TIJDSCHRIFT OVER PLANTEZIEKTEN

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EFFECT OF CULTURAL MEASURES ON THE POPULATION DENSITY OF THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* KOCH (ACARI, TETRANYCHIDAE)[1]

Met een samenvatting: Invloed van cultuurmaatregelen op de populatie ontwikkeling van het fruitspint, Metatetranychus ulmi *Koch (Acari, Tetranychidae)*

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1. INTRODUCTION AND STATEMENT OF THE PROBLEM

In spite of an apparently inexhaustible supply of new plant-protection products, the fruit tree red spider mite (*Metatetranychus ulmi* Koch), remains one of the most important pests in the orchard. The continuously increasing resistance of this mite to insecticides has intensified the seriousness of the problem in recent years.

Effective control is of great economic importance. Severe injury to the fruit tree causes a lower yield in the same year, but it also reduces the formation of fruit buds, which decreases the quantity of fruit in the following season (ASQUITH, 1959; BOULANGER, 1958; CHAPMAN et al., 1952; LATHROP, 1951; LIENK et al., 1956; UNTERSTENHÖFER, 1954b; VAN DE VRIE, 1956).

Satisfactory control requires an understanding of the factors which contribute to the development of the pest. An attempt can then be made to find a preventive control to replace repressive or curative control. The literature concerning the harmful increase of the mite indicates that attention has been particularly directed to the effect of the elimination of its natural enemies through the application of pesticides. In the opinion of many investigators, the increase of the pest must be ascribed to the absence of these natural enemies (see literature review).

The relation between the phytophagous mite and the plant on which it feeds has been studied only in more recent investigations. When the present study was begun in 1952, little was known about the relation of the fruit tree red spider mite and its host plants, the apple, pear, or plum. Investigations carried out by KUENEN (1946, 1949), however, had shown that the reproduction of the mites on leaves in a well-kept orchard was greater than on those in a neglected one; it was further shown by leaf analyses that in the well-kept orchard the total nitrogen content of the leaves lay higher than in the neglected orchard, as a result of the use of fertilizers and, possibly, the other kinds of treatment as well.

We can thus distinguish two groups of factors which play a role in the excessive increase of the fruit tree red spider mite. The first group of factors (the predators) affects the survival chances of the mite; the second group of factors (the physiological condition of the food plant) affects particularly its reproduction. When emigration and immigration are excluded, the increase of a population can occur as a result either of a reduced death rate or an increased rate of reproduction, or a combination of both. In the biocoenosis of the orchard, the death rate of the mite has dropped as a result of the absence of the predators removed by chemical control measures, while its reproduction has increased with the change in the nutritional position of the mite. In all probability, no exact qualitative measure of each of these groups of factors can be arrived at. It is nevertheless of great importance to pose the question whether both play a significant part in the massive increase of this mite or whether one of the two has a qualitative preponderance such that the other need not be taken into consideration.

The problem of the resistance of *M. ulmi* to many insecticides and the consequences of this resistance to the development of the mite do not come within the scope of this investigation.

2. REVIEW OF THE LITERATURE

In making a study of the pests and diseases which affect fruit culture, it becomes evident that only since the beginning of the twentieth century has there been a serious problem of injury to fruit trees by phytophagous mites. Previously, damage to trees and fruit by aphids, tortricids, etc. was frequently reported (ANONYMOUS, 1782; DU VIVIE, 1716; see also review by ORDISH, 1960). According to these authors, an attempt was made to combat these harmful insects as early as the beginning of the eighteenth century, even if only with the most primitive materials such as liquid manure, tobacco solutions, and soot mixed with water and distilled wine or strong gin. During the end of the nineteenth and the first half of the twentieth century, these were replaced by copper, sulphur, lead arsenate, the organic compounds tar oil and DNOC, and products derived from plants: derris, pyrethrum, and nicotine. In this period a more specific attack on pests was developed, using not only new materials but also steadily improved apparatus.

