

CHANGES IN THE RATE OF GAS EXCHANGE, WATER CONSUMPTION AND GROWTH IN STRAWBERRY PLANTS INFESTED WITH THE TWO-SPOTTED SPIDER MITE

Krzysztof Klamkowski¹, Małgorzata Sekrecka¹,
Hajnalka Fonyódi² and Waldemar Treder¹

¹Research Institute of Pomology and Floriculture
Pomologiczna 18, 96-100 Skierniewice, POLAND

²Corvinus University of Budapest, Villányi út. 29-34
H-1118 Budapest, HUNGARY

(Received August 9, 2006/Accepted October 10, 2006)

A B S T R A C T

The aim of this study was to determine the effects of infestation with the two-spotted spider mite (*Tetranychus urticae* Koch.) on gas exchange, water uptake and growth in strawberry plants of the cultivar 'Elsanta' cultivated under greenhouse conditions. The rate of photosynthesis, the rate of transpiration and water consumption were lower in infested plants than in uninfested control plants, depending on the initial infestation level. Vegetative growth was also reduced especially in plants infested by high population of spider mites.

Key words: *Fragaria ananassa*, *Tetranychus urticae*, photosynthesis, transpiration, 'Elsanta'

INTRODUCTION

The two-spotted spider mite (*Tetranychus urticae* Koch.) is an important pest on a wide range of horticultural crops, including the cultivated strawberry (*Fragaria x ananassa* Duchesne) (Gimenez-Ferrer et al., 1994; Greco et al., 2006).

The high reproductive potential of *T. urticae* allows populations to increase very rapidly, especially in

protected cultivation systems where climatic conditions are favourably for mite development and chemical control against pest infestation is difficult.

Spider mite infestation adversely affects many physiological processes, thereby reducing growth and yield (Hall and Ferree, 1975; Sances et al., 1981; Park and Lee, 2005). Reduction in the rate of leaf gas exchange as a result of two-spotted

spider mite feeding has been shown in various fruit crop species, including apple, grapevine, black currant (Ferree and Hall, 1981; Candolfi et al., 1992; Topa et al., 1999).

T. urticae infestation reduces growth and yield in strawberries (Sances et al., 1982a,b; Butcher et al., 1987; Walsh et al., 1998). However, there have been few studies on the physiological effects of two-spotted spider mite infestation in strawberries (Poskuta et al., 1975; Sances et al., 1979a).

A thorough understanding of pest ecology and host plant physiology is necessary to understand host-pest relationships and host resistance mechanisms. This is especially important for elaborating integrated pest management strategies.

The aim of this study was to determine how infestation by the two-spotted spider mite affects gas exchange, water consumption and plant growth in strawberry plants grown under greenhouse conditions.

MATERIAL AND METHODS

The experiment was carried out in 2005 at the greenhouse of the Research Institute of Pomology and Floriculture, Skierniewice, Poland

Frigo strawberry plants of the cultivar 'Elsanta' were planted in plastic pots with a volume of 1.2 dm³ filled with peat substrate (Degernes, Norway). The pots were fitted with strips of water absorbing material and placed on glass containers with a volume of 1.0 dm³ filled with nutrient solution (Treder, 2002). Loss of nutrient solution due to uptake by plants was recorded daily, and the

nutrient solution was replenished as necessary.

After three leaves were fully expanded, the plants were artificially infested with two-spotted spider mites. The mites had been raised on bean plants (*Phaseolus vulgaris*). They had been raised in a growth chamber with a temperature of 20 to 25°C and a relative humidity of 55 to 70%.

The plants were infested with either 10, 50 or 100 adult mites per leaf, that is, 30, 150 or 300 mites per plant. Active female mites were transferred with a brush from the bean plants onto paper discs, which then were placed on the strawberry leaves. Uninfested plants served as the control.

Mite populations were allowed to increase naturally. Population densities were determined sixty days after infestation. The number of mobile mites was counted using a magnifying glass. To keep the mites from migrating, the experimental plants were placed in plastic trays resting inside bigger plastic trays filled with water. The experiment was carried out in a completely randomized block design with six replicates of one pot each.

Every two weeks, the gas exchange rate was measured at noon on three leaves for each plant. Measurements were carried out using the LI-6400 portable photosynthesis system (LI-COR Inc., USA) fitted with an LED light source and a source of carbon dioxide. Conditions in the leaf chamber during the measurement (temperature, carbon dioxide concentration, irradiance) were set to be close to ambient values.

At the end of the experiment, the fresh mass of roots and leaves, the number of leaves, and the leaf surface area were recorded for all plants. Leaf surface area was determined with the help of the WinDIAS image analysis system (Delta-T Devices Ltd, UK).

