Influence of Three Irrigation Levels on the Reproduction of European Red Mite *Panonychus ulmi* Koch and on Some Biochemical Characteristics of Leaves of Potted Apple Plants

Lino B. Monteiro[1] and Guy Fauvel[2]

[1]UENF-CCTA, Av. Alberto Lamego 2000, 28015-620, Campos, RJ.
[2]Laboratory of Acarology, ENSA-M/INRA, Montpellier, 34000.

An. Soc. Entomol. Brasil 25(1): 13-19 (1996)

Influência de Três Regimes de Irrigação na Reprodução do Ácaro Vermelho *Panonychus ulmi* Koch e em Características Bioquímicas das Folhas de Macieiras Cultivadas em Pote

RESUMO - A fecundidade de *Panonychus ulmi* Koch foi observada sobre macieira cv. Granny Smith, enxertada sobre dois porta-enxertos (MM 106 e M 26) e três regimes de irrigação. O estresse hídrico sobre M 26 reduziu em quatro vezes a fecundidade de *P. ulmi* mas não ocorreu o mesmo sobre MM 106. De maneira geral, pode-se considerar que a fecundidade dos ácaros apresentou correlação com o regime de irrigação aplicado às macieiras em ambos porta-enxertos. As folhas de MM 106 foram mais ricas em minerais do que as M 26, esta relação poderia explicar a maior oviposição no primeiro porta-enxerto. Entretanto, não houve relação significativa entre a fecundação de ácaros e o teor de minerais e phloridzine sobre as folhas das macieiras.

PALAVRAS-CHAVE: Acari, Tetranychidae, biologia, estresse de água, macieira.

ABSTRACT - The fecundity of *Panonychus ulmi* Koch was studied on apple cv. Granny Smith with two apple rootstocks, MM 106 and M 26, and three different irrigation regimes. Water stress on M 26 caused a four fold reduction in the fecundity of *P. ulmi* but not on MM 106. Despite great variations mite fecundity was related to water regime applied to the trees with both rootstocks. Leaves of MM 106 were richer in minerals than M 26 and this may explain why oviposition levels were generally higher on the former. However no significant relationships were found between mite fecundity and leaf content of the main minerals or phloridzin.

KEY WORDS: Acari, Tetranychidae, biology, water stress, apple tree.

Nutrition is the principal factor in the natural decline of *Panonychus ulmi* (Acari: Tetranychidae) populations in late summer (Cutright 1951) and food quality actually influences female fecundity (Lees 1953). Chaboussou (1969) reported that changes in plant biochemistry induced by pesticides can cause mite outbreaks. Hare *et al.* (1989)

found that *Panonychus citri* (McGregor) populations are not influenced by irrigation while other authors have discovered negative correlations between mite development and the intensity of water stress applied to the host plant (Feese & Wilde 1977, Kattes & Teetes 1978, Oi *et al.* 1989). Youngman et al. (1988) showed that *Tetranychus pacificus* McGregor deposited significantly more eggs on trees under a variable water stress than under continuous water stress. With Red Delicious grafted to MM 104 Specht (1965) obtained six times more mites and eggs of *P. ulmi* when trees were grown on soils with a field capacity of 28% than on soils with a field capacity of 40%. Staübli (1982) observed that girdling on apple tree stems had a negative effect on *P. ulmi* development.

The purpose of this study was to verify the influence of water stress on mite fecundity on apple trees. This study was completed by analyses of leaf minerals and phloridzin content to determine if some biochemical changes could be eventually associated with changes in the response of mite populations.

Material and Methods

Two-year old 'Granny Smith' apple trees grafted on 'Malling 26' and 'Malling-Merton 106' rootstocks were planted in containers having 40 kg of soil (ca. 32 liters). They were kept for three months with normal irrigation to allow sufficient root development. Then they were randomly placed in a screenhouse whose top was lined with a clear plastic sheet. The pots were covered with black polyethylene plastic and three water regimes, low, medium (field capacity = 2/3 maximum retentive capacity) and high (maximum retentive capacity) were applied to the trees on the two rootstocks, with five replications. The wilting point of sunflowers and field capacity were used to determine the initial water adjustment: 1.5, 4.1 and 6.5 l per tree for each treatment, respectively. These water volumes were kept constant by weighting the pots regularly and adding water when necessary.

