



【Research report】

華盛頓州中部蘋果園中歐洲葉蟻之空間分布及分散度【研究報告】

Chi-Tung Chen, Lynell K. Tanigoshi and Garrell E. Long

*通訊作者E-mail :

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Abstract

摘要

歐洲葉蟻在“五爪”(Red Delicious) 蘋果樹上的族群分布，被分區為三個高度和三個區域來研究。在6月中旬以前，各期之歐洲葉蟻族群主要棲息在樹高2.3m以下和離樹幹1.3m以內；但在6月下旬以後，卵期和稚齡期之歐洲葉蟻在樹高1.3-2.3m內有較高的族群密度，且有往樹外緣分散的傾向。從6月25日到7月2日，雌成蟲在樹外緣的密度由每葉5.6隻增加到10.5隻。比較Green 係數(Cx)、標準化Morisita 係數(IP) 和變方/平均值(S²/X) 比率對各取樣日各期之歐洲葉蟻族群分散度的計算值發現IP值與族群密度沒有顯著的相關關係，顯示IP值較Cx及S²/X²更適合於測度歐洲葉蟻族群在蘋果樹上的分散度。稚齡期歐洲葉蟻比雌成蟲和卵期較為聚集，且各期族群分散度在蘋果結實期比果實成熟期為高，聚集度隨著族群密度之增加而遞減。Iwao的M-M直線迴歸和Taylor的S² = AXb適合於測度歐洲葉蟻在蘋果生長季的綜合族群分散度(P<0.01)，但不適合用於測度個別取樣目族群之分散度。

Key words:

關鍵詞:

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**SPATIAL DISTRIBUTION AND DISPERSION INDICES
FOR *PANONYCHUS ULMI* (KOCH) (ACARI:
TETRANYCHIDAE) ON APPLE IN
CENTRAL WASHINGTON***

Chi-Tung Chen, Lynell K. Tanigoshi
and Garrell E. Long

*Department of Entomology, Washington State University,
Pullman, WA 99164-6432, USA*

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ABSTRACT

Higher population densities of *Panonychus ulmi* (Koch) life stages were found in the 1.3-2.3 m level above the ground and 0.7-1.3 m zone from the trunk of 'Red Delicious' trees. Respective life stage distribution of females were 38% and 46% in the 1.3-2.3 m vertical level and 0.7-1.3 m horizontal zones on 2 July.

Comparisons among Green's coefficient (C_x), standardized Morisita's coefficient (I_p), and variance/mean (S^2/\bar{X}) ratio showed that I_p was a more suitable indicator of population dispersion for *P. ulmi*. Populations of *P. ulmi* life stages are aggregated on 'Red Delicious' apple trees. I_p indicated that immature mites were more aggregated than were the females and eggs. *P. ulmi* aggregation decreased with increasing population density. Calculation of parameters for Iwao's regression ($M^* = A + B\bar{X}$) and Taylor's power law ($\log_{10} S^2 = \log_{10} A + B \log_{10} \bar{X}$) showed aggregated population dispersion for *P. ulmi* based on pooled data. Both regressions did not significantly fit each sampling data set, but they fit the pooled data.

INTRODUCTION

European red mite, *Panonychus ulmi* (Koch), is a common phytophagous spider mite in western North American tree fruit orchards. A pest management program for mites on apple was implemented in 1965 in Washington (Hoyt, 1969b). Although Hoyt (1969a) reported that *P. ulmi* populations change with type and location of foliage on apple, their movements within the canopy and changes in dispersion have not been quantitatively described. The changing of population density was

* Department of Entomology, Washington State University, Pullman, WA 99164-6432, USA. Scientific Paper No. 0708.

expressed as "spatial distribution" to distinguish it from the "spatial frequency distribution." The latter is concerned with a graphic pattern that will describe the frequency of occurrence for each class of variate.

