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Relation of scarlet mite (Brevipalpus phoenicis) density in tea with injury and yield

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Abstract

The effects of scarlet mite infestation on symptom development and yield of tea were studied in the laboratory and the fields of the Research Institute for Tea and Cinchona, West Java, Indonesia. The relations of the mite density with the presence of a necrotic leaf base and with leaf duration were determined. A field trial over one year duration where the mite densities were diversified experimentally by spraying either dicofol or copper oxychloride did not show effects on yield with average densities up to 30 eggs and mites per leaf. This density is proposed as a preliminary minimum threshold for control.

Additional keywords: Camellia sinensis, Indonesia, copper oxychloride, dicofol, crop loss, symptoms, control threshold.

Introduction

Scarlet mite *(Brevipalpus phoenicis)* (Acarina: Tenuipalpidae) is considered to be a serious pest of tea *(Camellia sinensis)* in Indonesia (Kalshoven and Van der Laan, 1981; Oomen, 1982; Razoux Schultz, 1961). The injury or damage caused by this mite, however, has never been determined. In India and Sri Lanka, tea producing countries with a long history of tea research, damage by scarlet mite could not be separated from damage by spider mite *(Oligonychus coffeae),* a pest more harmful than scarlet mite with which it concurs (Danthanarayana and Ranaweera, 1970). On the relation of scarlet mite density with injury, only Banerjee (1971) has given the minimal mite densities that within 24 hours cause symptoms on tea leaves in NE India. These values are not informative about both the development of symptoms in practice and the damage. The damage caused in Sri Lanka is chronic and insidious and difficult to assess quantitatively. It often does not affect the weight of the crop in the same pruning cycle (Cranham, 1966). Infestations by scarlet mite in Indonesia usually are rather unmixed and more serious than those of spider mites which only rarely become numerous. Therefore, quantification of crop loss in relation to scarlet mite density is possible.

The damage by scarlet mites through crop loss and general weakening is thought to be serious (Baptist and Ranaweera, 1955; Danthanarayana and Ranaweera, 1970; Kalshoven and Van der Laan, 1981; Rao, 1970). Scarlet mites live on the mature or

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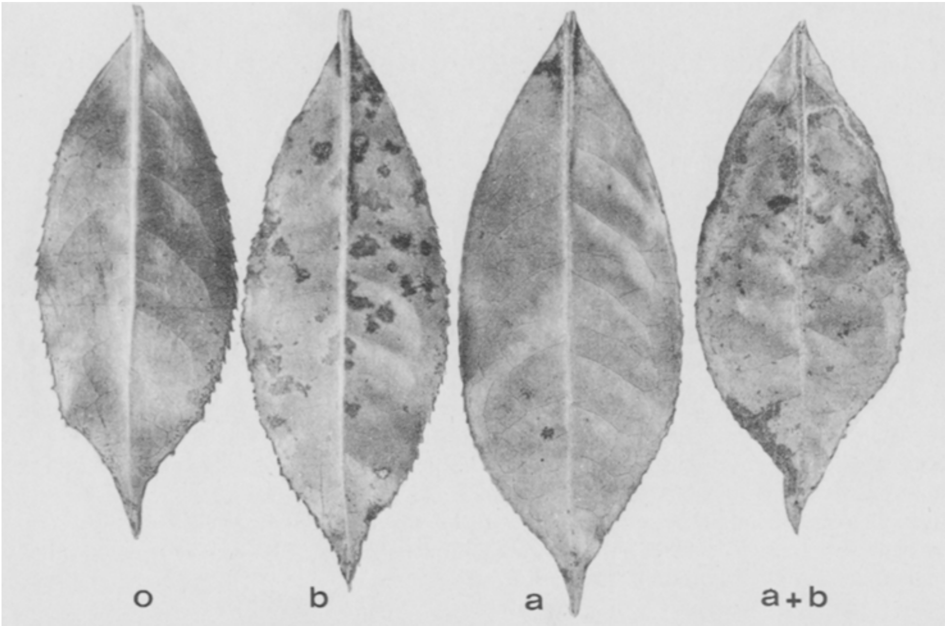

Fig. 1. Maintenance leaves of tea with a necrotic base (a) as a result of mite attack, and with a dispersed spotting (b) which appeared to be unrelated to mite density.

