Israel Journal of Entomology Vol. IV, 1969

THE ECONOMIC THRESHOLD AND TREATMENT FORECAST FOR THE CALIFORNIA RED SCALE (AONIDIELLA AURANTH MASK) IN CITRUS GROVES IN ISRAEL *

by

A. Grunberg**

ABSTRACT

The ecological conditions prevailing in citrus groves in Israel restrict the California red scale population until mid-summer. Climatic changes (mainly the cessation of dry desert winds) and a decisive drop in the activities of specific natural enemies in July and a marked increase in the use of insecticides applied from the air or ground at low or ultra low volumes (creating drift conditions), explain the predictable increase in summer. A definable correlation seems to exist between foliage and fruit injestation, once this correlation is known and the value of the economic threshold is established, forecast data on the necessity of chemical control can be supplied.

The determination of an economic threshold or economic injury level ("the level at which damage can no longer be tolerated" ref. - 5, p. 210) is of great importance the entomologist relying on the integrated control concept.

Low populations may tend to decline further due to adverse climatic and accidental factors, competitive displacement, non-specific entomophagous fac- tors, etc, and consequently chemical control against pest species with low population densities or pronounced declining tendencies may not be desirable. On the other hand, heavy populations are hard to control by chemicals; many individuals may survive due to conditions created by dense populations, as e.g. scale incrustation, increased genetic variability etc. Consequently when trying to fix an economic threshold, the dynamics of the injurious population is to be considered as well as that of its natural enemies. Proper timing of application is an integral part of the system.

In view of this there are several criteria concerning the economic threshold when chemical interference is contemplated. The most unsophisticated would be the purely economic approach, namely control expenses should be significantly lower than the expected loss of income from the crop due to the pest in question. However in this case no regard is taken of possible side effects of the proposed insecticidal treatment, such as its effect on non-target organisms. As time passes it becomes very difficult to ascertain whether an outbreak of certain mites or aphids, etc., is connected with a chemical which was previously applied against an insect pest - and the cost-reward relation may thus be wrongly interpreted.

A different approach to economic threshold is based on ecological considerations. Reviewing the multitude of variables involved in an ecosystem, such as a highly cultivated agricultural land, it seems quite logical to select the most important factors, to include them into "units of component functions" (5) and to try to evaluate their respective status relating to the economic threshold.

The different variables in this case may be subdivided into three groups: (a) abiotic factors, (b) natural enemies and (c) insecticidal drift and residues - all being closely connected with the red scale population explosion which starts around August. That such an explosion of red scale population actually takes place is illustrated by tables 1 and 2.

Table 1 - Fluctuation of population densities of the California red scale (females of second stage and above) on leaves of citrus, (Hulata, untreated grove) (Collecting and examination of leaves carried out by J. Heker of Hulata Kibbutz).

Date of examination	Live scales per 450 leaves	Scale distribution per plot	Average No. live scales per leaf	Scale distribution on the tree
13. V. 64	32	A - 0 B - 0 C - 32	0.07	Infestation focus: inside of the tree, at medium height
16. VI. 64	98	A - 0 B - 50 C - 48	0.21	Homogenous dispersion at lower and medium heights; the upper part not infested
10. VII. 64	74	A - 0 B - 16 C - 58	0.16	Trend of larval migration to the lower parts of the trees
17. VIII. 64	628	A - 64 B - 240 C - 324	1.39	Population levels high inside the trees and at lower parts
17. IX. 64	972	A - 42 B - 439 C - 491	2.16	" " "
15. X. 64	1142	A - 129 B - 691 C - 322	2.53	" " "
16. XI. 64				Incrustations;
15. XII. 64				exact counting
25. I. 65				very difficult

Table 2 - Population explosion of California red scale (females of second stage and above) on citrus fruit late in summer

Locality	Citrus sp.	Population densities: Date of first examination	Avg. No. live scales/ fruit	Date of second examination	Avg. No. live scales/ fruit	Rate of increase
Gan Yavne	Lemon	1. VIII. 65	1.1	30. IX. 65	7.7	7
Kefar Warburg	Valencia	20. VII. 66	0.62	10. IX. 66	7.9	10.2
Kastina	Jaffa	early Sept. 67	8.15	early Nov. 67	40.6	4.9
Ramat David	Washington Navel	15. VII. 68	3.05	7. IX. 68	36.87	12.08

Remark: Contrary to the phenomena illustrated in Tables 1 and 2, the red scale population on trunks and branches displayed a kind of stability during the long summer months; however, it tends to increase during the cooler months.

a) Abiotic factors and population explosion of red scale.