A great change in disease control took place as a result of the development of the chlorinated hydrocarbons, such as DDT and BHC and the organophosphorus compounds, such as parathion and Systox. After the Second World War great numbers of these materials came into use. Equally great progress was made in the field of spray techniques, as a result of which effective chemical control of diseases and pests could be obtained over large areas very rapidly. This chemical control was, of course, of great significance to the biocoenosis of the orchard. The number of species of harmful insects and mites was sharply reduced, but the number of individuals of the surviving species in general increased.

According to MASSEE (1953), the number of potentially injurious insect species in the orchard in 1900 was about 60, a number which is now very greatly reduced. However, where in the beginning two to three sprayings per season was sufficient to provide what was for those times a satisfactory fruit yield, after the introduction of the organic pesticides such as tar oil, DNOC and especially DDT and the organophosphorus compounds the frequency had to be continually increased, to the point at which at present a figure of ten to fifteen sprayings per season is considered normal (POST & TOORENAAR, 1957). Present-day standards of quality in fruit have naturally promoted this very intensive control.

The most important reason for the increase in the frequency of spraying was, however, the increase in the number of pests to be controlled: after one pest was suppressed by means of chemical pesticides others developed. These difficulties arose first in the United States of America and Canada, where intensive chemical control was used earlier than in Europe. In the citrus groves in California and Florida a sharp increase occurred in various scale insects after spraying with DDT to combat, among others, the citrus thrips (*Scirtothrips citri* Moult.), such scales as *Icerya purchasi* Mask., *Lepidosaphes beckii* Newm., *Aonidiella aurantii* Mask., *Chrysomphalus aonidium* L. etc., while at the same time the population density of mites and other insect species increased, e.g. the mites *Phyllocoptruta oleivora* Ashm., *Paratetranychus citri* McG., and *Tetranychus bimaculatus* Harv. and the tortricid *Argyrotaenia citrana* Fern. The scale insects also showed a strong increase after spraying with copper and zinc.

Investigation led to the conclusion that in many cases the cause of the increase in these originally economically unimportant insects and mites could be traced back to a disturbance of the existing balance between the harmful organism and its plant or animal parasites and predators as a result of the poisonous effect of the majority of the pesticides on these beneficial organisms (CLAUSEN, 1956; CUTRIGHT, 1944; DEBACH, 1946, 1947; DEBACH & BARTLETT, 1951; DEBACH et al., 1949; DEBACH et al., 1951; FISHER, 1950, 1951; FLESCHNER, 1958a, b; GARMAN & TOWNSEND, 1938; GRIFFITHS, 1951; GRIFFITHS & FISHER, 1949, 1950; GRIFFITHS & THOMPSON, 1947; MUMA, 1955, 1958; THOMPSON, 1939). In the apple orchards of Nova Scotia a heavy multiplication of scale insects (*Lepidosaphes ulmi* L.) was observed after the use of sulphur to control apple scab (*Venturia inaequalis* (Cke) Wint.), while at the same time *M. ulmi* and several tortricids, including *Spilonota ocellana* D. & S., *Carpocapsa pomonella* L. and *Argyrotaenia mariana* Fern. increased markedly.

Here, too, closer study showed that the sulphur sprays have had a very destructive effect on the beneficial organisms. As a result, PICKETT and his co-workers investigated the effect of various chemical spray programs on the development of the pests and of the insects, mites, and other organisms which have a direct or indirect importance for natural control. Where necessary, the effect of the individual pesticides: fungicides, acaricides, and insecticides, was studied (LORD, 1947; MACPHEE, 1953; MACPHEE & SANFORD, 1954, 1956; PICKETT & PATTERSON, 1953; PICKETT et al., 1946; STULTZ, 1955; THOMAS et al., 1959). Through this work PICKETT and his co-workers were able to set up a so-called modified spray program in which the natural enemies were spared as much as possible by use of only the less poisonous pesticides. Chemical control was in addition used only where it was required to support natural control. In this way it was possible to arrive at an economically sound control program.

In the fruit-growing area of British Columbia this spray program did not provide sufficient control. Because of entirely different climatic conditions the fruit trees in this region were severely affected by apple mildew (*Podosphaera leucotricha* (Ell. et Everh.) Salm.). Most of the materials used for control of this fungus disease contain sulphur and are very harmful to the beneficial organisms (DOWNING et al., 1958; MARSHALL & MORGAN, 1956; MORGAN & ANDERSON, 1957). A satisfactory replacement which is non-injurious to the beneficial organisms is not yet available.