All data were statistically elaborated using analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$. All calculations were performed using the Statistica 6.0 software package (StatSoft Inc., USA).

RESULTS AND DISCUSSION

There was an increase in the numbers of two-spotted spider mite mobile forms during the course of the sixty-day experimental period. At the end of the experiment, the plants initially infested with 10 mites per leaf were infested with 109 mites per leaf, or 10.9 times more than at the beginning. The plants initially infested with 50 mites per leaf were infested with 406 mites per leaf, or 8.1 times more than at the beginning. The plants initially infested with 100 mites per leaf were infested with 686 mites per leaf, or 6.9 times more than at the beginning.

The increase in spider mite populations was not very large. This agrees well with a previous study in which artificially infested strawberry plants were cultivated in a growth chamber (Poskuta et al., 1975). However, in that study, mite populations had increased from ten-fold to thirteen-fold by the 21st day after infestation. In another study in which apple trees infested with *T. urticae* were grown under greenhouse conditions, mite populations increased from

35-fold to 71 fold by the 21st day after infestation (Hall and Ferree, 1975).

The effects of two-spotted spider mite populations on photosynthesis and transpiration are presented in Table 1. In plants initially infested with 50 and 100 mites per leaf, there was a significant decrease in photosynthesis on all sampling dates. However, there were no significant differences between the plants initially infested with 10 mites per leaf and the control plants.

Infestation with two-spotted spider mites and other species of spider mites reduces carbon dioxide assimilation in many plants, including strawberry, apple, almond, grapevine, black currant and cotton (Kolodziej et al., 1974; Andrews and La Pre, 1979; Sances et al., 1981; 1982a; Candolfi et al., 1992; Lakso et al., 1996; Topa et al., 1999; Reddall et al., 2004). However, in some studies stimulation of photosynthesis and other physiological processes was observed. According to Tomczyk et al. (1987) under certain conditions resistance mechanisms may occur. When a population size of *T. urticae* was low or after short periods of feeding, some metabolic processes were stimulated in various plant species, including strawberries (Tomczyk et al., 1987). In the other study, photosynthesis in strawberries infested with two-spotted spider mites was not reduced significantly until the level of infestation was high (Poskuta et al., 1975). In apple and plum trees infested with the fruit tree red spider mite (*Panonychus ulmi*), photosynthesis was not affected until there was visible leaf damage (Avery, 1964).

Table 1. Effect of infestation with the two-spotted spider mite on the rate of photosynthesis (P) and the rate of transpiration (T) in strawberry plants

Initial population of mites per leaf	14 days after infestation		28 days after infestation		42 days after infestation		56 days after infestation	
	P	T	P	T	P	T	P	T
10	10.3 bc*	2.3 ab	9.3 b	2.1 c	10.7 b	3.8 b	9.4 ab	2.0 b
50	9.0 ab	2.0 ab	7.9 a	1.4 ab	9.5 a	3.5 ab	8.8 a	2.0 b
100	8.0 a	1.9 a	7.2 a	1.1 a	9.4 a	3.0 a	8.7 a	1.7 a
0 (control)	11.6 c	2.7 b	9.2 b	1.8 bc	11.5 b	4.3 c	10.3 b	2.4 c

*Means within columns with the same letter are not significantly different according to Duncan's multiple range t-test at $P \leq 0.05$

P – rate of photosynthesis ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)

T – rate of transpiration ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$)

Table 2. Effect of infestation with the two-spotted spider mite on growth parameters in strawberry plants

Initial population of mites per leaf	Leaf fresh weight [g]	Total leaf surface area [$\text{cm}^2 \text{ plant}^{-1}$]	Number of leaves per plant	Root fresh weight [g]
10	42.1 ab*	1178 bc	12.2 a	9.23 a
50	34.9 a	941 ab	13.8 a	8.55 a
100	34.2 a	900 a	12.2 a	7.78 a
0 (control)	45.4 b	1417 c	14.8 a	8.95 a

*Explanations, see Table 1

At higher levels of infestation, the inhibition of photosynthesis brought about a reduction in vegetative growth. The fresh weight and surface area of the leaves were reduced in plants which had been initially infested with 50 or 100 mites per leaf (Tab. 2). On the other hand, plant growth was not significantly affected in the plants which had been originally infested with only 10 mites

per leaf. Reduced growth and productivity as a result of infestation with spider mites have been observed in various vegetable, fruit and ornamental plant species (Golik, 1975; Jesiotr, 1978; Sances et al., 1982a; Łabanowski and Łabanowska, 1996; Park and Lee, 2005).