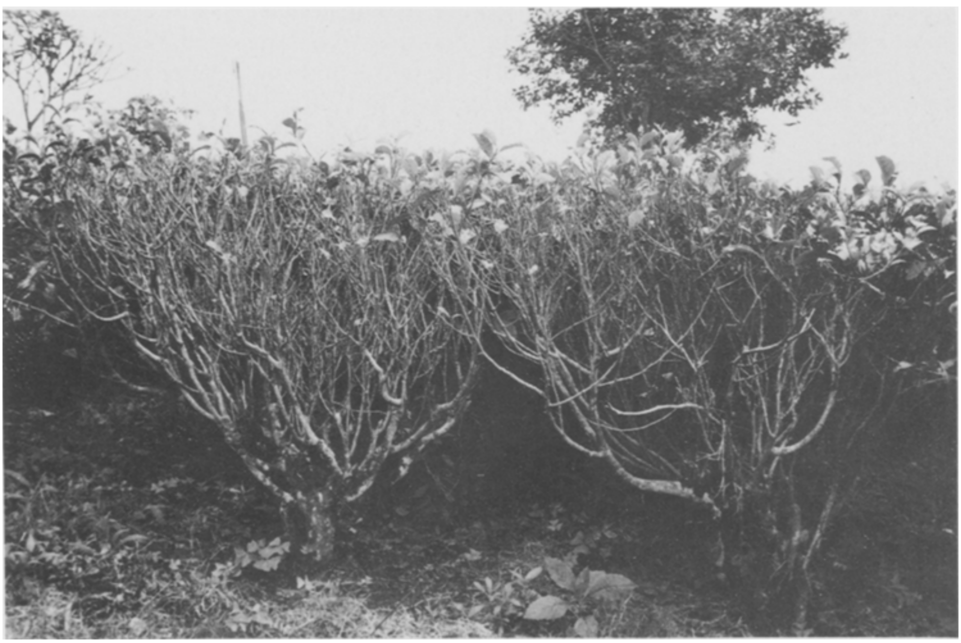

Fig. 2. Tea bushes largely defoliated after a severe mite attack.

'maintenance' leaves separated from the harvestable crop (the bud and two youngest leaves of young shoots). The harvestable crop itself is rarely attacked and is influenced only indirectly by malfunctioning of the whole tea bush. Mite outbreaks on the maintenance leaves likely affect this functioning.

The symptom is discolouration of the undersides of infested maintenance leaves which become brown and necrotic progressively from the petiole and the leaf base, along the midrib and the edges of the leaf (Bernard, 1909; Baptist and Ranaweera, 1955; Oomen, 1982) (Fig. 1). I found that the necrotic part rarely exceeded 1 cm^2. Usually the leaves are shed long before the discolouration is complete (Homburg, 1955). A severe outbreak may lead to a nearly complete defoliation (Fig. 2) (Bernard, 1909; Baptist and Ranaweera, 1955; Cranham, 1966; Rao, 1974).

Scarlet mites feed in the same way as Tetranychidae, by continuously piercing the leaf epidermis with their chelicerae (Jeppson et al., 1975). They also cause injury by injecting a toxic saliva when feeding (Jeppson et al., 1975). Apart from the local effects the toxic saliva is likely to have also remote effects by being transported to other parts of the plant (cf. Storms, 1971).

Damage and symptom development in quantitative relation to scarlet mite density were studied in these experiments in order to understand how these phenomena develop and to define a control threshold that could be related to easily observable symptoms. Yield and mite density were measured in a field experiment lasting 13 months; the quantitative relations of mite density with the development of some symptoms of attack were studied in the laboratory and in the tea gardens. The study was carried out between 1975 and 1980 at the Research Institute for Tea and Cinchona (RITC) near Bandung, West Java.

Materials and methods

The influence of the scarlet mite density on the shedding of leaves was studied in the laboratory (Experiment 1). The incidence of a discoloured leaf base (Fig. 1), of a dispersed spotting of the leaf (Fig. 1) and of leaf shedding in relation to mite density was studied in the field (Experiment 2 and 3). The direct relationship between yield and mite density was studied in the field (Experiment 4).

Laboratory experiment on leaf shedding (Experiment 1). Young, mature leaves of a tea clone (Cin 143) on which scarlet mites easily develop were collected from the clonal garden of RITC and kept with 5 cm of stalk in a water tray in the laboratory (cf. Oomen, 1982). The leaves were clipped to a diamond shape of 8.5 cm^2 and the axillary buds were removed. The part immersed in water developed callus and rootlets after some weeks. The stalk with leaf remained visually fresh for periods up to 429 days.

After cleaning by scrubbing with tap water, the leaves were inoculated with 0-20 adult mites which were left to reproduce. Reproduction in scarlet mite is parthenogenetic (Helle et al., 1980) and males are practically absent (Razoux Schultz, 1961). The adult mites on 81 leaves were counted every nine days until these succumbed, i.e. until the moment that the leaves were shed spontaneously by the stalks. The length of the whole periode was noted.

As the very high mite densities made counting of all stages often impossible, only adult mites were counted under the dissection microscope since this stage is likely to be the most important as to feeding activity and reproduction. The proportion of the adult mites in laboratory and field populations is usually rather constant: the average percentage of adults in 37 populations in the laboratory was 12% (standard deviation: 5%), and in two large populations in the field 10 and 16% (Oomen, 1982).

