoni, odmiany Close i Jester i truskawce odmiany Aga oraz Kent, badano wpływ egzogennego estru metylowego kwasu jasmonowego (JA-Me) na wielkość populacji przędziorka chmielowca (*Tetranychus urticae* Koch.), zasiedlającej rośliny. Doświadczenie prowadzono w insektarium (jabłoń) i w szklarni (truskawka). Na roślinach obydwu badanych odmian truskawki, stwierdzono ujemny wpływ JA-Me na rozwój populacji przędziorka chmielowca. W doświadczeniu przeprowadzonym na jabłoni, ujemny wpływ JA-Me na rozwój populacji przędziorka stwierdzono tylko na drzewach odmiany Close.