ON THE RELATIONSHIP BETWEEN THE EUROPEAN RED MITE AND APPLE LEAF CHLOROPHYLL

DANIEL L. JOHNSON[1]
Institute of Animal Resource Ecology
University of British Columbia, V6T 1W5

ABSTRACT

Chlorophyll content of Delicious and McIntosh apple leaves is shown to be uncorrelated with numbers of the European red mite (ERM). Hypotheses regarding movement by the ERM are examined. It is concluded that there is no evidence that the ERM seeks out the least damaged leaves, nor can leaf damage be attributed to the mites present on the leaves. Movement unrelated to leaf quality explains the lack of correlation.

INTRODUCTION

Spider mites have been serious orchard pests in British Columbia since the 1940s (Marshall, 1951, 1952). The most troublesome tetranychid orchard mite in most regions is the European red mite (*Panonychus ulmi* (Koch)), so-called since it is thought to have been introduced into North America from Europe in the early years of this century[2]. The European red mite (ERM) feeds on the leaves of apple, pear and a host of other fruit and ornamental trees. The attacks reduce fruit production and quality during the year of attack and the number of flower buds the following year (Madsen and Arrand, 1975; van de Vrie *et al.*, 1972).

The ERM has 6 to 8 generations per year, depending on temperature, photoperiod and food quality. In May, eggs hatch and give rise to the first generation. All stages, larvae, protonymphs, deutonymphs and adults, can be found throughout the summer. The production of winter eggs occurs in August and September.

Feeding Damage

Most spider mites are phyllophagous, that is, they feed on leaf tissue and not on other plant parts. European red mites feed by inserting cheliceral stylets into mesophyll cells and sucking out the cell contents. The mouth-parts penetrate to a depth of about 50-100 μ (Avery and Briggs, 1968), damaging the palisade mesophyll and, to a lesser extent, the spongy mesophyll. Parenchyma is not damaged. Fluid loss results in cell death, and cells adjacent to damaged cells exhibit aberrant organelle structure (Tanigoshi and Browne, 1981) and reduce their activity, or die. Leaf surfaces are characteristically speckled with dead and weakened cells at low to moderate levels of damage, and become chlorotic (light-coloured due to chlorophyll loss) if the damage is extreme. The tell-tale bronzing from the loss of fluid and pigments is recognizable from a distance as an indicator of high mite population density.

There is some evidence that European red mites move from damaged leaves. Asquith *et al.* (1980) report the effects of leaf damage caused by rust mites on the ERM. Although developmental time and survival were unaffected by the degree of damage, 60% of young adult females moved from damaged to undamaged leaves. Other laboratory and field observations suggest that young adult females have a tendency to walk away even from fresh, undamaged leaves (Johnson, 1983).

Within-tree dispersal, leaf condition and the reproductive success of mites are interrelated. Mite damage affects leaf condition, and leaf quality may influence mite behavior. Mites may or may not be highly mobile and sensitive to food-quality differences within a tree. They may disperse in response to food, randomly, or in response to the behavior they adopt during dispersive phases. The empirical relationship between mite numbers and chlorophyll content, an index of leaf damage, can provide indirect evidence that allows inference on the hypothetical relationships between dispersal and feeding. Chlorophyll concentration is also an indicator of leaf quality, since healthy, green leaves are generally believed to be the most nutritious (e.g., females on damaged leaves suffer a 90% decrease in fecundity, Asquith *et al.*, 1980).

Three hypotheses and corresponding predictions of the nature of the empirical relationship between mite numbers and chlorophyll content are detailed below.

I: European red mites are highly mobile and choose the best leaves, i.e., the leaves which are relatively undamaged and highly palatable. Prediction: a positive correlation between leaf chlorophyll content and the number of mites on the leaves, since mites search out the best feeding sites and remain until food quality degrades.

II: The mites are relatively incapable of movement between leaves and of food selection. They remain on the leaf even after it has sustained

---

[1] Present address: Research Station, Lethbridge, Alberta T1J 4B1.

[2] In Europe it is called the fruit-tree red spider mite.

heavy feeding damage.

Prediction: a negative correlation between chlorophyll content and mite numbers, since the degree of leaf damage reflects its present mite population.

III: Mites are capable of movement between leaves, but do so in a way which is not determined by food condition. They may move if the food quality declines, or they may move even if it remains high.

Prediction: no correlation between chlorophyll and mites.

Compound action of these hypothesized processes would produce compound results. If, for example, mites sought out leaves with high chlorophyll content and remained to feed, but at high densities they reduced chlorophyll content significantly, we would expect to find a parabolic relationship between chlorophyll content and number of mites per leaf.