Field experiments. Mite densities in the field experiments (2, 3 and 4) were assessed by sampling 50 maintenance leaves from all parts of the field or the bush. Sample size was fixed at 50 leaves as a compromise between accuracy and practicability. Accuracy at this sample size is not high (calculated by Oomen (1982) as a probability of 0.95 of making an estimate deviating less than 40% from the true value) but sufficient to the purpose. As mite densities in the field were much lower than those in the laboratory, all developmental stages were included. Eggs were counted separately from juveniles and adults. The mites and eggs were counted directly under a dissection microscope or by means of a mite brushing machine. The average densities as estimated by both methods deviate little (Oomen, 1982). Other arthropods than scarlet mites were invariably few.

Leaf symptoms (Experiment 2). Over a period of 1.5 year, 196 leaf samples were collected from 5 whole tea fields and 15 single bushes. The mites (eggs and other stages) in each sample were counted and the fraction of leaves showing a discoloured leaf base and/or a dispersed spotting of the leaf surface was noted.

Symptoms in bushes (Experiment 3). The scarlet mite density and canopy density of 20 tea bushes just before pruning, and the reserves of these tea bushes just after pruning were estimated in a plantation of about 60-year-old seedling tea bushes.

To estimate canopy density, the incident light at 8-9 a.m. was measured above and below the canopy (at the level of the plucking table and of the frame of the bush), by means of a light meter used for photography (Gossen Sixtomat Electronic) with a measuring angle of approximately 45°. Direct sunshine was avoided. The difference between both measurements in logarithmic light values represented the canopy density. To estimate the reserves of each tea bush, the length of the longest shoot (regrowth) at 78 days after clean pruning was measured.

Crop loss (Experiment 4). The relation of yield with the density of scarlet mite was studied in a field experiment of 13 months. Twelve plots of 10 × 10 m were laid out in a randomized complete block design within a plantation of 60-year-old seedling bushes. The plots were marked permanently by bamboo poles and plastic strings. The naturally occurring scarlet mite densities were made to diverge more strongly by spraying pesticides regularly. Four plots were left untreated. Four plots were treated by an acaricide (10 l of 0.1% dicofol 42 MF per plot) whenever the mite density exceeded one per leaf. Four plots were sprayed once in 3 weeks by a fungicide (10 l of 0.06% copper oxychloride 50 WP per plot). Copper fungicides are known to increase the density of scarlet and some other tea mites (Cranham, 1966; Danthanarayana and Ranaweera, 1970; Venkata Ram, 1966). Every 3 weeks, the scarlet mites in each plot were counted and every 10 or 11 days the crop was harvested and weighed.

Statistical analysis. The mite infestations in the laboratory experiment (Experiment

1) up to the moment of leaf shedding are represented as mite-days, i.e. the sum of the products of the number of adult mites on the leaf per interval times the interval duration in days. The mite numbers between the days of counting were estimated by linear interpolation. An average mite infestation was calculated by dividing the sum of mite-days by the number of days until shedding. The infestation values thus found were transformed to square roots or logarithms in order to make the values normally distributed.

The relationship of symptom development and yield with the average mite density (expressed either as mite-days or as number per leaf) was evaluated by correlation analysis (Pearson's correlation coefficient r) and regression analysis. The significance of r was found in Table 13 of Pearson and Hartley (1956). The effect of the treatments on mite density and yield (Experiment 4) was evaluated by analysis of variance.

Results

Laboratory experiment on leaf shedding (Experiment 1). The rooted stalks in the laboratoy were independent plants, but it is not known whether the stalks are representative of tea bushes in their reaction to mite attack.