Misuse of selective organotin acaricides in the Wenatchee River Valley in the past decade has caused European red mite to become increasingly difficult to control in this area. The selectivity of organotin acaricides has resulted in establishment of specifically timed applications amongst growers without regard to mite and predator population densities. Croft *et al.* (1987) pointed out that it was the program's lack of a comprehensive mite evaluation method that instituted selection for Washington populations of European red mite resistant to organotins. Higher rates and multiple applications of acaricides are needed to prevent *P. ulmi* from reaching their economic level. Because their natural enemies, primarily the western predator orchard mite, *Typhlodromus occidentalis* (Nesbitt), can not survive these higher rates, resurgence of *P. ulmi* in apple orchards is common. These facts underscore the importance of a sampling plan for integrated mite management programs cannot operate without accurate estimates of pest population densities.

Spider mites have a more homogeneous distribution within the infested host than among hosts (Sabelis, 1985). Thus between-plant variance has been found greater than within-plant variance for European red mite (Herbert and Butler, 1973). A negative binomial distribution has been fitted to the dispersion pattern of *P. ulmi* on apple by Croft *et al.* (1976), Mowery *et al.* (1980), and Zahner and Baumgaertner (1984) by using the common k or Taylor's power law (Taylor, 1961). Pielou (1960), however, adopted the zero-group of the frequency distribution to demonstrate the negative binomial distribution of *P. ulmi*. Her assumption was that a given proportion of mite-free samples will indicate higher density if the mites are aggregated than it would if they were randomly distributed.

In this study, we chose the three dispersion indices suggested by Myers (1978) to evaluate their correlation with density by Spearman's rank correlation analysis (SAS, 1985a). The spatial distribution and dispersion of *P. ulmi* in apple trees are reported. Three dispersion indices and two regression coefficients were calculated and compared.

MATERIALS AND METHODS

Spatial distribution

Five 'Red Delicious' apple trees were sampled weekly for *P. ulmi* (from 22 May to 2 July) during the 1985 growing season in a commercial orchard in Wenatchee, WA. Leaves of the experimental trees were severely bronzed by mite feeding in early July so that an application of acaricide was applied at which point this study was discontinued.

Each tree was divided into three vertical levels above the ground: below 1.3 m,

1.3-2.3 m, and 2.3-3.3 m; and three horizontal zones radially from the trunk: 0-0.7 m, 0.7-1.3 m, and greater than 1.3 m. Thus, each tree had a total of nine quadrats and was sampled using 5 leaves/quadrat. Sampled leaves of each quadrat were placed in a paper bag and refrigerated in the laboratory until *P. ulmi* were counted under a stereomicroscope. Numbers of females, immatures, and eggs of *P. ulmi* were counted under a stereomicroscope. Numbers of females, immatures, and eggs of *P. ulmi* were recorded for each leaf. Differences in density among quadrats were analyzed using SAS PROC GLM (SAS, 1985b).

Dispersion

Myers (1978) suggested that Green's coefficient (C_x) [$(S^2/\bar{X}-1)/(\sum X-1)$] (Green, 1966), the standardized Morisita's coefficient (I_p) (Smith-Gill, 1975), and the variance/mean ratio (S^2/\bar{X}) were all suitable for describing dispersion of arthropods. Mean and the above indices were calculated for each sampling date using SAS Basics (SAS, 1985a). Iwao's patchiness regression ($\bar{M}_i^* = A + B\bar{X}_i$) (Iwao, 1968), where $\bar{M}_i^* = \bar{X}_i + (S^2_i/\bar{X}_i) - 1$ (Lloyd, 1967),

\bar{M}_i^* = mean crowding per tree i

\bar{X}_i = mean density per tree i

S^2_i = variance per tree,

and Taylor's power law (Taylor, 1961) described as $\text{Log}_{10} S^2 = \log_{10} A + B \cdot \log_{10} \bar{X}$ were generated for each sampling date by SAS PROC GLM (SAS, 1985b).

Three dispersion indices were correlated with densities by Spearman rank correlation analysis using SAS PROC CORR (SAS, 1985a). Each index was transformed by arcsin square root of probability to make the variance independent of density and homogeneous before processing correlation analysis.