CLANCY & MCALISTER (1958) sought to develop a similar spray program for the apple orchards of West Virginia, also aimed at avoiding mass elimination of the natural enemies. After spraying with lead arsenate and DDT to control the codling moth, they had also experienced a severe increase of the phytophagous mites *Paratetranychus pilosus* C. & F. (= *M. ulmi*) and *Tetranychus bimaculatus* (CLANCY & POLLARD, 1948, 1952). In Quebec PARENT et al. (1956, 1959) investigated the effect of several fungicides on *T. bimaculatus* and *M. ulmi* on apple.

In western Europe after the introduction of tar oil winter washes in fruit culture the increase of *M. ulmi* attracted special attention. MASSEE (1929) and GEYSKES (1938) reported the unsatisfactory effect of these sprays. Further investigation (MASSEE, 1929; MASSEE & STEER, 1929) brought out the fact that the winter eggs of the fruit tree red spider mite were not killed by the tar oil washes, in contrast to the winter stages of such harmful insects as the green apple aphid (*Aphis pomi* De G.), the apple sucker (*Psylla mali* Schm.), the winter moth (*Operophtera brumata* L.) and tortricid species. According to MASSEE (1953), however, the eggs and hibernating stages of beneficial mites and insects were for the most part destroyed while, in addition, for many harmful, but also for many beneficial insect and mite species, the hibernating quarters were limited by killing foreign growth on the tree bark by spraying with tar oil. BLAIR & GROVES (1952) were of the opinion that the use of tar oil as a winter wash for fruit trees must be considered as the primary cause of the extraordinary increase of the fruit tree red spider mite in the orchards because of the elimination of the hibernating predacious enemies of this mite. According to them, the subsequent use of DDT as a summer spray accelerated this process, since DDT is not toxic to the phytophagous mites as it is for the predacious mites and insects (see also SOLOMON, 1953).

As a result of the vast multiplication of *M. ulmi* and locally of *T. urticae* in both fruit and vine culture, research was begun in Europe to study the effect of predacious mites and insects on the increase of the injurious phytophagous mites, and into the effect of fungicides, insecticides, etc. on their enemies. The first of this work to be mentioned is that done in southeastern England, where COLLYER (1949, 1952, 1953 a, b, c, d, 1954, 1955, 1956; COLLYER & MASSEE, 1958) made an inventory of the predator populations of well-kept and neglected apple orchards and studied the effect of the predators on the increase of *M. ulmi*. Similar studies were also made of the effect of fungicides, insecticides, etc. on the natural enemies (COLLYER, 1952; COLLYER & KIRBY, 1955, 1959; KIRBY & COLLYER, 1959). In other places too, attention was devoted to the influence of natural enemies in the effort to check phytophagous mites (BERKER, 1956, 1958; BRAVENBOER, 1959; FRITZSCHE, 1958; GEIER & BAGGIOLINI, 1952; GÜNTHART, 1956, 1959; MATHYS, 1958) and the elimination of this beneficial effect by the use of pesticides (GÜNTHART, 1957; MATHYS, 1956 a, b; REED, 1959; STEINER, 1956, 1958, 1959; VAN DE VRIE & DE FLUITER, 1958). REDENZ-RÜSCH (1959) and STEINER (1958, 1960) investigated in addition the effect of several organophosphorus compounds on the entire biocoenosis of beneficial, harmful, and neutral species.

In all of these investigations in both America and Europe emphasis was put primarily on the disturbance of an existing balance between harmful mites and insects and their parasites and natural enemies as the cause of many outbreaks, in particular that of the phytophagous mite *M. ulmi*. In view of the radical changes in the orchard fauna brought about by the application of chemical pesticides, it is not surprising that interest was concentrated in this way. As a consequence, rather a good deal is now known concerning the relation between phytophagous mites and predators, while rather little is known about the effect of other factors on the population increase of *M. ulmi*, the effect of the nutrition of the mite being certainly one of the most important.