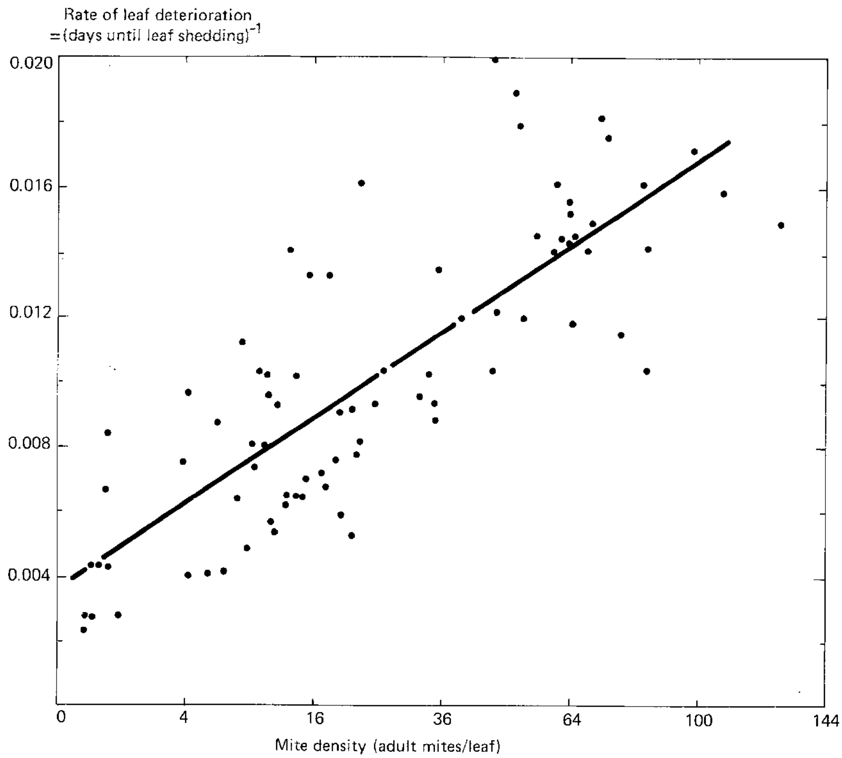

Fig. 3. Rate of leaf deterioration (y) in relation to the square root of the mite density (x). The rate of deterioration is the inverse of the period between the start of the experiment and the moment of leaf shedding (= leaf duration). The mite density is the number of mite-days divided by the leaf duration. The correlation is significant ($r = 0.81$, $n = 81$, $P < 0.001$). The linear regression line is $y = 0.0013x + 0.0037$.

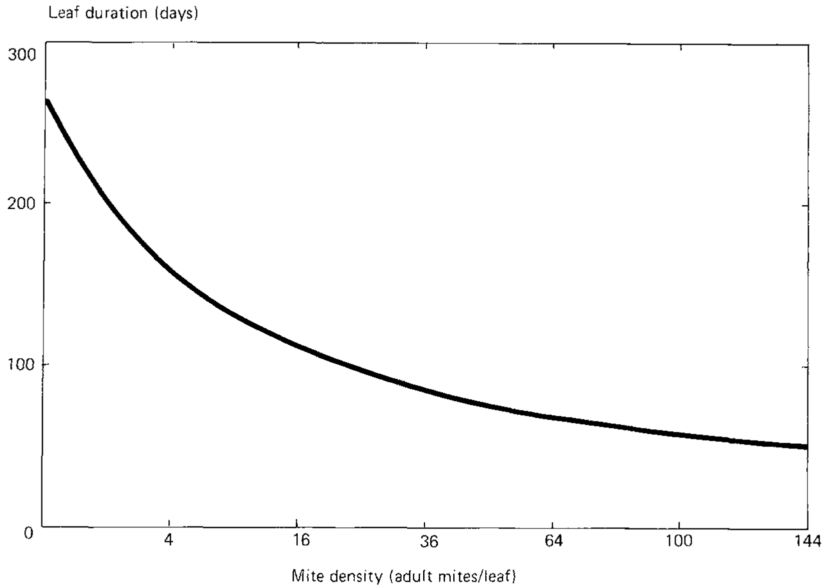

Fig. 4. Leaf duration (= inverse of the rate of leaf deterioration) in relation to the square root of the mite density. This function is derived from the regression line in Fig. 3.

The rate of deterioration of the maintenance leaves in the laboratory, resulting in leaf shedding, was low (leaf duration up to 429 days) when the average mite density had been low, or high (leaf duration about 60 days) when the average density had been high (Fig. 3). The rate of deterioration and the (square root of the) mite density were significantly correlated ($P < 0.001$); a linear regression line fits the data at the given transformation of the original measurements. Inverting the rate of deterioration back to leaf duration results in the graph of Fig. 4. The expected leaf duration of mite-free leaves is found by extrapolation to be 271 days. At the highest end of the infestation range, the leaves supporting about 100 adult mites are expected to succumb after about 60 days.

Leaf symptoms (Experiment 2). The symptom of a discoloured, necrotic base (Fig. 1) on any leaf is supposed result from the preceding mite infestation. The actual mite density on the leaf results from the same infestation. Therefore, a relation is likely to exist between the actual mite density and the incidence of this symptom in leaf samples. This incidence is given as the fraction of affected leaves in 196 samples of 50 leaves. Principally, the expected relation may be considered to be of a quantal type (Finney, 1971) as in bio-assays. Mite density is considered as the stimulus and the appearance of symptoms as the all-or-nothing response. Quantal relations in biology usually take the form of a straight line after transformation of the stimulus intensity to logarithms and the response to probits. A linear regression line fits the transformed observations (Fig. 5). The correlation is significant ($r = 0.64$, $P < 0.001$). The considerable dispersion is likely to be due to the difference between the leaves in age, origin, season of sampling, infestation history and to sampling error.