RESULTS

Spatial distribution

Hoyt (1969a) reported that six generations of *P. ulmi* are produced per year in central Washington apple orchards. *P. ulmi* completed two generations with the third generation immatures starting to increase at the end of this study. Mean densities in the middle vertical level and in the central horizontal zone tend to be higher than that of other quadrats (Tables 1-2). From 18 June to 2 July, ca. 38% of the female population was found in the middle vertical level of each tree (Table 1). Similar vertical population was found for immature and egg stages. Higher density of immature and egg populations was found in the middle vertical level throughout the sampling period except on 22 May and 18 June for immature stages. Herbert and Butler (1973) reported that the preponderance of *P. ulmi* eggs was within 1-1.3 m above the ground in Nova Scotia. Whereas higher density of eggs was found between 1.3 m and 2.3 m above the ground in the

Table 1. Mean numbers of each life stage of *P. ulmi* per leaf on apple at heights of: 0-1.3, 1.3-2.3, and over 2.3 m

| Date | Female | | | Immature | | | Egg | | |
|---------|--------|---------|------|----------|---------|-------|-------|---------|-------|
| | 0-1.3 | 1.3-2.3 | 2.3- | 0-1.3 | 1.3-2.3 | 2.3- | 0-1.3 | 1.3-2.3 | 2.3- |
| May 22 | 2.8 | 2.0 | 1.0 | 0.3 | 0.0 | 0.0 | 127.6 | 135.2 | 55.6 |
| May 28 | 0.7 | 1.8 | 0.8 | 12.1 | 22.5 | 11.3 | 80.9 | 131.0 | 78.0 |
| June 4 | 1.3 | 1.8 | 0.5 | 30.6 | 34.3 | 15.7 | 51.3 | 52.3 | 23.8 |
| June 11 | 3.1 | 3.6 | 2.4 | 29.8 | 38.9 | 19.0 | 46.3 | 59.6 | 34.3 |
| June 18 | 7.2 | 11.1 | 10.7 | 11.4 | 7.2 | 5.0 | 209.4 | 357.4 | 285.4 |
| June 25 | 4.1 | 6.1 | 5.5 | 83.6 | 130.7 | 74.0 | 275.8 | 444.2 | 377.5 |
| July 2 | 6.9 | 8.2 | 7.1 | 161.3 | 224.8 | 149.3 | 174.3 | 234.2 | 163.8 |

Wenatchee Valley. Hoyt (1969a) reported that equal numbers of mites were found in the peripheral and the central horizontal portions of apple trees in June, but 54% and 62% were found on peripheral foliage in July and August. The proportion of population that occurred in any horizontal zone was less than 54% in this study. Proportion of female population in the middle horizontal zone increased from 32% to 46% from 25 June to 2 July (Table 2) indicating that female *P. ulmi* tended to move to the peripheral foliage later in the season. The horizontal pattern of immature and egg productions does not follow that of female populations. Higher numbers of immature stages occurred in the central horizontal zone from 28 May to 18 June. After 18 June, higher density of immature stages was found in the middle horizontal zone. In Nova Scotia, Herbert and Butler (1973) reported that *P. ulmi* populations tended to distribute densely within 1 m from the periphery. In the Wenatchee Valley, egg densities were higher within 0.7 m radially from the trunk from 28 May to 11 June; on 2 July, 37% of the eggs were in the outer horizontal zone.

Results of general linear analysis indicate that interactions between data and

Table 2. Mean numbers of each life stage of *P. ulmi* per leaf on apple at horizontal distances from the trunk of: 0-0.7, 0.7-1.3, and over 1.3 m

| Date | Female | | | Immature | | | Egg | | |
|---------|--------|---------|------|----------|---------|-------|-------|---------|-------|
| | 0-0.7 | 0.7-1.3 | 1.3- | 0-0.7 | 0.7-1.3 | 1.3- | 0-0.7 | 0.7-1.3 | 1.3- |
| May 22 | 2.0 | 2.0 | 1.7 | 0.0 | 0.2 | 0.1 | 111.3 | 116.5 | 90.2 |
| May 28 | 1.2 | 1.2 | 0.9 | 21.9 | 11.6 | 12.5 | 107.3 | 89.1 | 95.7 |
| June 4 | 1.7 | 1.2 | 0.7 | 31.7 | 25.3 | 23.7 | 46.7 | 38.2 | 43.2 |
| June 11 | 2.7 | 3.9 | 2.4 | 37.9 | 28.1 | 21.2 | 58.3 | 49.3 | 31.4 |
| June 18 | 8.9 | 11.0 | 9.0 | 10.7 | 8.9 | 3.4 | 300.3 | 313.7 | 236.9 |
| June 25 | 4.7 | 5.5 | 5.6 | 93.4 | 108.6 | 87.8 | 318.4 | 403.2 | 383.6 |
| July 2 | 5.6 | 6.6 | 10.5 | 167.9 | 201.2 | 168.0 | 161.5 | 202.8 | 214.1 |

