Impact of European red mite on Golden Delicious and Oregon Spur apples in Israel

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ABSTRACT

To develop a damage threshold for the European red mite (ERM), *Panonychus ulmi* (Koch), the effect of ERM injury on fruit weight and return crop in the apple cultivars (CVs) Golden Delicious and Oregon Spur were studied in the Upper Galilee of Israel for two consecutive seasons. The ERM significantly affected the leaf colour, chlorophyll content, fruit weight and return harvest in both CVs. High population levels of 450 adult female cumulative mite days (ACMDs) reduced the fruit weight on Golden Delicious but not on Oregon Spur. Population levels above approximately 600 and 900 ACMDs in Golden Delicious and Oregon Spur, respectively, caused a substantial reduction in the return harvest. Because no damage was observed at low population levels, an action threshold of 150 ACMDs is recommended.

Key words: European red mite, apple, Golden Delicious, Oregon Spur, *Panonychus ulmi*, mite days, damage threshold, chlorophyll content.

INTRODUCTION

The European red mite (ERM), *Panonychus ulmi* (Koch) (Acari: Tetranychidae), is an important secondary pest in most apple orchards the world over (Blair and Groves, 1952). These mites feed by inserting cheliceral stylets into leaf cells and removing their contents, thereby causing reductions in the leaf chlorophyll content (Lathrop and Hilborn, 1950; Lienk *et al.*, 1956; Zwick *et al.*, 1976) and photosynthetic rates (Campbell and Marini, 1990). These reductions in photosynthates affect both the vegetative and reproductive growth.

The literature abounds with variable reports on the effect of the ERM on apple yields. The fruit set was affected in a few cases (Chapman *et al.*, 1952; Briggs and Avery, 1968; Hardman *et al.*, 1985) but not in another (Beers and Hull, 1990). Significant reductions in the fruit size were demonstrated in a number of studies (Lathrop and Hilborn, 1950; Baker, 1983; Beers and Hull, 1990, Marini *et al.*, 1994), but not in others (Chapman *et al.*, 1952; Lienk *et al.*, 1956; Zwick *et* *al.*, 1976; Ames *et al.*, 1984; Hull and Beers, 1990). Similarly, the return fruit load was decreased in a number of situations (Lienk *et al.*, 1956; Baker, 1983; Beers and Hull, 1990) and unaffected in others (Zwick *et al.*, 1976, Beers *et al.*, 1990). The differences in the above results are probably due to the effects of additional factors, such as tree vigour, cultivar (CV), weather conditions, mode of irrigation and the size and timing of pest infestations.

Approximately 4500 ha of apples are grown in Israel with the CVs Golden Delicious and Starking being the most important (30 and 24%, respectively, of the total area; A. Zur, personal communication). Most (94%) orchards are located in the north. All substantial rain in Israel falls during the dormant season and orchards are regularly irrigated (mostly by drip) during summer. Approximately nine ERM generations occur annually (Shahar, 1985), more than twice the number that develop in temperate zones (Blair and Groves, 1952). The basic biology of this pest in Israel was studied by Shahar (1985), who noted that the phytoseiid mite, *Typhlodromus athiasae* Porath and Swirski, is a major predator. No research has hitherto been conducted in Israel on the impact of ERM injury on fruit yield and quality.

In this paper we report on experiments in which the ERM impact on apple yields was studied. The work was undertaken to provide a basis for the development of action thresholds. Such thresholds would ideally prevent economic damage, reduce the use of acaricides and pave the way for further use of natural enemies.

MATERIALS AND METHODS

Two experiments were conducted on Golden Delicious and Oregon Spur (a major Starking CV in Israel), at two localities in the north of the country. Experiments were replicated six times in a completely randomized block design (plot details in Table 1). At fruit set two trees were selected within each replicate, based upon the estimated uniformity of size and anticipated yield, prior to mite infestation.