In Indonesia a dispersed, dark green spotting (Fig. 1) is often considered as a symp-

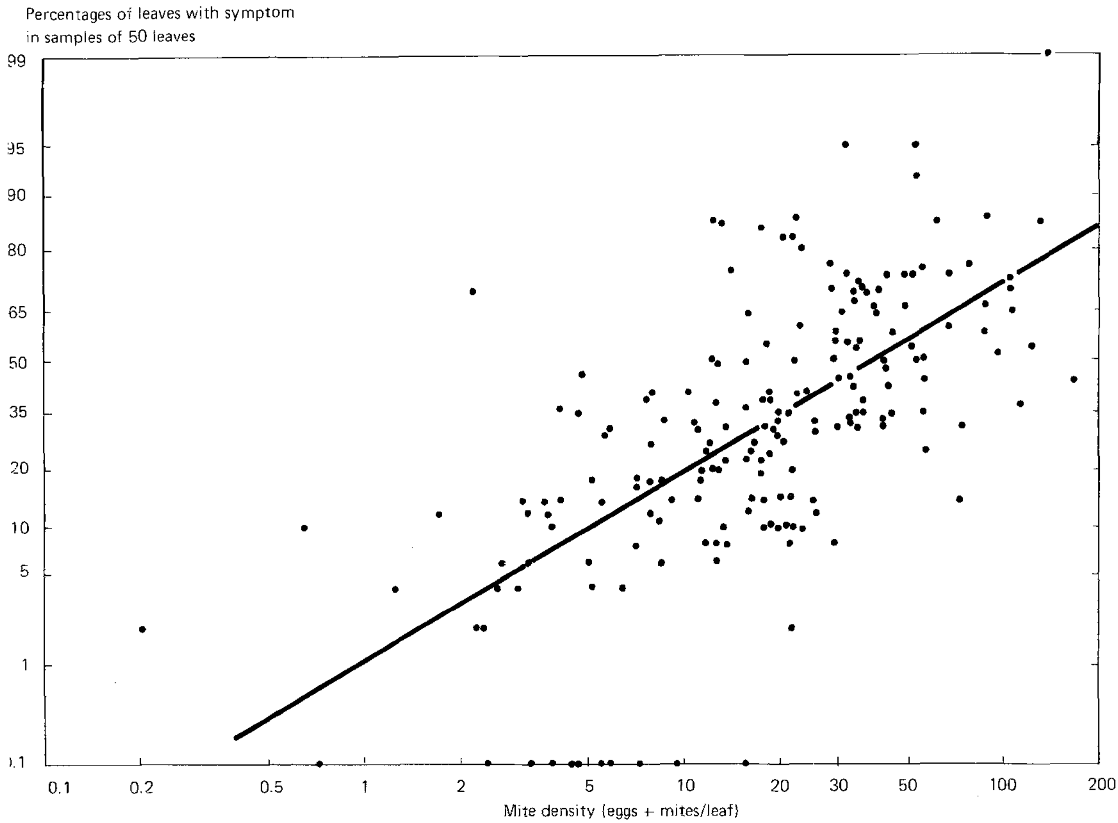

Fig. 5. The fraction of leaves (on a probit scale) showing the symptom of a discoloured, necrotic base, in relation to the average mite density (on a ^{10}log scale) in 196 leaf samples taken from 20 bushes and fields. The correlation is significant ($r = 0.64$, $P < 0.001$) and is described by the regression line $y = 1.44x + 2.70$.

tom of scarlet mite attack. The fraction of leaves showing this symptom appeared not to be correlated to the mite density in the 196 samples ($r = 0.12$, $P > 0.1$). The spotted appearance therefore is likely to be caused by other factors.

Symptoms in bushes (Experiment 3). Scarlet mite infestations are reported (see introduction) to cause leaf shedding and general weakening of the tea bush. I explored the importance of these effects by relating measurements of the mite density, canopy density and growth rate of young shoots (regrowth) in the field (Fig. 6). The density of scarlet mites appeared to be only just significantly correlated to the density of the canopy (Fig. 6 A) but not significantly correlated to the regrowth of the tea bush (Fig. 6 B). Canopy density and regrowth of the bushes were not significantly correlated either. These loose correlations were all negative. The negative signs confirm that infestation by scarlet mites causes both canopy thinning and exhaustion of plant reserves. The low level of significance indicates that the density of the scarlet mites within the range of the experiment (3-35 eggs and mites per leaf) is not one of the main factors influencing these aspects of plant functioning.