Table 3. Results of linear analysis for *P. ulmi* populations within an apple tree

| Source of variance | d. f. | Female | | Immature | | Egg | |
|--------------------|-------|---------|-------------------|----------|---------|---------|--------|
| | | F-value | PR>F ^a | F-value | PR>F | F-value | PR>F |
| Trees (T) | 4 | 17.41 | 0.0001 | 16.90 | 0.0001 | 15.92 | 0.0001 |
| Dates (D) | 6 | 78.25 | 0.0001 | 214.11 | 0.0001 | 130.86 | 0.0001 |
| Heights (H) | 2 | 6.29 | 0.0019 | 23.02 | 0.0001 | 24.47 | 0.0001 |
| Zones (Z) | 2 | 2.08 | 0.1257 | 3.99 | 0.0187 | 2.16 | 0.0739 |
| D * H | 12 | 2.01 | 0.0206 | 4.55 | 0.0001 | 3.83 | 0.0001 |
| D * Z | 12 | 3.12 | 0.1002 | 1.43 | 0.1474 | 1.90 | 0.0305 |
| H * Z | 4 | 2.76 | 0.0266 | 3.08 | 0.0154 | 2.92 | 0.0204 |
| D * H * Z | 24 | 1.14 | 0.2859 | 0.96 | 0.5234 | 0.97 | 0.4997 |
| Residual | 1320 | 10.03 | 0.0001 | 23.49 | 0.00011 | 5.57 | 0.0001 |

^a Small significance probability indicates that F-value of the parameter is significantly different from zero.

height, date and zone, and height and zone were significant for female and egg life stages (Table 3). No significant interaction between date and zone was found for the immature stages. Significant interaction indicates that the variation of population densities of female and egg stages among horizontal zones changed over time. For all life stages, significant tree effects indicate that significant variation of population density exists among trees. Significant differences among trees imply that patchy infestations of *P. ulmi* exist in orchards.

Dispersion

A population is considered aggregated with $S^2/\bar{X} > 1$, random when $S^2/\bar{X} = 1$, and uniform when $S^2/\bar{X} < 1$ (Southwood, 1978). The variance/mean ratio always remained above 1.0 suggesting aggregation for all life stages (Table 4). However, it is impossible to interpret degree of aggregation because S^2/\bar{X} ratios have no upper limit. Great variation for variance/mean ratios occurred after mid-June for all life stages and on 22 May for eggs. The variance/mean ratios were consistently greater than 1 for all life stages and they tended to increase with density.

Most values of Green's coefficient (C_x) were slightly greater than 0 except immature stages which were highly aggregated early in the season. Higher values of C_x occurred early in the season. Green's coefficient varies from -1 to +1, with uniform ca. -1, random 0, and aggregated ca. 1 (Green 1966). The standardized Morisita's index (I_p) ranges from -1 to +1 with $I_p > 0.5$ for clumped distribution, $I_p < -0.5$ for uniform, and random for $-0.5 < I_p < +0.5$ (Smith-Gill, 1975). The values of I_p ranged from 0.517 to 0.824, indicating that all life stages of *P. ulmi* have an aggregated distribution on apple throughout the sampling period.