ERM populations developed naturally in all plots. In order to achieve discrete mite day treatments of 50, 150, 450 and over 1000 adult female cumulative mite days (ACMDs), each replicate was sprayed with an acaricide (Table 2) as it reached its designated target threshold. We hypothesized that mites would not cause damage to the yield at the first two levels and expected damage at the third

TABLE 1

Plot location, age, season, replicate size (per treatment) and spray method for experiments 1 and 2

Experiment number	Location	Plot age (yr)	Season	Replicate width (m)	Replicate length (m)	Spray method
1	Yiron	7	1992	10	15	Air blast
2	Yiron	8	1993	10	15	Gun sprayer

TABLE 2

Acaricides and insecticides used to control the ERM and predators in experiments 1 and 2

Experiment number	Compound	Common name	Formulation	Active ingredients	Concentration (%)	Manufacturer
1	Abamectin	Vertimec	EC	18 g l^{-1}	0.1	Mercks & Dohme
2	Fenazaquin	Magister	SC	200 g l^{-1}	0.05	Dow Elanco
2	Etofenprox	Sensor	EC	300 g l^{-1}	0.1	Mitsui Toatsu
2	Carbaryl	Sevin	WP	85 g l^{-1}	0.1	Rhone Poulenc
2	Fluvalinate	Mavrik	EC	240 g l^{-1}	0.05	Sandoz

Abamectin and fenazaquin were used as acaricides. Etofenprox, carbaryl and fluvalinate were applied in experiment 2 only, to prevent the development of mite predator populations.
EC–emulsifiable concentrate; SC–suspension concentrate; WP–wettable powder.

and/or fourth levels. Our first level is quite similar to the currently used threshold, which is approximately two mites per leaf. The second level, 150 mite days, is a level often reached when the ERM is controlled by the local predatory mite, *T. athiasae*. The third and fourth levels were chosen to distinguish the differences between CVs and to establish the level at which mites cause damage in the same as well as in the following year. ACMDs, rather than CMDs (cumulative mite days) were used because growers can easily distinguish adult mites but not the small immatures.

Shahar (1985) found that when a stable age distribution was reached by the beginning of June, the female adult population was approximately 29% of all motile stages. This ratio can be used to make a rough transformation from ACMDs to CMDs, as defined by Beers and Hull (1990).

Each experiment was conducted for 2 years. In the first year, mite day treatments were achieved as described. In the second year, mite injury was prevented by simultaneously spraying the entire experimental plot at the two adult female mites per leaf level. This was done to measure the effect of the first year mite day treatments on the yield parameters of the second year (return harvest).

All plots were maintained commercially except for acaricide treatments. Plots were regularly drip irrigated, according to class 'A' pan potential evapotranspiration (ET), adjusted with extension service recommended crop coefficients (Hupert *et al.*, 1991).

The mite densities were estimated weekly from mid-April (hatch of overwintering eggs) until mid-August (at the onset of diapause), when the motile stages disappeared. Ten leaves were sampled randomly from the perimeter of each of two trees (a replicate), collected into a paper bag and transported to the laboratory in a chilled ice chest. The leaf samples were processed through a brushing machine (Leedom Enterprises, Mi-Wuk Village, CA) in the laboratory. Mites were brushed onto glass discs coated with soap paste and counted. The females of the ERM and of *Tetranychus urticae* Koch, the two spotted spider mite (TSSM), along with all motile stages of *T. athiasae*, were recorded.

All fruits were picked from each of the two trees that comprised a replicate and stored at a packing house until sorting. For the year in which mite injury occurred, sample sizes were ≥ 500 fruit. In experiment 2, the fruit drop from the Oregon Spur trees was collected and weighed weekly, commencing 4 weeks prior to harvest. This was not done for the Golden Delicious trees because the fruit drop was insubstantial. Fruit were sorted on an automatic sorting line according to size. The yield data included the number of fruit in each weight class and total yield.

Leaf colour and chlorophyll were assessed at harvest in the second experiment. Twenty leaves were collected randomly and brushed. Two leaf colour measurements (hue angle) of 8 mm in diameter were taken from the upper surface of each leaf, one on either side of the mid vein with a chromameter (model Cr-200, Minolta). For chlorophyll assessment 25 leaves were obtained from each replicate, as previously described. Two 1 cm diameter discs were cut from each leaf (50 discs per treatment per replicate). The discs were placed in 5 ml 80% acetone in darkness for 14 days at 4°C. The concentrations of chlorophyll a and b (mg l^{-1}) were calculated from the absorption values at 645 and 663 nm, respectively (Arnon, 1949) and recorded with a spectrophotometer (Bausch & Lomb Spectronic 1001). To reach the linear range of absorbance all samples were diluted by a factor of 17.66. The total chlorophyll content $(a+b)$ per unit leaf area was calculated as

$$T_{chl}\ (\text{mg m}^{-2}) = (8.02A_{663} + 20.2\ A_{645})[V/(N\pi r^2)]$$

where A_ω is the absorbance at wavelength ω, V is the volume of solvent in litres multiplied by the dilution factor (0.005 l $\times$ 17.66), N is the number of leaf discs and r is the radius of the disc in metres.