The reduction in photosynthesis is caused by decreased stomatal opening and increased mesophyll resistance

(Sances et al., 1979a). Experiments on cotton infested by *T. urticae* revealed that both stomatal and nonstomatal components of photosynthesis were reduced by mite feeding injuries (Reddall et al., 2004). Disturbance in stomatal action mechanism is probably the main reason for the decrease in the rate of gas exchange in infested plants. In one study, more than 60% of stomata were closed on strawberry leaves damaged by two-spotted spider mites (Sances et al., 1979b). This reduced stomatal conductance and gas exchange. In chrysanthemums infested with *T. urticae*, the stomata were closed and deformed (Tomczyk and Kropczyńska, 1984).

Photosynthesis is also dependent on biochemical carbon fixation, which takes place inside the leaf tissue. Mechanical destruction of the leaf tissue by spider mites can therefore also affect photosynthesis. Infestation with spider mites may also impair the transport and distribution of nutrients, assimilates, water and hormones (Poskuta et al., 1975; Sances et al., 1979a; Reddall et al., 2004).

In this study, infestation with the two-spotted spider mite reduced stomatal opening, thereby reducing the rate of transpiration (Tab. 1). A reduction in the rate of transpiration is a primary response to spider mite infestation and it has been reported in many plant species (Sances et al. 1979a, 1981, 1982a; Andrews and La Pre, 1979; Candolfi et al., 1992; Reddall et al., 2004).

In the plants initially infested with 100 mites per leaf, the rate of transpiration was significantly reduced as early as fourteen days after

infestation. In plants initially infested with 10 mites per leaf, the rate of transpiration was significantly reduced 42 days after infestation. This indicates that the disturbances in stomatal behavior which affect the rate of transpiration depend on the length of the feeding period and the intensity of feeding. In chrysanthemums infested with the two-spotted spider mite, the proportion of stomata that were closed or damaged increased during the course of the feeding period (Tomczyk and Kropczyńska, 1984).

A reduction in the rate of transpiration also brings about a reduction in the rate of water loss in infested plants, which in turn affects water consumption (Cohen et al., 1993; Liang et al., 2002; Aharon et al., 2003). The effect of infestation with *T. urticae* on water uptake in strawberry plants had not been previously studied. In this study, water consumption was lower in infested plants than in the control plants (Fig. 1). Water consumption was reduced in the highest degree (by about 18%) in the plants which had been initially infested with 100 mites per leaf.

CONCLUSIONS

Infestation with *T. urticae* reduced gas exchange in strawberry plants. The magnitude of the effect depended on the level of infestation. Impairment of physiological processes due to feeding by mites is therefore probably responsible for the reduction in growth rate in infested plants.

The reduced level of water consumption of injured plants points out that no additional amounts of

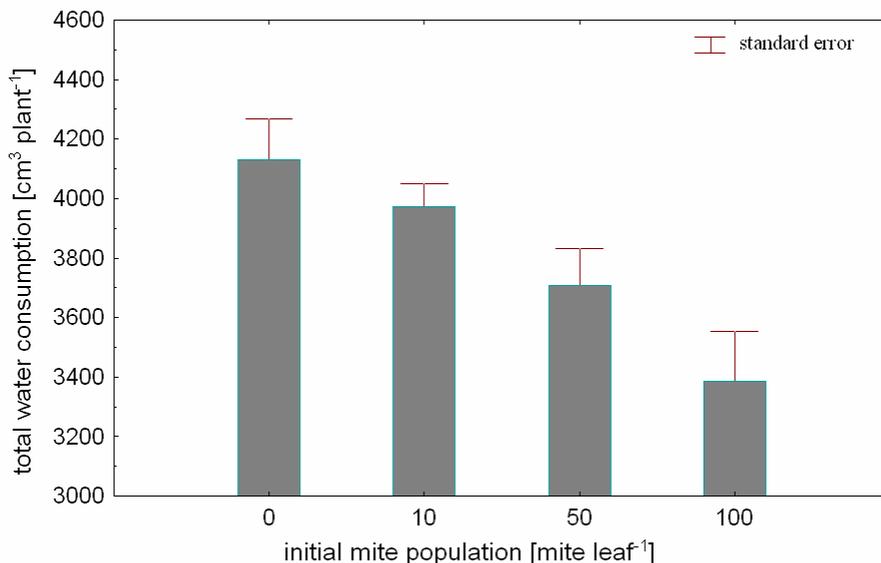


Figure 1. Effect of infestation with the two-spotted spider mite on water consumption in strawberry plants

water need to be applied during two-spotted spider mite infestation.