Table 4. Dispersion indices for certain *P. ulmi* life stages on apple during 1985

| Date | \bar{X} | S^2 | S^2/\bar{X} | C_x | I_p |
|----------|-----------|--------|---------------|-------|-------|
| Female | | | | | |
| 22 May | 1.9 | 6.28 | 3.31 | 0.009 | 0.524 |
| 28 May | 1.1 | 3.28 | 2.99 | 0.011 | 0.527 |
| 4 June | 1.2 | 4.97 | 4.09 | 0.012 | 0.525 |
| 11 June | 3.0 | 11.91 | 3.93 | 0.005 | 0.519 |
| 18 June | 9.7 | 124.60 | 12.89 | 0.006 | 0.523 |
| 25 June | 5.2 | 19.90 | 3.81 | 0.003 | 0.518 |
| 2 July | 7.4 | 35.10 | 4.74 | 0.002 | 0.515 |
| Immature | | | | | |
| 22 May | 0.1 | 6 | 5.54 | 0.300 | 0.824 |
| 28 May | 15.6 | 1135 | 73.49 | 0.027 | 0.761 |
| 4 June | 27.0 | 1279 | 47.34 | 0.008 | 0.758 |
| 11 June | 29.5 | 1375 | 46.69 | 0.007 | 0.758 |
| 18 June | 7.9 | 249 | 31.55 | 0.018 | 0.765 |
| 25 June | 97.1 | 10019 | 103.24 | 0.005 | 0.756 |
| 2 July | 175.5 | 14942 | 83.23 | 0.002 | 0.755 |
| Egg | | | | | |
| 22 May | 105.9 | 18061 | 170.48 | 0.011 | 0.526 |
| 28 May | 97.4 | 13471 | 138.28 | 0.008 | 0.520 |
| 4 June | 42.7 | 3011 | 70.54 | 0.008 | 0.522 |
| 11 June | 47.0 | 3141 | 66.81 | 0.007 | 0.520 |
| 18 June | 285.8 | 60750 | 212.57 | 0.003 | 0.517 |
| 25 June | 367.6 | 66506 | 180.91 | 0.002 | 0.517 |
| 2 July | 191.8 | 20483 | 106.81 | 0.003 | 0.517 |

Higher values of I_p (more aggregated) occurred for immature stages as compared with the other two stages. This agreed in general with the results of C_x . *P. ulmi* populations tended to be more clumped earlier in the season. Similar patterns of dispersion occurred for aphids on strawberries (Trumble *et al.*, 1984).

Results show that standardized Morisita's coefficient (I_p) is not significantly correlated with density for all stages (Table 5). I_p is a better index for estimating the dispersion patterns of *P. ulmi* population on apple trees in this study.

Iwao's regression and Taylor's power law coefficients significantly fit 15 and 16 of 21 data sets with 5 and 6 slopes significantly greater than 1, respectively (Table 6). The intercept, (A) of the simple linear regression, $\bar{M} = A + B\bar{X}$ was defined by Iwao (1968) as the "index of basic contagion." It indicates whether a single individual or a group of individuals is the basic component of population distribution. The slope, (B) was defined as a "density-contagiousness coefficient"

Table 5. Correlation coefficients between mean density per leaf and dispersion indices for *P. ulmi* on apple

| Stage | N^a | C_x | S^2/\bar{X} | I_p |
|----------|-------|--------------------|-------------------|-------|
| Female | 7 | -0.67 | 0.81 ^b | -0.53 |
| Immature | 7 | -0.47 | 0.66 | -0.44 |
| Egg | 7 | -0.85 ^b | 0.75 | -0.67 |

^a Number of data points, each point consists of 3-5 trees.

^b Significant at $p < 0.05$.

 Table 6. Parameters of Iwao's regression ($\bar{M} = A + B\bar{X}$) and Taylor's regression ($\log_{10} S^2 = \log_{10} A + B \log_{10} \bar{X}$) for *P. ulmi* on apple during 1985