The SAS Institute (1992) general linear models procedure (GLM) was used for data analysis. The ACMDs and crop load (in experiment 1) and fruit per tree (in experiment 2) were independent variables in an analysis of covariance intended to determine the effect on fruit weight and return harvest. The separation of the means was by Duncan's multiple range test. Linear regression was used to analyse the ACMD and cultivar effect on leaf colour and chlorophyll. The interaction between the ACMD and cultivar was included in the analysis.

RESULTS

Fruit weight and drop

Discrete ACMD levels were reached for both CVs in experiments 1 and 2 (Figs 1 and 2) by the end of July. The mean fruit weight was reduced in Golden Delicious in both experiments by approximately 6% (10 g) as a result of 573 and 464 ACMDs during 1992 and 1993, respectively (Fig. 2). No reduction in the mean fruit weight was recorded in both experiments at the second ACMD level (300 and 142 ACMDs, respectively). The mean fruit weight was not affected in Oregon Spur in experiment 1 at all ACMD levels. Only in experiment 2, at a

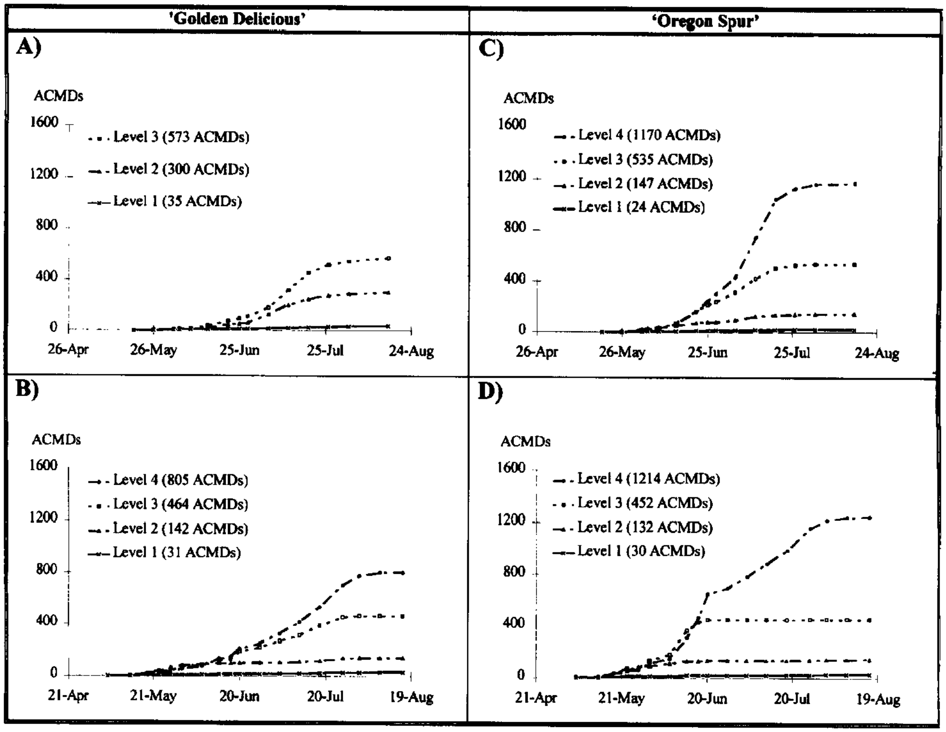

Fig. 1. Seasonal ACMDs. (A) Golden Delicious in experiment 1, (B) Golden Delicious in experiment 2, (C) Oregon Spur in experiment 1 and (D) Oregon Spur in experiment 2.

level of 1214 ACMDs, was there a significant reduction of 22 g in the mean fruit weight along with a significant increase in the fruit drop (Figs 2 and 3).