The physiological responses of strawberries observed in this study may provide a basis for further studies in order to determine the economic threshold level of infestation by *T. urticae* based on population density and the length of the feeding period.

REFERENCES

- Aharon R., Shahak Y., Winger S., Bendov R., Kapulnik Y., Galili G. 2003. Overexpression of a plasma membrane aquaporin in transgenic tobacco improves plant vigor under favorable growth conditions but not under drought or salt stress. *PLANT CELL* 15: 439-447.
- Andrews K.L., La Pre L.F. 1979. Effects of Pacific spider mite on physiological processes of almond foliage. *J. ECON. ENTOMOL.* 72: 651-654.
- Avery D.J. 1964. Carbon dioxide exchange by plum and apple leaves damaged by fruit tree red spider mite. *ANN. RPT E. MALLING RES. STA.* 1963: 94-97.
- Butcher M.R., Penman D.R., Scott R.R. 1987. The relationship between two-spotted spider mite and strawberry yield in Canterbury. *NEW ZEALAND J. EXP. AGIC.* 15: 367-370.
- Candolfi M.P., Boller E.F., Wermelinger B. 1992. Influence of twospotted spider mite, *Tetranychus urticae*, on gas exchange of Pinot noir grapevine leaves. *VITIS* 31: 205-212.
- Cohen M., Girona J., Valancogne C., Ameglio T., Cruziat P., Archer P. 1993. Water consumption and optimization of the irrigation in orchards. *ACTA HORT.* 335: 349-357.
- Ferree D.C., Hall F.R. 1981. Influence of physical stress on photosynthesis and transpiration of apple leaves. *J. AMER. SOC. HORT. SCI.* 106: 348-351.
- Gimenez-Ferrer R.M., Erb W.A., Bishop B.L., Scheerens J.C. 1994. Host-pest relationship between the two-spotted

- spider mite (Acari: Tetranychidae) and strawberry cultivars with differing levels of resistance. J. ECON. ENTOMOL. 87: 168-175.
- Golik Z. 1975. A study of the destructiveness of the fruit tree red spider mite, *Panonychus ulmi* (Koch) on apple. ZESZ. PROBL. POST. NAUK ROLN. 171: 15-34.
- Greco N.M., Pereyra P.C., Guillade A. 2006. Host-plant acceptance and performance of *Tetranychus urticae* (Acari, Tetranychidae). J. APPL. ENTOMOL. 130: 32-36.
- Hall F.R., Ferree D.C. 1975. Influence of twospotted spider mite populations on photosynthesis of apple leaves. J. ECON. ENTOMOL. 68: 517-520.
- Jesiotr L.J. 1978. The further study on the injurious effects of the twospotted spider mite (*Tetranychus urticae* Koch) on greenhouse carnations. EKOLOGIA POLSKA 26: 305-310.
- Kolodziej A., Kropczyńska D., Poskuta J. 1974. Comparative study on carbon dioxide exchange rate of strawberry and chrysanthemum plants infested with *Tetranychus urticae* Koch. Proceedings of the 4th International Congress of Acarology, pp. 209-214.
- Lakso A.N., Matti G.B., Nyrop J.P., Denning S.S. 1996. Influence of European red mite on leaf and whole-canopy carbon dioxide exchange, yield, fruit size, quality, and return cropping in 'Starkrimson Delicious' apple trees. J. AMER. SOC. HORT. SCI. 121: 954-958.
- Liang Z., Zhang F., Shao M., Zhang J. 2002. The relations of stomatal conductance, water consumption, growth rate to leaf water potential during soil drying and rewetting cycle of wheat (*Triticum aestivum*). BOT. BULL. ACAD. SIN. 43: 197-192.
- Łabanowski G.S., Łabanowska B.H. 1996. Effect of different levels of the twospotted spider mite infestation on growth and yield of blackcurrant. ACTA HORT. 422: 366-367.
- Park Y., Lee J. 2005. Impact of twospotted spider mite (Acari: Tetranychidae) on growth and productivity of glasshouse cucumber. J. ECON. ENTOMOL. 98: 457-463.
- Poskuta J., Kołodziej A., Kropczyńska D. 1975. Photosynthesis, photorespiration and respiration of strawberry plants as influenced by the infestation with *Tetranychus urticae* (Koch.). FRUIT SCI. REP. 2: 1-11.
- Reddall A., Sadras V.O., Wilson L.J., Gregg P.C. 2004. Physiological responses of cotton to two-spotted spider mite damage. CROP SCI. 44: 835-846.
- Sances F.V., Toscano N.C., Oatman E.R., LaPre L.F., Johnson M.W., Voth V. 1982a. Reductions in plant processes by *Tetranychus urticae* (Acari: Tetranychidae) feeding on strawberry. ENVIRON. ENTOMOL. 11: 733-737.
- Sances F.V., Toscano N.C., LaPre L.F., Oatman E.R., Johnson M.W. 1982b. Spider mites can reduce strawberry yields. CALIFORNIA AGRICULTURE 36: 14-15.
- Sances F.V., Wyman J.A., Ting I.P. 1979a. Physiological responses to spider mite infestation on strawberries. ENVIRON. ENTOMOL. 8: 711-714.
- Sances F.V., Wyman J.A., Ting I.P. 1979b. Morphological responses of strawberry leaves to infestation of twospotted spider mite. J. ECON. ENTOMOL. 72: 710-713.
- Sances F.V., Wyman J.A., Ting I.P., Van Steenwyk R.A., Oatman E.R. 1981. Spider mite interactions with photosynthesis, transpiration and productivity of strawberry. ENVIRON. ENTOMOL. 10: 442-448.
- Tomczyk A, Kropczyńska D. 1984. Feeding effects of *Tetranychus urticae* Koch on the physiology of some plants. In: Acarology VI – Vol. 2. Griffiths D. A., Bowman C.