| Date | N^a | Iwao's regression | | | Taylor's regression | |
|----------|-------|-------------------|--------|--------|---------------------|--------|
| | | Intercept | Slope | r^2 | Slope | r^2 |
| Female | | | | | | |
| 22 May | 4 | 1.02 | 1.42 | 0.98** | 1.30 | 0.99** |
| 28 May | 5 | 0.57 | 1.96 | 0.68 | 1.42 | 0.86** |
| 4 June | 5 | -0.41 | 3.66 | 0.64 | 1.78 | 0.70 |
| 11 June | 5 | -0.71 | 2.07 | 0.91** | 1.89 | 0.86** |
| 18 June | 5 | 1.00 | 1.62* | 0.99** | 1.71** | 0.99** |
| 25 June | 5 | 0.70 | 1.34 | 0.87* | 1.65 | 0.86* |
| 2 July | 5 | 3.99 | 0.92 | 0.76 | 0.94 | 0.47 |
| Immature | | | | | | |
| 22 May | 3 | -1.08 | 20.89 | 0.97 | 1.80 | 0.95 |
| 28 May | 5 | -17.80 | 5.12* | 0.89* | 21.16* | 0.97 |
| 4 June | 5 | 2.52 | 2.34 | 0.76 | 2.18 | 0.84 |
| 11 June | 5 | 9.57 | 1.86** | 0.99** | 1.71** | 0.99 |
| 18 June | 5 | 2.46 | 2.72* | 0.96** | 2.06 | 0.95** |
| 25 June | 5 | 4.27 | 1.87 | 0.89* | 1.97 | 0.91* |
| 2 July | 5 | 61.60 | 1.09 | 0.87* | 1.22 | 0.70 |
| Egg | | | | | | |
| 22 May | 4 | 28.53 | 2.01 | 0.95* | 1.72 | 0.93* |
| 28 May | 5 | 45.32 | 1.69 | 0.91* | 1.54 | 0.83* |
| 4 June | 5 | 10.87 | 1.93 | 0.93** | 1.99 | 0.93** |
| 11 June | 5 | -7.50 | 2.23* | 0.96** | 2.23* | 0.95** |
| 18 June | 5 | -94.96 | 1.90* | 0.95** | 2.67* | 0.95** |
| 25 June | 5 | 237.67 | 0.84 | 0.64 | 0.63 | 0.22 |
| 2 July | 5 | -56.00 | 1.79 | 0.93** | 2.48 | 0.84* |

^a Number of data points, each point consists of average of 45 pooled leaves.

that described how population components are dispersed in the habitat at different densities (Iwao, 1968). Dispersion is aggregated if B is significantly greater than 1. Although Iwao's and Taylor's regressions significantly fit 15 and 16 of 21 data sets, the low number of data points (3-5) in this study could cause statistical bias of the conclusions. The lower number of data points may also account for the disagreement between results of Iwao's and Taylor's regressions and that of dispersion indices throughout the sampling season.

Results of regression of pooled life stage data for each date are shown in Figs. 1 and 2. All slopes of both regressions are significantly greater than 1. Because substantial changes in dispersion occurred during the season, the regression values based on data pooled over the season would not provide biologically accurate information for the within-field distribution.

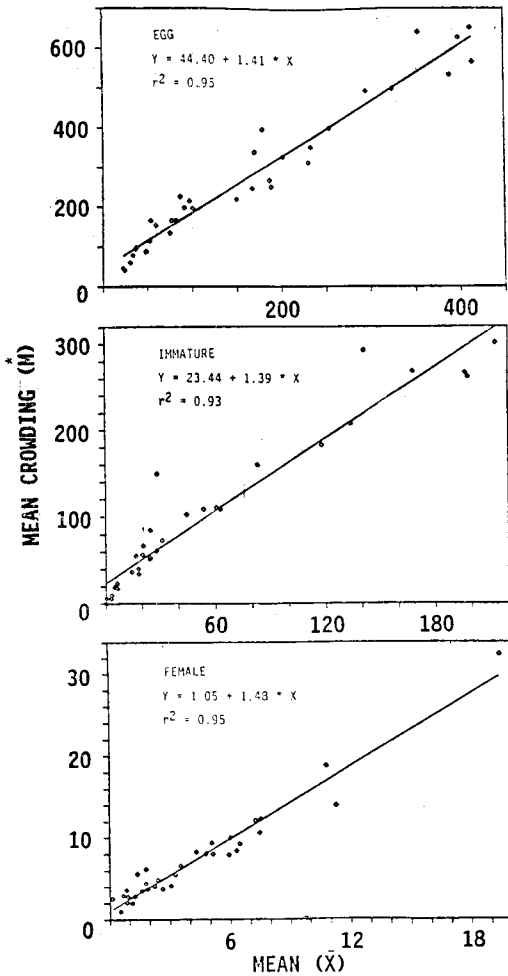


Fig. 1. Mean crowding (M^*)—mean (\bar{X}) relationship for *P. ulmi* on apple.