A relative humidity of 70-75% combined with temperatures between 25 and 28°C are considered optimal for red scale development. Deviations from the optima have an unfavorable influence on the number of red scale offspring (6). Such deviations during summer are created by "sharav" conditions combining two extremes: highest temperatures with lowest humidities. In his "Animal Life of Palestine" Bodenheimer remarked, "Very many insects show enormous mortality of the early and most sensitive stages of development" - which occur during a sharav (3). Referring specifically to Aonidiella aurantii he stated that "Red scale population ebb always occurs in April-July" (4). However, this is exactly the period when sharavs are very frequent and unquestionably contribute to the population's ebb by decimating the young age groups. These age groups are especially abundant on fruits in the early summer, - since the red scale population there is not built up at that period through reproduction but mainly due to continuous migration of crawlers from other parts of the tree. After the April - June period the sharav spells gradually cease; temperatures are high and so are macro and microhumidities in the irrigated groves. Climatic obstacles no longer hinder the high reproductive potential of the scale. When the sharav winds return late in autumn, they face a strong, overlapping red scale population, with a high percentage of mature forms, much less sensitive to climatic extremes.

There may be other pertinent climatic factors responsible for the high rate of red scale reproduction during August-October such as photoperiod - prominent in many Homoptera, climate and sex ratio, but little is known about these phenomena in coccids.

b) The decline in activity of natural enemies and its effect on population explosion of red scale.

The examination of the natural enemies complex can be approached by means of a conceptual device originating in systems analysis (5). In this context the term "black box" will then comprise the activities of groups of natural enemies - the final effect of which on red scale epidemiology is known - without full knowledge or understanding of separate components and their interaction. Thus it is possible to claim that the activity of entomophagous fauna is definitely declining in the second half of the summer and is no more in a position to curb the red scale population (as proved by its explosion). The large number of Arthropods having a marked influence on the economic level of A. aurantii can be subdivided into three aetiologically unequal groups: a) Coccinellidae (mainly Chilocorus bipustulatus L.); b) parasitic Hymenoptera; and to a certain degree c) predatory mites.

The combined action of these various entomophaga may reduce the injurious red scale population at certain periods to very low economic levels; unfortunately, there is no synchronization between the population ebb and the fruit picking season, and the closer we come to harvest and shipping time the heavier the scale's population.

c) Drift and residues.

In a review of factors involved in the rebuilding of the red scale population late in summer, the persistent insecticidal drifts and toxic residues cannot be omitted. With the advance of summer, several polyphagous insects, very injurious to Israeli agriculture, appear at very high population levels, and require repeated chemical control. E.g., the Mediterranean fruit fly; the Noctuidae, some specific cotton pests; orchard pests and many others. The increase in pest populations is followed by extensive use of pesticides mostly applied from the air or as low- or ultra low-volume treatments, which cause drift over adjacent agricultural land. As citrus plantations are not limited to definite areas in Israel but intermingle with other agricultural crops, they are exposed to the above mentioned conditions. The implications are well known (1, 8): the adult populations of parasites and predators are drastically reduced either by direct contact or by drift and residues; their reestablishment after dissipation of toxic residues is slow (2). Thus one more serious obstacle to the spread of the red scale is removed.

Host and pest phenology

There are considerable differences in the mortality of each physiological age of scales, and consequently the age composition of red scale populations determines its economic danger. The effectiveness of control measures is also strongly influenced by the age composition, due to differences in the susceptibility of various developmental stages to insecticides.