After two weeks of tree conditioning two young, mated female *P. ulmi* were placed on each of four leaves per plant. They were collected from laboratory rearings maintained on leaf disks kept on moist cotton at 21 ± 1°C and 60 ± 10% RH (Monteiro 1991) and using a mite population from anornamental apple tree, *Malus* sp. The mites were isolated by a layer of Vaseline petroleum jelly applied to the leaf petiole. After the seventh day, the leaves were collected and the eggs counted.

Leaf base potential was measured with a pressure chamber, according to the methods of Scholander *et al.* (1965) and Boyer (1969) on Luly 25, a day before mites were placed on the trees, and August 1st. Leaf analyses for mineral contents followed Martins-Prevel *et al.* (1984). Phloridzin extraction followed Bastide (1983) with modification for apple trees by J.J. Macheix (personal communication) and its dosage was made with a spectrometer at 283 nm. Data were analysed following the general linear model (GLM) procedures of SAS (SAS Institute).

Results and Discussion

The day before the mites were placed on the plants, the base potential for each water regime was proportional to the initial water adjustments (Fig. 1). The average leaf tensions (± 2 SE) for rootstocks M 26 and MM 106 were very close to the low regime (-8.96 ± 0.5 and -8.82 ± 1.6 bars respectively) and differed by about -0.8 bars with the medium regime (-5.56 ± 0.5 and -6.36 ± 1.5 bars). In the high regime they fell to -4.48 ± 0.4 and -4.36 ± 0.6 bars.

The base potential increased in all treatments over time, except for rootstock M 26 in the medium regime. In the last measurement leaf tensions for rootstocks M 26 and MM 106 were lower than -22 bars in the low regime; -5.76 ± 0.7 and -6.16 ± 0.7 bars respectively in the medium and -3.84 ± 0.3 and -4.18 ± 0.2 bars for the higher irrigation rate.

The increase in tension values from the initial measurements suggests that water regimes did not completely compensate for daily evapotranspiration (Waring & Cleary 1967).

On M 26 rootstock the average fecundity of *P. ulmi* females with low and medium treatments was 2.9 ± 1.8 and 12.7 ± 3 eggs per female (Fig. 2). Besides *P. ulmi* produced eggs on only half of the leaves in the low water regime and on all of them in the medium. These results are similar to those of Specht (1965), who obtained six times more eggs on irrigated vs non-irrigated apple trees. On the contrary no significant differences in fecundity were observed between the low and medium water regimes on MM 106. Similar results were obtained for *P. citri* on *Citrus sinensis* (L.) by Hare *et al.* (1989).

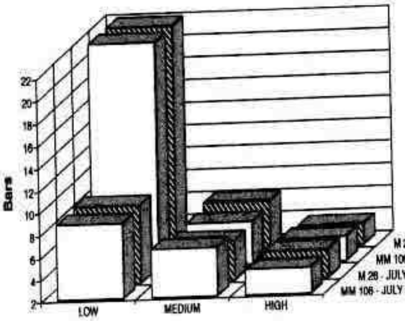

Figure 1. Leaf water potential of potted apple trees cv Granny Smith on two rootstocks and with three irrigation treatments in a screenhouse.

For both rootstocks, fecundity in the high water regime was about eight eggs/female significantly lower than that observed with normal irrigation. Considering the three irrigation treatments, there was a significant relationship between fecundity and water dose. Statistical analyses showed that curves (Fig. 2) could correctly fit the results with the general form: $y = a + bx + cx^2$ with x = dose of water. For M 26: $a = 9.98 \pm 2.22$; $b = -1.11 \pm 0.27$; $c = -9.54 \pm 3.66$; (SE) $p < 0.01$; $r^2 = 0.3$; df = 2,59. For MM 106: $a = 2.83 \pm 2.77$; $b = -0.48 \pm 0.34$; $c = -10.86 \pm 4.58$ (SE) $p < 0.05$; $r2 = 0.1$; df = 2.59.

The evolution of *P. ulmi* populations on apple foliage depends on changes in the composition of leaves (minerals, aminoacids and sugars) and eventually on the concentration of phenolic compounds which are mainly represented by phloridzin in apple leaves (Bielak & Dabrowski 1985). We must also think of the plant's turgor, as mites with their thin integument have high requirements for water. The irrigation regime applied to the trees affects simultaneously all these factors. So the analysis of the phenomena may be rather difficult.