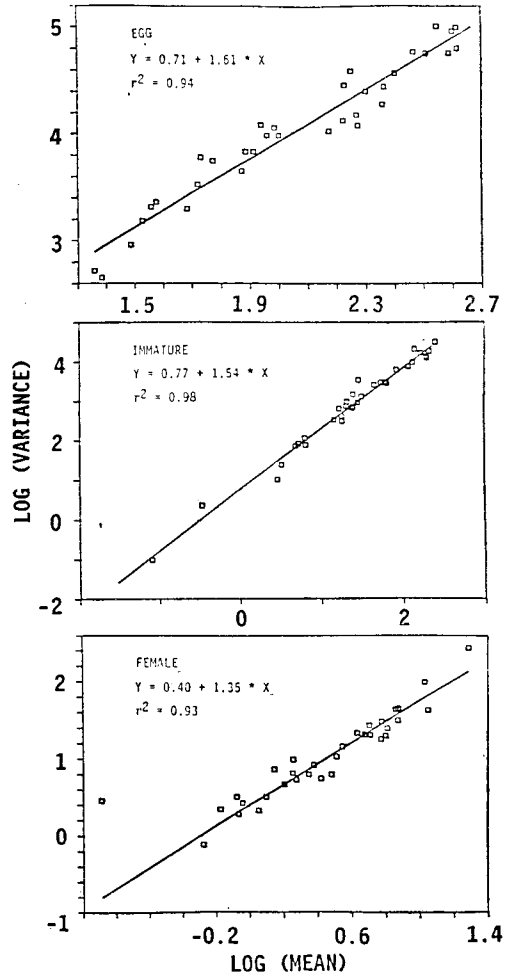


Fig. 2. Variance (S^2)—Mean (\bar{X}) relationship for *P. ulmi* on apple.

DISCUSSION

Spatial distribution

Although predation by *T. occidentalis* and stigmatid mite *Zetzellia mali* (Ewing) may reduce densities of *P. ulmi* on apple in central Washington (Hoyt, 1969a), few predators were found in this study. Other biological factors such as intraspecific competition (Putman and Herne, 1966), interspecific competition with apple rust mite, *Aculus schlectendali* (Nalepa), (Croft and Hoying, 1977) or McDaniel spider mite, *Tetranychus mcdanieli* McGregor, (Hoyt, 1969a; Tanigoshi *et al.*, 1979) may account for population changes and variation of spatial distribution of *P. ulmi* on apple. In Michigan the competitive superiority of apple rust mite over *P. ulmi* was demonstrated in field and laboratory experiments (Croft 1975; Croft and Hoying, 1977). However, Hoyt (1969a) stated that the competitive superiority of apple rust mite over *P. ulmi* would be reduced by the greater tendency of *P. ulmi* to inhabit the upper surface of leaves. The competitive relationship between *P. ulmi* and *T. mcdanieli* was less conclusively studied than between *P. ulmi* and apple rust mite; however Hoyt (1969a) reported that competition occurred in certain quadrats based on the population dynamics of these two species.

It has been suggested that the profuse webbing produced by high densities of the two spotted spider mite, *Tetranychus urticae* (Koch) will trap *P. ulmi* and reduce their ovipositional sites (Foott, 1963). *T. mcdanieli* also produces webbing at high densities. Because adult females of *T. mcdanieli* overwinter primarily under bark scale on the trunk, they were observed to occur in the lower inner area of the tree. Consequently, interspecific competition between *T. mcdanieli* and *P. ulmi* may partially account for the lower densities of *P. ulmi* in lower inner quadrats late in the season. However, interspecific competition between *P. ulmi* and *T. mcdanieli* may not totally explain the outward movement of *P. ulmi* in apple. First, the densities of *P. ulmi* immatures and eggs were still high in the central quadrats, although 87% of *T. mcdanieli* could be in these areas in mid-June (Hoyt, 1969a). Hoyt (1969a) stated that *T. mcdanieli* tended to move up into the inner portion of the tree as density increased and may increase competitive pressure on *P. ulmi* in central quadrats. Results in the present study indicate that there are no significant differences between *P. ulmi* densities in central and peripheral quadrats. Tanigoshi (1975) reported that the distribution of *T. mcdanieli* rapidly changed from a uniform pattern to a highly aggregated one as their mite density increased on potted apple trees. Therefore, the higher *T. mcdanieli* density may show a more aggregated distribution in the tree so that interspecific competition with *P. ulmi* would be relatively reduced. Secondly, *P. ulmi* females were observed to begin dispersing in late June in this study, this radial movement of *P. ulmi* could be a natural dispersal behavior of population rather than a result of interspecific competition. A dispersal behavior may be involved in the variation of dispersion patterns over time. Near the end of this study, leaves were bronzed