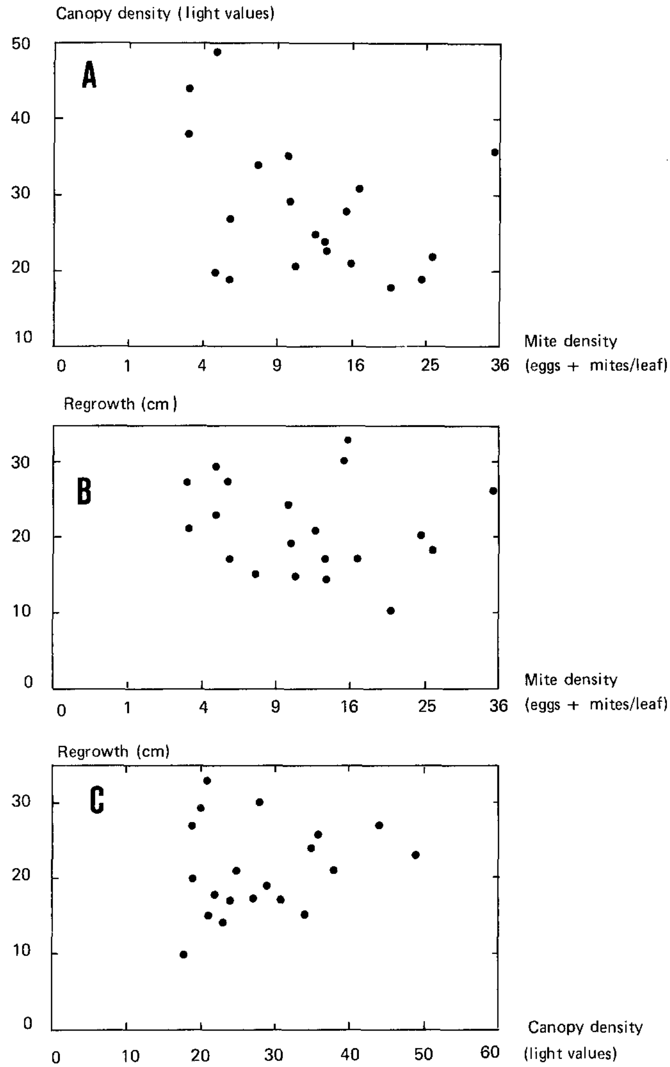

Fig. 6. Scarlet mite density and symptom development in 20 tea bushes.
A. Correlation of canopy density with the square root of the mite density, both just before pruning (r = −0.37, P = 0.05).
B. Correlation of regrowth at 78 days after pruning with the square root of the mite density, just before pruning (r = −0.33, P < 0.1).
C. Correlation of regrowth at 78 days after pruning with canopy density just before pruning (r = 0.18, P > 0.1).

Crop loss (Experiment 4). Measurements of both mite density and yield in 12 experimental plots after an establishing period of two months (after which mite densities had more or less established and a first yield maximum had passed) are given cumulatively in Figs. 7 and 8. Mite densities strongly diverged as a consequence of the

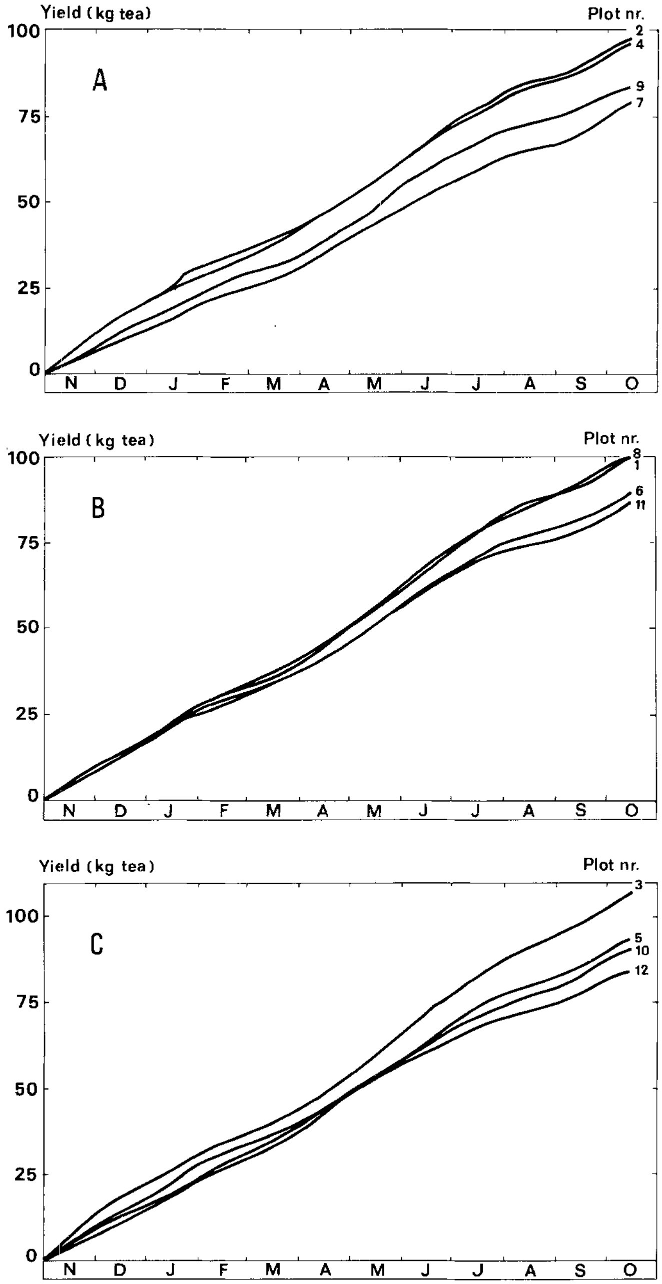

Fig. 7. Accumulated yield of fresh tea (kg/100 m^2) from 12 experimental plots with different mite densities (cf. fig. 8) during nearly one year. The accumulation departs from two months after the start of mite density differentiating treatments.
A. Highest mite density, treated with a copper fungicide.
B. Normal mite density, untreated.
C. Lowest mite density, treated with an acaricide.