Return harvest

In experiment 1, when the two lower damage levels 1 and 2 were compared with the two higher levels 3 and 4, both CVs showed significant reductions in the number of fruit per tree at the higher damage levels: 24% in Golden Delicious and 17% in Oregon Spur (Fig. 4A and C). In experiment 2 there was a 48% reduction in the number of fruit per tree in Golden Delicious (Fig. 4B). In Oregon Spur the differences between the treatments were not significant (Fig. 4D). The yields of both CVs, particularly Oregon Spur, were below average in this season, possibly due to the very mild winter and exceedingly high temperatures during blossom.

Leaf colour and chlorophyll

For leaf colour the interaction between the variety and ACMDs was very significant ($p = 0.0005$), meaning that the mite days affected the leaf colour of

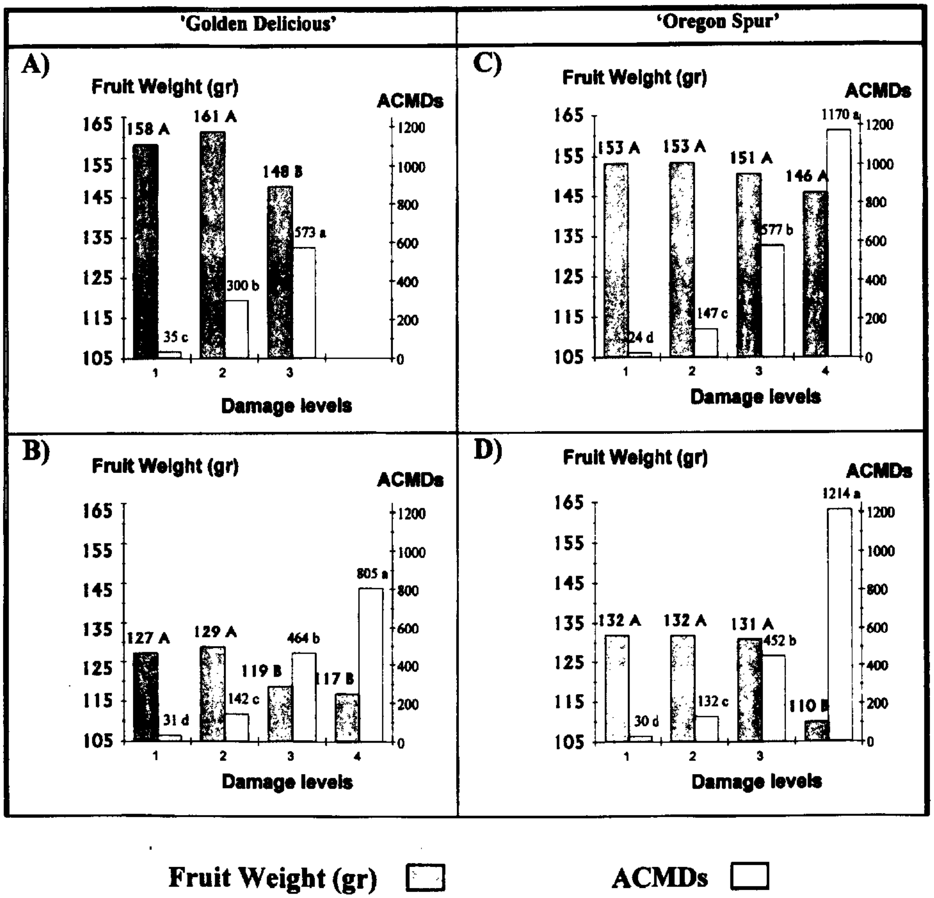

Fig. 2. The effect of the ERM on the mean fruit weight (g) in Golden Delicious and Oregon Spur. (A) Golden Delicious in experiment 1, (B) Golden Delicious in experiment 2, (C) Oregon Spur in experiment 1 and (D) Oregon Spur in experiment 2. Columns with the same letters are not significantly different ($p > 0.05$). Different capital letters indicate the differences in fruit weight, whereas different lowercase letters refer to the differences in ACMDs.

Golden Delicious more than that of Oregon Spur (Fig. 5A and Table 3). For chlorophyll content the same interaction was not significant, whereas the effects of both ACMDs ($p = 0.0001$) and variety ($p = 0.0108$) were very significant (Fig. 5B and Table 3). This indicates that initially there was a higher level of chlorophyll in Oregon Spur than in Golden Delicious but the rate of chlorophyll content decrease, caused by ACMDs, was similar in both CVs.