At setting, the fruit is obviously free from sacles; later, two phases occur in red scale migration to the fruit. The first takes place immediately after fruit setting, with the crawlers apparently migrating from branches to fruits, by-passing the leaves. (This period - April-May - is characterized by significant defoliation, which reduces the total red scale population). The extent of damage to fruit at this phase may be considerable, causing pitting of the rind and thus precluding the affected fruit from export; it is obviously connected with over-wintering population levels, and should be taken care of accordingly. However, from the point of view of population dynamics, this phase seems to be of limited importance, considering the specific age group found at this period on the fruits, and its high mortality. The next phase in fruit infestation is connected with the red scale population explosion on leaves and its subsequent migration to fruits, and to a lesser degree due to the development of survivors on fruits. It is usually this second phase that affects the crop.

Fixation of economic threshold

Climatic, ecological and cultural factors, combined, explain the red scale population explosion on leaves and fruits late in the summer, with July being the turning point. It has been found empirically that a definable correlation exists between the level of infestation on leaves and on fruits; thus examination of leaves in July or later may give a reasonably accurate indication of the extent of fruit damage in terms of cull percentage due to red scale, in the harvesting season. Correlation values (categories) have been found in several instances.

Methods of work

Small plots of untreated citrus trees (Jaffa - orange, lemon, Valencia orange, grapefruit and Washington Navel orange), displaying various degress of A. aurantii infestation, were marked at the beginning of summer. The plots were distributed over the main citrus cultivating areas, with observations repeated during the years 1964-1968.

Subsequently, leaves from the marked trees within the plots were collected*, and examined, and the number of live female scale of second instar and above was recorded ("average live scales per leaf"). During the harvesting season, fruits from marked trees were picked, the number of scales upon them was counted, and the fruit was then graded according to standards of the Israeli Ministry of Agriculture for export fruit. According to these standards, only fruit with less than ten scales per fruit are fit for export; fruits with 10-20 scales are usually assigned to the local market and fruit with over 20 scales are assigned to industrial use ("cull"). Each examined sample usually consisted of no less than 600 or 700 fruits and in some cases even more (up to 2, 000).

The results are summarized in Figs. 1 and 2.

---

* The otherwise random foliage sampling excluded young and yellowing leaves; the first may not have chance to get infested and the latter are not attractive to crawlers and tend to drop.

Unlike Fig. 1, the data compiled in Fig. 2 pertain to one single grove at Bet Dagan. This grove was selected for its relatively low red scale population level (as opposed to the heavily infested trees in the previous observation plots). The grove was subdivided into several portions - each consisting of 6-10 observation units. The number of examined fruits per unit at harvest amounted to about one hundred - the average of a portion (sample) consisted of 500-600 fruits or more. Leaf examination was carried out on 15. VII. 68, and fruit picking and grading on 9. II. 69.

Standard of economic threshold

The proposed value for economic threshold, equivalent to 10% culls, is based on the assumption that expenses for spraying against the California red scale amount to approximately 30 IL per duname (1000 m^2) - and the difference in price between export fruit and cull is about 135 IL. per ton or 1.35% (7). In a good commercial grove (yield of 4 tons/dunam), an increase of 5% in exportable fruit gained through spraying may cover the expenses. In younger plantations or less profitable groves, the economic level expressed in terms of cull percentage will tend to increase.

As a rule, economic threshold levels may change with changing marketing conditions, control techniques, the ability of the host to compensate for insect attack, end use of the agricultural product, etc.

Discussion and conclusions

Examination of data in Fig. 1 and 2.