- E. (eds) Proceedings 6th International Congress of Acarology. Ellis Harwood, Chichester, pp. 740-746.
- Tomczyk A., Kropczyńska D., Kielkiewicz M. 1987. Przejawy odporności na przędziorki u roślin uprawnych. Materiały XXVII sesji naukowej IOR: 65-79.
- Topa E., Piłko A., Tomczyk A. 1999. Zmiany aktywności fotosyntetycznej liści porzeczki czarnej pod wpływem żerowania przędziorka chmielowca (*Tetranychus urticae* Koch.). PROG-RESS IN PLANT PROTECTION/POSTĘPY W OCHRONIE ROŚLIN 39: 521-523.
- Treder W. 2002. Badania nad bezglebową uprawą truskawek w zamkniętym obiegu pożywki. ZESZ. NAUK. INST. SADOW. KWIAC. 10: 137-147.
- Walsh D.B., Zalom F.G., Shaw D.V. 1998. Interaction of the twospotted spider mite (Acari: Tetranychidae) with yield of day-neutral strawberries in California. J. ECON. ENTOMOL. 91: 678-685.

WPŁYW ŻEROWANIA PRZĘDZIORKA CHMIELOWCA NA WYMIANĘ GAZOWĄ, POBIERANIE WODY ORAZ WZROST ROŚLIN TRUSKAWEK

Krzysztof Klamkowski, Małgorzata Sekrecka,
Hajnalka Fonyódi i Waldemar Treder

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

W doświadczeniu badano wpływ żerowania trzech zróżnicowanych liczebnie populacji przędziorka chmielowca (*Tetranychus urticae* Koch.) na intensywność wymiany gazowej, wzrost oraz wielkość zużycia wody przez rośliny truskawek odmiany 'Elsanta'. Doświadczenie przeprowadzono w warunkach szklarniowych. Przędziorki nakładano na rośliny w momencie wykształcenia przez nie 3 liści w liczbie 0, 10, 50 oraz 100 dorosłych osobników na każdy liść złożony. W doświadczeniu wykazano ograniczenie natężenia wymiany gazowej u roślin, na których żerowały przędziorki. Najsilniejszą redukcję fotosyntezy stwierdzono u roślin, na których populacja przędziorków była najliczniejsza. Natomiast u roślin zasiedlonych w najmniejszym stopniu poziom fotosyntezy był zbliżony do wartości uzyskanych dla roślin kontrolnych. U roślin tych stwierdzono również najmniejsze ograniczenie wzrostu (masy oraz powierzchni liści). W doświadczeniu wykazano ograniczenie intensywności transpiracji u roślin porażonych przez przędziorki. Redukcja transpiracji wskazuje na ograniczenie utraty wody z liści, co wpływa modyfikująco na wielkość zużycia wody przez rośliny. Potwierdziły to obserwacje, w których porównano pobieranie wody przez rośliny zdrowe oraz porażone przez przędziorki. Największą ilość wody w trakcie trwania doświadczenia zużyły rośliny kontrolne, najmniejsze zużycie stwierdzono u roślin najbardziej porażonych przez przędziorki.

Słowa kluczowe: *Fragaria ananassa*, *Tetranychus urticae*, fotosynteza, transpiracja, 'Elsanta'