by mite feeding. The shortage of food resources may affect dispersal behavior instead of interspecific competition with *T. mcdanieli*. Temperature, light and humidity are known to influence the ability and tendency of *T. urticae* and *Phyto-seiulus persimilis* A.-H. to disperse (Sabelis, 1981).

Dispersion

Taylor (1984) summarized six attributes of the "perfect coefficient" to measure "degree of nonrandomness." One of these attributes is that the coefficient should be uninfluenced by variation in sample size, sample number, and density. Myers (1978) has evaluated the relationship between density and commonly used indices by using a simulation model to generate patterns of egg dispersion. She found that Green's coefficient (C_X) and standardized Morisita's coefficient (I_p) were not influenced by population density, while variance/mean ratio was weakly correlated with density. There is no coefficient which is best for all possible cases where a measure of population is desired. Variance/mean ratio is easier to compute and understand, but it does not have limits on its values that make it possible to interpret the degree of aggregated dispersion pattern.

Downing (1986) found that the range and size of B values in Taylor's regression vary with number of samples taken and the range of means considered. He also pointed out that the dissimilarity of B within species is common because spatial heterogeneity varies significantly among environments. Therefore, a B value based on pooled data from one location should not be used to evaluate dispersion pattern that changes with time and location. The B value should vary with time as do environmental changes that result in heterogeneous distributions for the same species. Ito and Kitching (1986) showed that a plot of $\log S^2$ on $\log \bar{X}$ is likely to be linear because of the great linear power of log-log plots. If interpretation is restricted to linearized plots, meaningful changes in dispersion pattern will be overlooked as density changes.

The standardized Morisita's coefficient seems to be the best one to evaluate dispersion pattern of *P. ulmi* populations that change with time. However, the value of the index may vary with different *P. ulmi* populations at different locations. We suggest that more than one index be calculated and compared rather than deciding on one to draw conclusions about the population dispersion of *P. ulmi*.

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華盛頓州中部蘋果園中歐洲葉蟎之空間分布及分散度

Chi-Tung Chen, Lynell K. Tanigoshi and Garrell E. Long

華盛頓州立大學昆蟲學系

歐洲葉蟎在“五爪”(Red Delicious) 蘋果樹上的族羣分布，被分區為三個高度和三個區域來研究。在6月中旬以前，各期之歐洲葉蟎族羣主要棲息在樹高 2.3 m 以下和離樹幹 1.3 m 以內；但在6月下旬以後，卵期和稚齡期之歐洲葉蟎在樹高 1.3~2.3 m 內有較高的族羣密度，且有往樹外緣分散的傾向。從6月25日到7月2日，雌成蟲在樹外緣的密度由每葉 5.6 隻增加到 10.5 隻。

比較 Green 係數 (C_x)、標準化 Morisita 係數 (I_b) 和變方/平均值 (S^2/\bar{X}) 比率對各取樣日各期之歐洲葉蟎族羣分散度的計算值發現 I_b 值與族羣密度沒有顯著的相關關係，顯示 I_b 值較 C_x 及 S^2/\bar{X}^2 更適合於測度歐洲葉蟎族羣在蘋果樹上的分散度。稚齡期歐洲葉蟎比雌成蟲和卵期較為聚集，且各期族羣分散度在蘋果結實期比果實成熟期為高，聚集度隨着族羣密度之增加而遞減。

Iwao 的 $\bar{M}^* - M$ 直線迴歸和 Taylor 的 $S^2 = A\bar{X}^b$ 適合於測度歐洲葉蟎在蘋果生長季的綜合族羣分散度 ($p < 0.01$)，但不適合用於測度個別取樣目族羣之分散度。