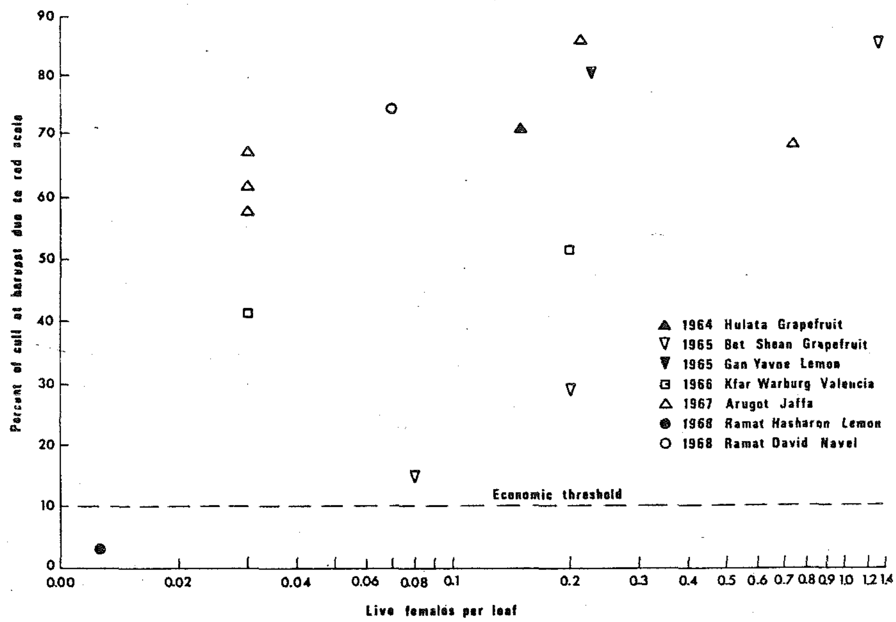

Fig. 1 - Correlation between leaf infestation due to Red Scale and cull percentage (different localities and Citrus varieties).

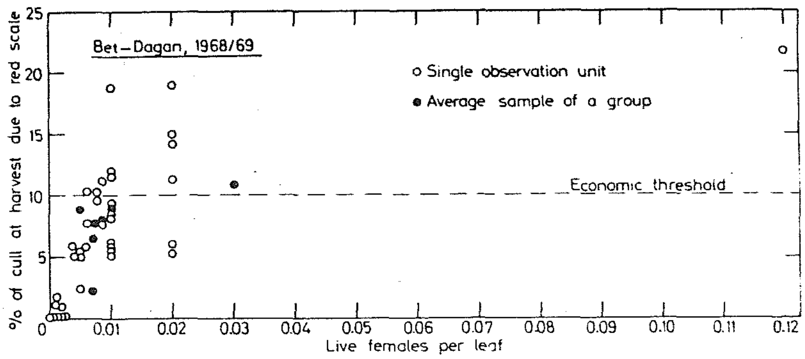

Fig. 2 - Correlation between leaf infestation and cull percentage; Bet Dagan, Jaffa oranges.

In 1964 at Hulata, an average leaf infestation of 0.16 live female scales (of second stage and above) per leaf in July yielded 70% of cull due to red scale at the harvesting season. In July 1965 at Bet Shean, the population levels of red scale varied considerably in different plots of the extensive plantation area, namely: 0.03, 0.08, 0.23, and 1.41 live scales/leaf; the respective percentages of cull were 8.9, 14.4, 27.8 and 87.6%. Late in July 1965, lemon trees in the observation plot at Gan Yavne displayed a leaf infestation of 0.25, and cull percentage at harvest (on 7.II.66) was 79.7. In this particular case, however, it should be kept in mind that the blooming and setting of lemons is irregular and therefore may have some bearing on fruit infestation. In 1966 in the observation plot of Valencia trees at Kefar Warburg the correlation figures for leaf and fruit infestation (examined in late July 1966 and mid March 1967, respectively) were 0.033 females/leaf and 0.22 females/leaf and 41.3% and 51.4% cull respectively. The respective figures at Arugot (in September 1967) were: population density on leaves of 0.03 yielded 56-68% of cull and 0.2 live scales/leaf, resulting in 86% rejected fruit. A 0.07 leaf infestation on Washington Navel in Ramat Dawid (14.VII.68) resulted in 73.8% of cull (on 22.XII.68) - while>0.01 live females per lemon leaf yielded 2.85% of infested fruit (Ramat Hasharon, Lemons 21.VI.68 - 1.II.69).