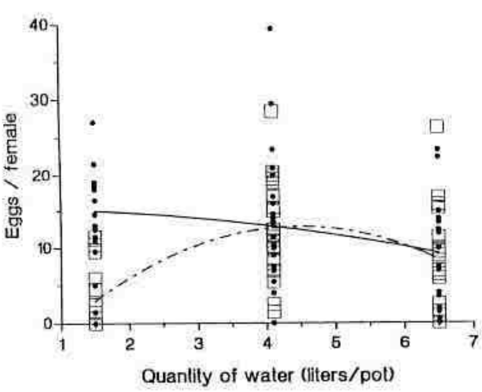

Figure 2. Effects of three irrigation treatments on the fecundity of *Panonychus ulmi* (Koch) (eggs/female in seven days) on two rootstocks (dots and continuous line = MM 106, empty squares and interrupted line = M 26).

A positive correlation between leaf mineral concentration and mite fecundity has been observed (Rodriguez 1958, Chabousson 1969, Storms 1969, Suski & Badowska 1975). In our experiment trees grafted to MM

Table 1. Phloridzin concentration in the apple leaves cv. Granny Smith on two rootstocks with three irrigation treatments under a screenhouse (g/100 g dry weight).

Irrigation treatment	In rootstocks	
	M 26	MM 106
Low	3.63	3.78
Medium	3.49	3.09
High	3.83	3.86
Average	3.65	3.58
S.D.	0.14	0.34

106 rootstock had generally higher N, P, K, and Ca levels than those on M 26 (Table 1). Mite fecundity on the former was equal or superior to that on the latter. We observed also that K and P levels were lower in the low water regime in both rootstocks. This can be related to lower availability of these elements in the soil under dry conditions or to a lesser absorption. However there was no significant correlation between fecundity and mineral levels, both between and within rootstocks. In the field Monteiro (1991) could not demonstrate any influence between leaf mineral concentration and mite fecundity.

Higher leaf content of N, P and K are normally associated with a greater richness in aminoacids or proteins and sugars. Increasing water stress lowers leaf water content and induces an enrichment with simple carbohydrates, and in particular sorbitol in apple leaves (Fanjul & Rosher 1984, Jones *et al.* 1985, Wang & Stutte 1992). Proline and other aminoacids also frequently accumulate while protein synthesis is reduced (Hsiao 1973). So with the lower irrigation rate we can expect higher concentration of these nutrients counterbalanced however by water deficit. In fact average and maximum fecundities on both rootstocks were at best equal and generally inferior to those of the controls. Low mite fecundity on trees grafted to M 26 indicates that turgor is certainly more important than nutrients enrichment. The greater egg production with MM 106 in these conditions may be related to the higher vigor

Table 2. Chemical analysis of Granny Smith apple trees on two rootstocks and with three irrigation treatments.

Elements	In rootstocks					
	M 26			MM 106		
	High	Medium	Low	High	Medium	Low
Kjedldahl Nitr.	1.97	1.54	1.57	1.67	1.87	1.72
Phosphorus	0.40	0.28	0.20	0.55	0.67	0.33
Potassium	1.90	1.98	1.63	2.15	2.12	1.76
Calcium	1.65	1.71	1.75	2.23	1.69	1.82
Magnesium	0.25	0.30	0.30	0.16	0.16	0.22
Boron	37.00	33.00	29.00	38.00	44.00	31.00
Iron	103.00	97.00	98.00	128.00	99.00	93.00
Manganese	51.00	65.00	64.00	38.00	37.00	48.00
Organic subst.	91.58	91.46	91.85	89.84	90.96	91.55
Raw ashes	8.42	8.54	8.15	10.16	9.04	8.45

Units of the analysed elements: N, P, K, Ca, Mg, organic substance and raw ashes in g of the element/100 g of dry substance; B, Fe and Mn in mg/kg of dry leaves.

of this rootstock. A better resistance to drought was noted by Denardi (1986) when plants were grafted to more vigourous rootstocks. In the present study this could minimize the difficulties for the mites to feed.

On the other hand, an enhancement of phenolics production is a common reaction of the plant to the alterations of its environment (Glass 1973). Abdallah (1985) observed increases in phenols in cotton suffering from a water deficit. Dabrowski & Bielak (1978) found that phloridzin levels and mite fecundity were negatively correlated. We can imagine that the higher content of phenolic compounds for the null dose may play a role. But as the levels did not differ significantly between M 26 and MM 106 while fecundities are quite different we can again accept that leaf water deficit had a greater effect with the former.