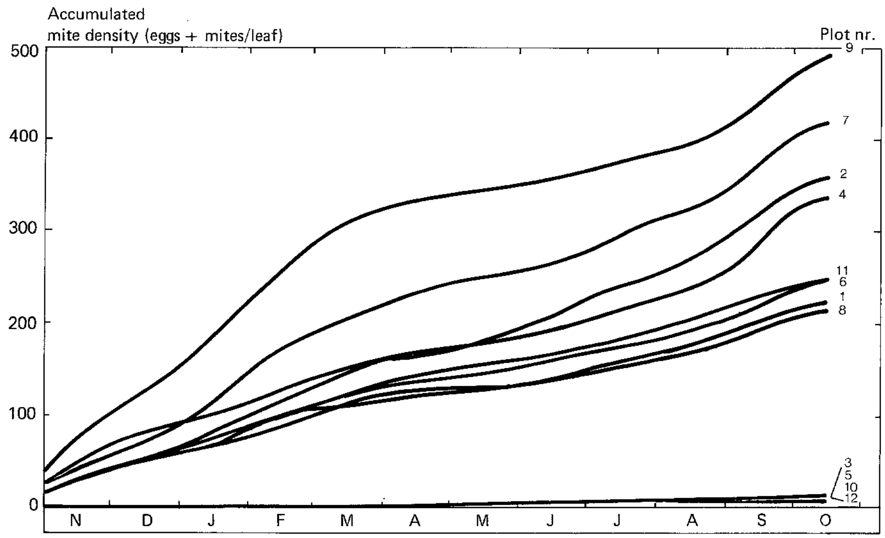

Fig. 8. Average densities of scarlet mites per leaf in 12 experimental plots, accumulated during nearly one year over 16 sampling dates three weeks apart. The accumulation departs from two months after the start of the mite density differentiating treatments. The plots 9, 7, 2 and 4 were treated with a copper fungicide (cf. Fig. 7A); the plots 11, 6, 1 and 8 were left untreated (cf. Fig. 7B); the plots 3, 5, 10 and 12 were treated with an acaricide (cf. Fig. 7C).

Table 1. Average scarlet mite density in 12 experimental plots (of 100 m^2) and total yield of fresh tea during nearly one year.

Replicate	Average mite density per leaf			Total yield/plot (kg/100 m^2)		
	fungicide	untreated	acaricide	fungicide	untreated	acaricide
1	23.0	14.3	0.9	97.8	99.6	107.5
2	21.3	15.8	0.6	96.2	89.5	93.9
3	26.3	13.7	0.7	79.8	100.6	91.2
4	31.0	15.9	0.6	83.5	87.0	84.0
	Analysis of variance			Analysis of variance		
	SS	df	F ratio	SS	df	F ratio
Replicates	20.36	3	1.07	439.63	3	3.69
Treatments	1229.56	2	96.94**	62.41	2	0.79
Error	38.05	6		238.18	6	
Total	1287.96			740.21		

** $P < 0.01$. Analysis of variance shows that only the mite densities are significantly different between treatments.

pesticide treatments and showed considerable seasonal fluctuations. The copper fungicide treatments appeared successful in increasing mite densities over the normal level. The densities in the acaricide treated plots remained negligible (Fig. 8). Yield showed smaller fluctuations in time and less divergence between treatments (Fig. 7). The effects of scarlet mite on yield are indirect (cf. introduction) and therefore are likely to be delayed. Hence it seems reasonable to limit the statistical analysis to yield totals and average mite densities over one year for effects of densities on yield (Table 1).

The treatments by an acaricide and a copper fungicide made the mite densities to diverge very significantly. These divergences are not reflected in the yield per plot. The variation of the yield per plot is large, both within and between treatments (Table 1). The correlation of total yield with average mite density has a negative correlation coefficient ($r = -0.28$) which is according to the expectation that scarlet mite depresses yield, but the correlation is not significant ($P > 0.1$). This means that under the experimental conditions of the rather heterogeneous plots and average mite densities below 30 eggs and mites per leaf, scarlet mites did not significantly reduce yield.

Discussion

On starting the experiments on scarlet mite and induced injury and damage, I expected to find positive correlations of mite density with the symptoms of attack, a necrotic leaf base and a reduction of leaf duration, and with crop loss, similar to the reduced growth increment in apple with the accumulated density of *Tetranychus mcdanieli* (Tanigoshi and Browne, 1981). The correlation with the symptom of a necrotic leaf base was stated and quantified from a large number of field data (Fig. 5). The extent to which the mites reduce the chlorophyll content and the photosynthetic capacity of the leaves is not known. The necrotic surface, however, is small and negligible compared to the reduction in leaf surface as a consequence of a shortened leaf duration.