MATERIALS AND METHODS

The relationship between the ERM and apple leaf chlorophyll was assessed in the Entomology Orchard at the Agriculture Canada Research Station, Summerland, British Columbia. The sampling design was part of a predator-removal experiment described by Johnson (1983). This larger experiment provided trees with a wide range of densities of the ERM.

On each of three dates (June 10 & 11, June 24 & 25 and August 5 & 6) 10 leaves were collected from each of 32 Delicious and 32 McIntosh apple trees arranged in an 8 x 8 Latin square. Of the 10 leaves in a sample, 5 came from the north and 5 from the south branch of each tree. Leaves were collected randomly, with the proviso that no very young or very old leaves were taken. Each leaf was individually placed into a 15 cm diameter plastic petri dish. These were transferred to 2-4 °C storage within 15 minutes of collection. Collections were made row by row, with the order randomized on each sampling date. This pattern ensured that any variability in the results due to time or order of collection could be accounted for by row effect. Sampling was restricted to the period between 9 a.m. and 8 p.m. In the field laboratory, the leaves were examined individually with a binocular dissecting microscope. The mites were counted via direct observation and categorized according to species, sex and instar. Collection of the 640 leaves per sampling date was usually accomplished in two days, with examination and counting requiring up to another two days.

At each of the three dates, an additional sample of 100 leaves was randomly selected and used for determination of moisture content. These leaves were weighed fresh, examined for mites and dried to constant weight at 70 °C.

After the mites were counted, each of the 64 10-leaf samples per date was immediately bagged and frozen. The samples were kept frozen from 2 to 5 months. The mite counts on the 10 leaves per tree were pooled; thus one 10-leaf sample represents one observation on mite density and chlorophyll content. From each leaf in a sample a 1.6 cm diameter disk was cut with a brass cork-borer and used for quantitative determination of chlorophyll a and b by the spectrophotometric method of Bruinsma (1963). A second set of similar disks was cut from

TABLE 1. Mean numbers of the European red mite per leaf. The means for each date are calculated from the counts on 320 leaves, with standard errors ( ).

				adults		total
	eggs	larvae	nymphs	♀	♂	active ERM
a) Delicious						
June 10&11	22.7 (3.1)	3.8 (.38)	.50 (.08)	.55 (.07)	.03 (.01)	4.9 (.48)
June 24&25	88.8 (5.9)	1.1 (.12)	2.0 (.16)	8.1 (.43)	1.4 (.16)	12.6 (.68)
Aug. 5&6	60.7 (3.0)	8.5 (.61)	42.3 (3.1)	9.2 (.44)	4.3 (.35)	64.3 (4.1)
b) McIntosh						
June 10&11	8.0 (1.0)	.84 (.13)	.013 (.01)	.22 (.04)	.003 (.003)	1.1 (.15)
June 24&25	36.0 (3.2)	.50 (.08)	.97 (.11)	3.6 (.22)	.49 (.07)	5.6 (.39)
Aug. 5&6	30.1 (1.9)	3.0 (.23)	15.2 (1.2)	4.8 (.28)	1.6 (.16)	24.6 (1.7)

TABLE 2. Mean chlorophyll content in mg/g dry weight, of McIntosh and Delicious leaves. Means and standard errors ( ) are based on 32 samples.

Date	McIntosh	Delicious
June 10 & 11	3.05 (0.095)	3.81 (0.078)
June 24 & 25	3.22 (0.094)	3.63 (0.090)
August 5 & 6	2.82 (0.065)	3.37 (0.066)

the same leaves for dry weight determination. From each sample, the 10 leaf disks were finely chopped in a blender in 50 ml of cold (1-4 °C) 80% acetone, 20% distilled water. The slurry was suction-filtered over ice, and washed with 20 ml of cold 80% acetone solution. Determinations of total chlorophyll were made with a spectrophotometer by measuring absorbance at 652 nm against an 80% acetone standard. This peak absorbance wavelength, given by Bruinsma (1963), was verified by a scan of sample filtrate with a more precise Unican SP.800 spectrophotometer. As a check on total chlorophyll, absorbances at 663 nm and 645 nm were measured for calculation of chlorophyll a and b content respectively. Concentrations of chlorophyll were determined using the equations of Bruinsma (1963). These were converted to mg/g dry weight, based on the second set of leaf disks from each sample, and to mg/cm^2 leaf area. Determinations were made for a total of 192 10-leaf samples, collected on the three sampling dates: June 10 & 11, June 24 & 25, and August 5 & 6.