We lack information about what happens when plants are overwatered. Perhaps there is a dilution of the nutrients available to the females as occurs in the fruit (Cemagref 1983) but we observed also that this treatment led to higher levels of phloridzin (Table 2). This suggests that too much as well as too little water caused stress and stimulated the production of phenolic compounds. As mite fecundity decreased in comparison to control trees we can think of a negative correlation between mite fecundity and phloridzin content of the leaf as indicated by Dabrowski & Bielak (1978). However it was not statistically significant here and we must also consider the possible effect of simultaneous changes occurring in the concentrations of the other nutrients.

This experiment confirms that apple trees suffering from a water stress have mite numbers but it is clear that rootstock is an important factor in mite population dynamics. Monteiro & Fauvel (1993) came to a similar conclusion in the field. The mechanisms involved appear complex but water status of the leaf seems important. It is difficult to ascertain the effects of phenolic concentrations on mite fecundity. Working with *T. urticae* reared on micro-propagated apple trees receiving different levels of the macronutrients NPK Wermelinger *et al.* (1991) concluded similarly that "... it is not possible (...) to pinpoint a single factor as the true cause controlling the development of spider-mite populations. In fact, the balance between the adverse effects of phenolic compounds and the beneficial effects of aminoacids and carbohydrates is suggested as the determining factor in the performance of a population."

In the present state of knowledge we cannot generalize these results to other mite species as the effect of water stress on *P. ulmi* seems different from that on *Oligonychus pratensis* (Banks) (Feese & Wilde 1977, Kattes & Teetes 1978, Chandler *et al.* 1979), *Tetranychus cinnabarinus* (Boisduval) (Chandler *et al.* 1979), *T. pacificus* (Youngman *et al.* 1988), and *T. urticae* (Ferree & Hall 1980).

Acknowledgments

We express our thanks to Dr. D. Raworth (Agriculture Canada, Vancouver Research Station) for his kind assistance in the statistical treatment of these data during a sabbatical leave in Montpellier.

References Cited

Abdallah, M.M. 1985. Effect of drought conditions at different stages of growth on phenol and carbohydate content of cotton leaves. J. Agron. Crop Sci. 155: 246-252.

Bastide, P. 1983. Relations entre composés phénoliques et résistance du pücher *Prunus persica* (L.) Batsch au puceron vert *Myzus persicae* Sulzer. Ph.D., USTL, Montpellier.

Bielak, B. & Z.T. Dabrowski. 1985. Techniques and methods used in studies of resistance to *Panonychus ulmi* in apple varieties. Insect Sci. Appl. 6: 473-478.

Boyer, J.S. 1969. Measurement of the water status of plants. Annu. Rev. Plant Physiol. 20: 351-364.

Cemagref. 1983. Influence de l'irrigation sur le développement végétatif des arbres et la qualité gustative des fruits. CEMAGREF, 499.

Chaboussou, F. 1969. Recherches sur les facteurs de pullulation des acariens phytophages de la vigne à la suite des traitments pesticides du feuillage. Etude particulibre des répercussions du DDT, du Parathion et du Carbaryl sur la reproduction de *Panonychus ulmi* Koch, Eotetranychus carpini vitis Boisd et *Tetranychus urticae* Koch. Ph.D. dissertation, Fac. Sci. Paris.

Chandler, L.D., T.L. Archer, C.R. Ward & W.M. Lyle. 1979. Influences of irrigation practices on spider mite densities on field corn. Environ. Entomol. 8: 196-201.

Cutright, C.R. 1951. Late season control of european red mite. J. Econ. Entomol. 44: 363-367.

Dabrowski, Z.T. & B. Bielak. 1978. Effect of some plant chemical compounds on the behaviour and reproduction of spider mites (Acarina: Tetranychidae). Entomol. Exp. Appl. 24: 117-126.

Denardi, F. 1986. Porta-enxertos, pp. 92-132. In EMPASC (eds.) Manual da cultura da macieira. Florianópolis, 562.

Fanjul, L. & P.H. Rosher. 1984. Effects of water stress on internal water relations of apple leaves. Physiol. Plant. 62: 321-328.

Ferree, D.C. & F.R. Hall. 1980. Effects of soil water stress and twospotted spider mites on net photosynthesis and transpiration of apple leaves. Photosynthesis Res. 1: 189-197.

Feese, H. & G. Wilde. 1977. Factors affecting survival and reproduction of the banks grass mite, *Olygonychus pratensis*. Environ. Entomol. 6: 53-56.

Glass, A.D.M. 1973. Influence of phenolic acids on ion uptake. I. Inhibition of phosphate uptake. Plant Physiol. 51: 1037-1041.