The correlation of mite density with leaf duration (or rate of leaf deterioration) was stated and quantified from laboratory data (Figs. 3 and 4). Infestation by scarlet mites apparently reduces the leaf surface of tea bushes by increasing the rate of deterioration of the leaves, i.e. by inducing early leaf shedding. This seems to confirm the statement by Cranham (1966) and other authors that scarlet mites would cause severe defoliation even at fairly low densities per leaf. In the field, however, such effects of the prevalent mite densities up to about 30 eggs and mites per leaf were hardly measurable as effects on canopy density (Fig. 6 A).

Between mite density and yield no correlation at all became evident from a large body of field measurements (Figs. 7 and 8, Table 1). Two explanations are given which may account for the seemingly absent influence of mite density on yield.

1. The average densities in the field experiments (where all mites including eggs were counted) were relatively low compared to those in the laboratory experiments (where only adult mites were counted). In normal populations only 10-15% of scarlet mites is adult (Oomen, 1982). As with strawberry plants, it is likely that during low rates of mite-day accumulations, i.e. at relatively low mite densities, mature plants can compensate for the mite stress and thereby reductions in productivity may not occur (Sances et al., 1982). Tea therefore seems to be tolerant of the average scarlet mite densities at least up to the highest prevalent in the field experiment. This tolerance is also

likely to account for the low significance of the correlation of canopy density with mite density. Higher densities however occurred in some places outside the experiment. In an incidental observation I counted 4600 eggs and mites on a single leaf. Effects on canopy density and yield were very evident here. As the highest mite densities in the experiment on yield were far below those apparently possible elsewhere, it is not likely that early leaf shedding of the most infested leaves would have influenced mite counts in this experiment and that it therefore would have obscured otherwise detectable correlations with yield.

2. The correlation of yield with mite density may have been insignificant not only because of a relatively low mite density but also because of the delayed reaction of tea bushes to defoliation. Tea seems very resilient to the effect of defoliation, firstly because bushes, in the way they are grown, usually have a dense foliage (leaf area indices between 3.6 and 8.5 were found by Hadfield (1974)), and secondly because largely defoliated bushes appear to have sufficient reserves to continue to yield for a considerable time. This is confirmed by the insignificance of the negative correlation of the regrowth as a measure of plant reserves with both mite density and canopy density (Figs. 6 B and C). This delayed effect of defoliation permits other factors (e.g. plot variability because of old age and seedling origin of the bushes) to obscure the relation of yield with scarlet mite density, at least up to the average densities prevalent in the field experiment.

Therefore, all observations point to the conclusion that the yield of tea is not appreciably reduced by scarlet mites at least up to the densities prevalent in the field experiments, i.e. up to an average of 30 eggs and mites (or about 4 adults) per leaf. The density of scarlet mites at which yield is actually reduced did not appear from the experiments.

Although the detached parts of clone Cin 143 in the laboratory and the specific conditions in the fields of experimentation are not completely representative of the Indonesian tea growing and the reaction to scarlet mite attack in general, these quantitative data on scarlet mite density, symptom development and yield of tea are to my knowledge the first available and may serve therefore to preliminary define threshold values in scarlet mite control. Average mite densities below 30 eggs and mites per leaf affected yield hardly if at all. Measures to suppress populations below this density level are useless. Also densities temporarily exceeding this average are likely to be harmless when periods with a lower density compensate for it.

A precise and practical device to assess the densities in leaf samples is the mite brushing machine (cf. Oomen, 1982). Easier but less dependable is an indirect method that makes use of the relation of mite density with symptom incidence. A density of 30 eggs and mites per leaf corresponds roughly to a symptom incidence of 40-45% (Fig. 5). The relationship, however, is rather loose and this symptom incidence should therefore be used only with reservation as an indication for control measures.

For a definitive assessment of the crop loss in tea it is advisable to further experiment in young, homogeneous plantations (e.g. clonal fields), to use more replicates, to continue the experiment during a sufficiently long period (preferably including pruning) and to include higher mite densities. Statistical analysis might considerably be improved by developing methods that could relate also fluctuations in yield with fluctuations in mite density.

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Samenvatting

De dichtheid van palmmijt (Brevipalpus phoenicis) in thee in relatie tot beschadiging en opbrengst

De symptoom- en schadeontwikkeling in thee als gevolg van aantasting door palmmijt (oranje mijt) werd onderzocht in het laboratorium en de theetuinen van het Proefstation voor Thee en Kina in West Java, Indonesië. Het verband tussen de mijtdichtheid, het optreden van een necrotische bladvoet, en de levensduur van het blad werd kwantitatief bepaald. Een veldproef waarin de mijtdichtheden experimenteel werden gespreid door bespuitingen met het acaricide dicofol en het fungicide koperoxychloride toonde over meer dan een jaar geen opbrengstverschillen aan tussen veldjes met gemiddelde dichtheden tussen 0 en 30 eieren en mijten per blad. Deze laatste dichtheid wordt daarom voorgesteld als voorlopige minimum bestrijdingsdrempel.

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