Other mites

In experiment 1, the predator populations (*T. athiasae* only) remained low (<1) until mid-July, by which time the target levels were attained for the first two

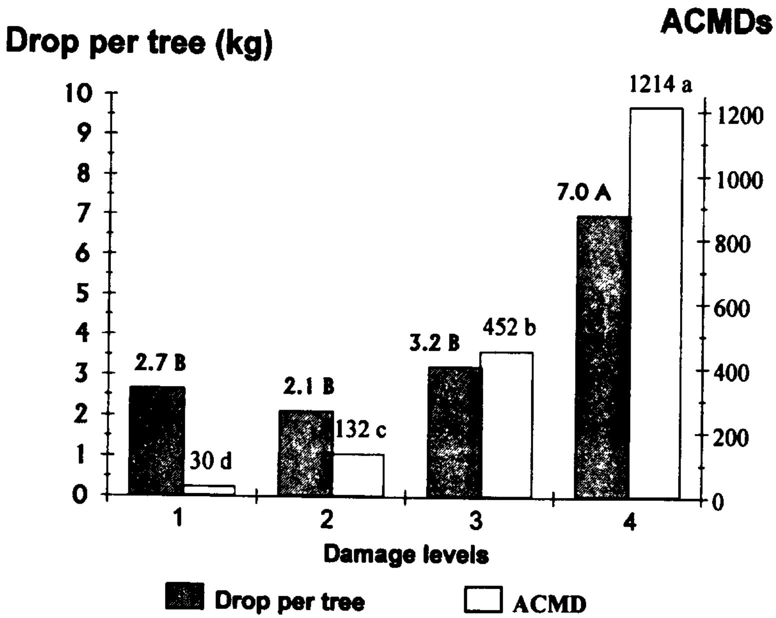

Fig. 3. The effect of the ERM on Oregon Spur fruit drop per tree (kg) in experiment 2. Columns with the same letters are not significantly different ($p > 0.05$). Different capital letters indicate the differences in fruit weight, whereas different lowercase letters refer to the differences in ACMDs.

levels. The third and fourth levels continued to accumulate ACMDs for 1–3 weeks despite the predator populations. In experiment 2, the predator populations were kept low throughout the season with selective insecticides. The TSSM

TABLE 3

Effects of the ERM on leaf colour and total chlorophyll content per unit leaf area, in Golden Delicious and Oregon Spur in experiment 2

		$p > F$			
	Linear regression estimates	Variety	ACMDs	Variety and ACMDs interaction	R^2
Leaf colour (hue in degrees)					
Golden Delicious	$y = 130.83 - 0.0249$ ACMDs	0.3674	0.0001	0.0005	0.94
Oregon Spur	$y = 129.97 - 0.0176$ ACMDs				
Chlorophyll (mg m^{-2})					
Golden Delicious	$y = 406.18 - 0.1675$ ACMDs	0.0107	0.0001	0.2907	0.71
Oregon Spur	$y = 456.90 - 0.1270$ ACMDs				