Fig. 2 includes data from Bet Dagan where the leave infestation varied from less than 0.01 live scale per leaf to 0.03 (with one exception of 0.12 females/leaf).

Scale population levels up to 0.01 females per leaf yielded fruit with a low percentage of cull, though there were differences between individual observation units; and average of 23 units of > 0.01 infestation yielded 5.32% of cull, an average of 11 units of 0.01 females/leaf yielded 8.41% cull. Trees with 0.02 scales/leaf reached an average of 11.9% cull.

Table 3 - Leaf infestation and cull percentage at harvest. Leaf infestation of order of magnitude of up to 0.01 was further subdivided into 3 categories; up to 0.005, 0.007 and 0.01 and superimposed on 0.02 and 0.03 scale/leaf infestation compiled from different localities.

Locality	Year	Total examined leaves	Females/ leaf	Total examined fruits	% of cull
Bet Dagan	1968/9	800	up to 0.005	2400	5.87
" "	"	300	0.007	617	7.13
" "	"	800	0.01	525	8.19
Bet Dagan and coast	"	450	0.02	687	10.55
Coastal plain and inner valleys	1965-69	750	0.03	6000	47

It would therefore appear from the compiled data (Table 3) that; (a) a correlation exists between leaf infestation and fruit cleanliness; and b) values expressing this correlation can be established - at least in an economic sense. It also seems that a density of up to 0.01 live females per leaf (= 1% infested leaves) in July-August, yields fruit with less than 10% of cull (below the economic threshold) - therefore not justifying control measures. However when the population level of scales reached 0.02 or above, the percentage of infested fruits at harvest surpassed the tolerance limit (economic threshold) as this density almost invariably yielded above 10% of culls.

The discrepancies in cull percentages at similar scale population levels on leaves, or even cases of lower cull percentages at higher levels of leaf infestation, are generally of limited economic consequence, once the critical threshold of 10% is surpassed. Ecologically, this phenomenon of a seemingly irregular rate of increase of scale populations on fruits may be explained by the multitude of factors involved: the more factors, the greater the variability in outcome. Thus, for instance, 0.01 scales per leaf may have a different significance according to distribution and exposition of the scales upon the tree, including border effect, the ratio of foliage to fruit, local components of entomophagous or competitive fauna, cultural practices, weather spells, etc. It should be noted that the red scale problem in this paper has been considered in terms of immediate losses through fruit deterioration; obviously, this is not the only approach, and the horticultural aspect including cumulative damage - should not be disregarded.

I am indebted to Dr. P. Vermes of the Volcani Institute of Agricultural Research for his assistance in evaluating the submitted data.

REFERENCES

1. Akesson, N. B. and Yates, W. E. 1964. Problems relating to application of agricultural chemicals and resulting drift residues. A. Rev. Ent. 9:285-316.

2. Bartlett, B. R. 1964 Integration of chemical and biological control in: Biological Control of Insects and Weeds - Edited by P. DeBach pp. 489-511. Chapman and Hall Ltd., London.

3. Bodenheimer, F. S. 1935. Animal Life in Palestine. p. 52. "Sefer", Publ. Co., Tel-Aviv.

4. ________ 1951. Citrus Entomology. Uitgevrij Dr. W. Junk, S-Gravenhage pp. 247, 339, 344, 345-350.

5. Chant, D. A. 1966. Integrated control systems in: Scientific Aspects of Pest Control. (A Symposium) National Academy of Sciences, National Research Council Publication 1402 pp. 208, 210. U. S. A.

6. Harpaz, I. 1961. Armoured scales in: Pests of the Cultivated Plants of Israel. Ed. by Avidov, Z. (in Hebrew) p. 159, 161. The Magnes Press, The Hebrew University, Jerusalem.

7. Patt, J. 1968. New problems in Citriculture (in Hebrew) Alon Hanotea (3), 101.

8. Rollins, R. Z. 1960. Drift of pesticides. Bull. Calif. Dep. Agric. Vol. 44, (1) pp. 34-39.