RESULTS

All stages of the ERM were about twice as numerous on Delicious as on McIntosh (Table 1). This difference is well-known to growers and entomologists (Downing and Moilliet, 1967). Delicious trees often require more acaricide applications than do trees of other apple varieties (B.C.M.A., 1980). The difference can be attributed to some quality of the leaves, and not to indirect effects of phytoseiid predators. Counts of *Typhlodromus* spp. were about twice as high on Delicious leaves as on McIntosh leaves (Johnson, 1983).

Leaf moisture content was unrelated to the number of mites present; the slope is not significantly different from zero ($p \simeq 0.3$). On all three dates, 70-78% of fresh weight was lost during drying.

Leaves of Delicious had a higher chlorophyll content than those of McIntosh on all three dates ($p < .0001$). Chlorophyll content (mg/g dry weight) was higher in June than in August in both cultivars ($p < .0001$) (Table 2). Chlorophyll per unit area (not shown) gave similar results. Although a wide range of mite densities was present in the data, varying from 0 to 2260 per 10-leaf sample, correlations between mite counts per 10-leaf sample and chlorophyll determinations (a, b and total) were not significant ($p > .05$) for either cultivar on any of the three sampling dates (Table 3). When apple cultivar was ignored, a significant but spurius positive correlation ($p < .01$) resulted, due to the fact that more European red mites were found on Delicious than on McIntosh.

DISCUSSION

There does not seem to be any evidence for the ERM seeking out the least damaged leaves, at least as indicated by chlorophyll content. Nor can leaf damage be attributed to the mites present on the

TABLE 3. Correlation (r) between number of European red mites and chlorophyll content in mg/g dry weight of leaves. Each statistic is based on 32 observations.

Date	McIntosh	Delicious
June 10 & 11	0.130	0.260
June 24 & 25	0.326	-0.239
August 5 & 6	-0.234	-0.141

leaves. This lack of correlation supports hypothesis III, not I or II. In effect, mites are not consistently influenced by food quality during their movements between leaves.

It is well-known that the presence of large numbers of ERM is associated with apple leaf bronzing. Orchards with high average densities of mites will show more yellowing than orchards with few mites. However, the results of this study show that chlorophyll content is not related to the associated density of mites at the scale of the leaf. It can be concluded that ERM dispersal among leaves is relatively rapid and not strongly related to leaf condition. High within-branch, within-tree and within-orchard (Johnson, 1983) dispersal rates probably account for this distribution of mite damage.

ACKNOWLEDGEMENTS

I am indebted to Dr. R. D. McMullen for his permission to work at the Summerland Research Station, and to Simon Fraser University for the use of their facilities. I thank Dr. W. G. Wellington for his comments and critical review. Hélène Contant, Cathy Johnson and Roy Ward provided invaluable technical assistance. The author was supported by an NSERC Scholarship and a Killam Predoctoral Scholarship during the study.

REFERENCES

Asquith, D., B. A. Croft, S. C. Hoyt, E. H. Glass and R. E. Rice. 1980. The systems approach and general accomplishments toward better insect control in pome and stone fruits. **In: New Technology of Pest Control**, C. B. Huffaker (ed.), John Wiley, N.Y., pp. 249-317.

Avery, D. J. and J. B. Briggs. 1968. Damage to leaves caused by fruit tree red spider mite, **Panonychus ulmi** (Koch). **J. Hort. Sci.** 43: 463-473.

British Columbia. Ministry of Agriculture. 1980. Tree fruit production guide for interior districts. 63 p.

Bruinsma, J. 1963. The quantitative analysis of chlorophylls a and b in plant extracts. **Photochem. Photobiol.** 2: 241-249.

Downing, R. S. and T. K. Moilliet. 1967. Relative densities of predacious and phytophagous mites on three varieties of apple tree. **Can. Ent.** 99: 738-741.

Johnson, D. L. 1983. Predation, dispersal and weather in an orchard mite system. Ph.D. thesis, University of British Columbia, Vancouver.

Madsen, H. F. and J. C. Arrand. 1975. The recognition and life-history of the major orchard insects and mites in British Columbia. British Columbia. Department of Agriculture. Publication.

Marshall, J. 1951. Applied entomology in the orchards of British Columbia, 1900-1951. **Proc. Ent. Soc. B.C.** 48: 25-31.

Marshall, J. 1952. A decade of pest control in British Columbia orchards. **Proc. Ent. Soc. B.C.** 49: 7-11.

Tanigoshi, L. K. and R. W. Browne. 1981. Coupling the cytological aspects of spider mite feeding to economic injury levels on apple. **Protection Ecol.** 3: 29-40.

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