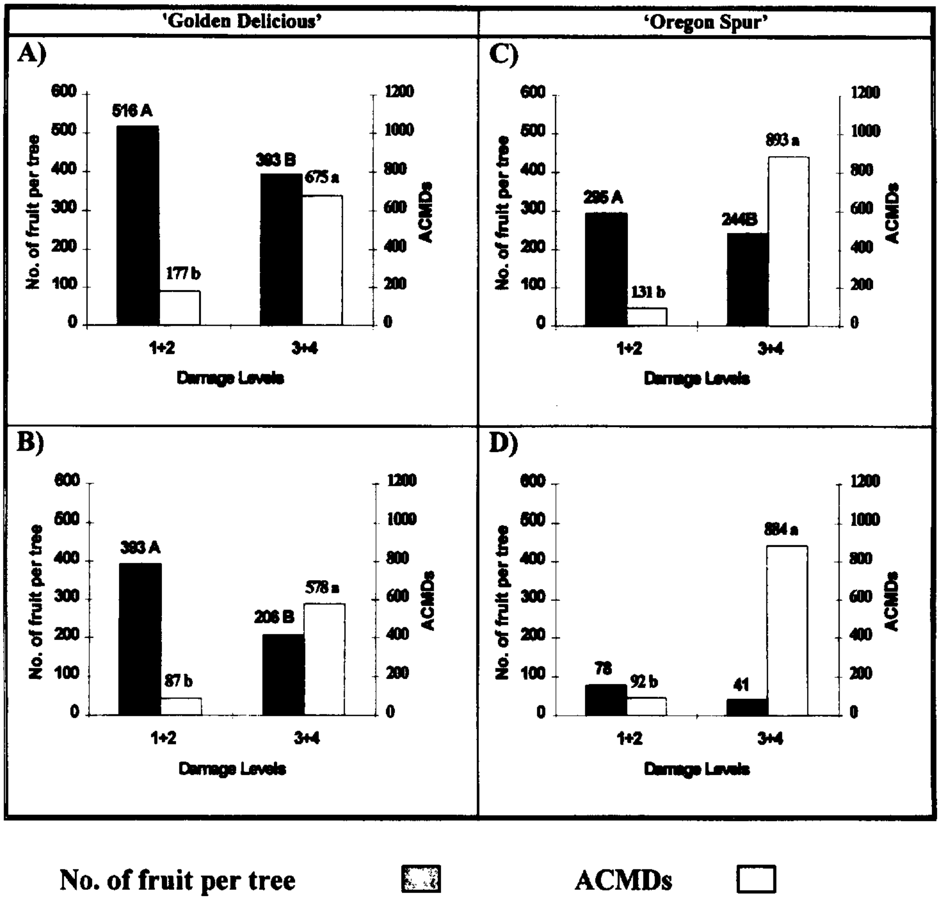

Fig. 4. The effect of the ERM on return harvest (number of fruit per tree). (A) Golden Delicious in experiment 1 in 1993, (B) Golden Delicious in experiment 2 in 1994, (C) Oregon Spur in experiment 1 in 1993 and (D) Oregon Spur in experiment 2 in 1994. Columns with the same letters are not significantly different ($p > 0.05$). Different capital letters indicate the differences in return harvest, whereas different lowercase letters refer to the differences in ACMDs.

populations were very low in both experiments (<1 ACMD in experiment 1 and <35 ACMDs in experiment 2). No other pest mites or predators were observed.

DISCUSSION

Our results indicate that Golden Delicious was more sensitive to ERM damage than Oregon Spur in all four response variables, namely leaf colour, chlorophyll content, fruit size and return harvest in the following year. Several studies have found similar results. Hoyt *et al.* (1979) observed 'a greater tendency for mite

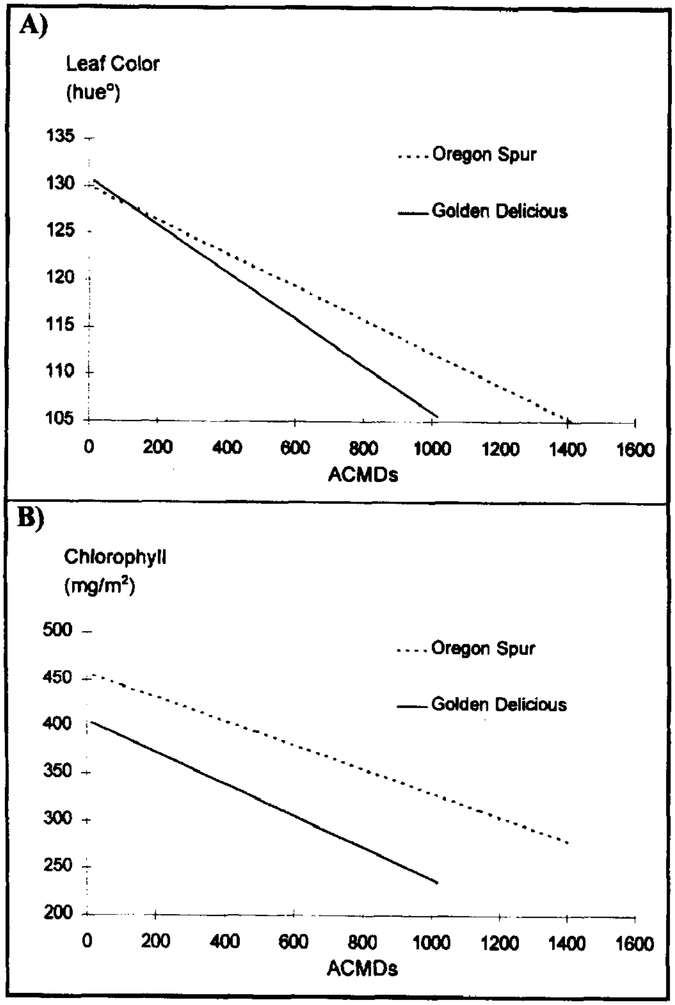

Fig. 5. The effect of the ERM on (A) leaf colour (hue in degrees) and (B) the total chlorophyll content per unit leaf area (mg m^{-2}) in Golden Delicious and Oregon Spur in experiment 2.