Hare, J.D., J.M. Rettig & J.E. Pehrson. 1989. Egg production and population growth of the citrus red mite (Acari: Tetranychidae) on differentially irrigated citrus trees. Environ. Entomol. 18: 651-659.

Hsiao, T.C. 1973. Plant responses to water stress. Annu. Rev. Plant Physiol. 24: 519-570.

Jones, H.G., A.N. Lakso & J.P. Syvertsen. 1985. Physiological control of water status in temperature and subtropical fruit trees. Hortic. Rev. 7: 301-344.

Kattes, D.H. & G.L. Teetes. 1978. Selected factors influencing the abundance of banks grass mite in sorghum. Tex. Agri. Exp. Stn. B-1186: 2-7.

Lees, A.D. 1953. Environmental factors controlling the evocation and termination of diapause in the fruit tree red spider mite *Metatetranychus ulmi* Koch (Acarina: Tetranychidae). Ann. Appl. Biol. 40: 449-486.

Martins-Prevel, P., J. Gagnard & P. Gautier. 1984. L'Analyse végétale dans le contrôle de l'alimentation des plantes tempérées et tropicales. Ed. Lavoisier, Paris.

Monteiro, L.B. 1991. Etude de la relation entre l'alimentation hydrique, la physiologie du pommier et le développement de l'araignée rouge *Panonychus ulmi* (Koch, 1836) (Acari: Tetranychidae). Ph.D. dissertation, ENSA, Montpellier.

Monteiro, L.B. & G. Fauvel. 1993. Effet de quatre porte-greffes sur la dynamique des populations de l'acarien rouge, *Panonychus ulmi* (Koch) (Acari: Tetranychidae) sur pommier var Granny Smith, pp. 621-629. In Proceeding, 3td Conf. Internat. Ravag. Agric., 7-9 December 1993. ANPP Service, Montpellier.

Oi, D.H., J.P. Sanderson, R.R. Youngman & M.M. Barnes. 1989. Developmental times of the pacific spider mite (Acari: Tetranychidae) on water stressed almond trees. Environ. Entomol. 18: 208-212.

Rodriguez, J.G. 1958. The comparative NPK nutrition of *Panonychus ulmi* (Koch) and *Tetranychus telarius* (L.) on apple trees. J. Econ. Entomol. 51: 369-373.

Scholander, P.F., H.T. Hammel, E.D. Bradstreet & E.A. Hemmingsen. 1965. Sap pressure in vascular plants. Negative hydrostatic pressure can be measured in plants. Science 148: 339-346.

Specht, H.B. 1965. Effect of water stress on the reproduction of european red mite *Panonychus ulmi* (Koch) on young apple trees. Can. Entomol. 97: 82-85.

Staübli, A. 1982. Relation fertilité et ennemis des plantes. Influence de la vigueur de l'arbre sur les pullulations d'acariens rouges (*P. ulmi*) en verger de pommier. Bull. OILB/SROP 1: 46-49.

Storms, J.J.H. 1969. Observations on the relationships between mineral nutrition of apple rootstocks in gravel culture and the reproduction rate of *Tetranychus urticae* (Acarina: Tetranychidae). Entomol. Exp. Appl. 12: 297-311.

Suski, Z.W. & T. Badowska. 1975. Effect of host plant nutrition on the population of the twospotted spider mite *Tetranychus urticae* Koch (Acarina: Tetranychidae). Ekol. Polsk. 23: 185-209.

Van de Vrie, M., J.A. McMurtry & C.B. Huffaker. 1972. Ecology of tetranychid mite and their natural enemies: a review. III. Biology, ecology and pest status, and host-plant relations of tetranychids. Hilgardia 41: 343-432.

Wang, Z. & G.W. Stutte. 1992. The role of carbohidrates in active osmotic adjustment in apple under water stress. J. Amer. Soc. Hort. Sci. 117: 816-823.

Waring, R.H. & B.D. Cleary. 1967. Plant moisture stress: evaluation by pressure bomb. Science 3: 1248-1254.

Wermelinger, B., J.J. Oertili & J. Baumgartner. 1991. Environmental factors affecting life-tables of *Tetranychus urticae* (Acari: Tetranychidae). III. Host-plant nutrition. Exp. Appl. Acarol. 12: 259-274.

Youngnman, R.R., J.P. Sanderson & M.M. Barnes. 1988. Life history parameters of *Tetranychus pacificus* McGregor (Acari: Tetranychidae) on almonds under differential water stress. Environ. Entomol. 17: 488-495.

Received 10/05/94. Accepted 11/28/95.