populations to develop on Red Delicious but a greater effect of comparable mite populations on Golden Delicious' (note that Red Delicious and Starking are close CVs). Zwick *et al.* (1976), in 2 years of their 4 year study, found significant decreases of 25 and 30% in the leaf chlorophyll content in Golden Delicious, whereas in Newtown (not related to any of the above CVs) it was significantly lowered only in one season, by a mere 2%.

The effects of 0–2000 CMDs on the vegetative growth and flowering in non-bearing, field-grown trees over a 3 year period in the apple CVs Bisbee Delicious, Triple Red Delicious, Golden Delicious and Red Stayman 201 were studied by Beers and Hull (1987). Only the return blooms of the two latter CVs were significantly reduced, while those of the other two were unaffected by injury levels ≤ 2000 CMDs.

In our two experiments the ERM populations peaked in late June and dropped to zero by the beginning of August; the fruit weight and return harvest were both affected. Similar results were obtained by Beers and Hull (1990) in their study on the effect of the timing of ERM injury on blossom and fruit development. In mid-season (mid-June to late-July) ERM injury (1264 CMDs) decreased the fruit size and return crop load.

Hull and Beers (1990) showed that ERM injury had a greater effect on apple trees subjected to moisture stress. Our orchards were regularly irrigated and thus did not suffer any moisture stress, which could explain our relatively low fruit weight reductions in Golden Delicious, despite the high ACMD levels.

Zwick *et al.* (1976) found no significant reductions in the fruit weight despite exceedingly high mite populations (>4100 CMDs on Golden Delicious during 1 year). Their sample of 60 fruit (approximately one-tenth of ours) may have been too small to detect mite damage. We believe that a fairly large sample is needed in order to demonstrate clearly that such damage occurs. The availability of computerized automatic sorters for small operations has made it possible to sort large numbers of fruit (thousands per sample) separately in a short time.

CONCLUSION

Our study showed that the ERM significantly affected the leaf colour, chlorophyll level, fruit size and return harvest in the two important apple CVs grown in Israel, namely Golden Delicious and Starking (represented by the Oregon Spur CV). At the lower damage levels (approximately ≤ 150 ACMDs) there was no reduction in the yield parameters. At the third damage level (approximately 450 ACMDs) only the Golden Delicious fruit weight was significantly decreased by 8 to 10 g per fruit. The ERM impact on leaf colour was greater on Golden Delicious than on Oregon Spur. Reductions in the return fruit load, at the higher damage levels, were substantial for both CVs (in experiment 1). Because no enonomic damage was observed at 150 ACMDs, we advocate the adoption of this level as an economic injury threshold for small-scale validation trials by growers. Its adoption could substantially reduce the use of pesticides without fear of economic damage. This threshold is similar to the one proposed by Hull and Beers (1990) of 750 CMDs (the larger figure is due to the inclusion of all motile stages). The ACMD threshold, as presented, allows the grower to decide to spray only if damage is imminent, in contrast to the frequent spraying currently performed using low mite per leaf thresholds. Applying the first spray in June, instead of mid-May, might significantly improve the efficacy of certain acaricides, such as propargite, which is more effective at higher temperatures (Marshall and Pree, 1993).

The next step in our research is to study how the implementation of the proposed damage threshold will affect acaricide use, pest resistance and predator populations in the main apple CVs in Israel.

ACKNOWLEDGEMENTS

The authors are grateful to the orchardists of the kibbutz farms Malkia and Yiron for their outstanding cooperation, to Smadar Eidlin-Harari for her help in collecting the data, to Avri Zur (regional orchard extension adviser) for horticultural advice and Dr Hilary Voet for her assistance in the statistical analysis. We also appreciate the thorough reviews of the two anonymous reviewers. We thank Uri Schachar and Isaac Dahan (Upper Galilee Agricultural Co.) for their commendable support. This research has been supported by the office of the Chief Scientist of the Department of Agriculture, the Israeli Fruit Board Commission and the apple growers of the Upper Galilee.

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