In addition to the great changes in the field of chemical pesticides, equally great changes have taken place in the entire field of fruit-tree culture. In many places there has been a change-over from standard trees to bush trees and spindles, and both pruning and fertilization are practiced very intensively. As a result, the physiological condition of the trees has been radically modified. Since the fruit tree serves as the source of food for many phytophagous mites and insects, it may justifiably be assumed that these cultural modifications also exert an influence on the development and increase of the harmful organisms affecting fruit culture.

The connection between population expansion and the quality and quantity of the available food has been studied extensively in certain phytophagous insects, and especially in aphids (ARANT & JONES, 1951; AUCLAIR, 1953; AUCLAIR & MALTAIS, 1950; AUCLAIR et al., 1957; BARKER & TAUBER, 1951; EVANS, 1938; FRAENKEL, 1953; FRIEND, 1958; GRISON, 1958; HASEMANN, 1946; HOFFMANN, 1916; KENNEDY, 1958; MALTAIS, 1951; MALTAIS & AUCLAIR, 1957; MEYAARD, 1956; MITTLER, 1957, 1958 a, b; NUORTEVA, 1952; RODRIGUEZ, 1960; VÖLK & BODE, 1954).

The effect of the chemical composition of the leaf, in this case the food source, on the population increase of the two-spotted spider mite has been investigated by various authors. WHITCOMB (1943) observed less mite damage to roses with a high p_H of the cell sap. GARMAN & KENNEDY (1949) concluded from their experiments that the population density of the two-spotted spider mite varied with a change in the condition of the host plant (i.e. bean and apricot) which followed the use of fertilizer.

RODRIGUEZ & NEISWANDER in 1949 established the relationship between the specific conductivity of the soil soluble salts and the population density of *T. bimaculatus* on tomatoes growing in greenhouses: a decrease in the concentrations of the soil soluble salts over a period of three years was accompanied by a simultaneous reduction in the mite population. RODRIGUEZ (1951) then studied the effect of mineral nutrition, and found that doubling of the concentration of the macro-elements in the nutrient solution was followed by a doubling of the mite population. Analysis of the leaves showed that the nitrogen content had a negative correlation with the mite populations. With an increase in the quantity of nitrogen in the leaf there was also an increase in three vitamins: riboflavin, thiamin, and niacin. A conclusive correlation between the vitamin content of the leaf and the increase in the number of mites could not, however, be demonstrated (RODRIGUEZ & RODRIGUEZ, 1952).

LEROUX (1954) investigated the effect of various levels of nitrogen, phosphorus, and potassium, in a nutrient solution applied to cucumbers, on the fertility of the two-spotted spider mite with which they were infected. He found that an excessive supply of both nitrogen and potassium gave an increase in the mite's egg production; an excess of only one of these elements, however, increased the fertility even more. An excess of phosphoric acid gave variable results. Since LEROUX carried out no leaf analyses, the reaction of the mites cannot be correlated with the chemical composition of the leaves. On the basis of his results, LEROUX thought that a carefully balanced soil fertilization program might reduce the injury to the cucumber caused by the two-spotted spider mite, which could then be more easily controlled by chemical methods.

FRITZSCHE (1957) and FRITZSCHE et al. (1957) found in experiments with *T. urticae* Koch (= *T. bimaculatus*) on bean plants (*Phaseolus vulgaris* L.) that the increase in the population density of the mite was proportional to the increase in the total content of nitrogen and reducing sugars in the plant brought about by the use of fertilizers. According to them, of the total nitrogen content of the plant it is particularly the content of insoluble nitrogen compounds and of glutamine and glutamic acid which are important. In field tests with two varieties of *P. vulgaris*, the most severe mite injury was also observed on the variety with the highest content of nitrogen and reducing sugars.

HAMSTEAD & GOULD (1957) investigated the effect of the condition of apple trees in connection with the use of nitrogen fertilizer on the mite population of the orchard. During two seasons the population density in the plots with a high nitrogen content of the leaves was higher than in the plots with a low nitrogen content, although these differences were not significant in either year for the two mite species *T. telarius* and *M. ulmi*. The increase of the population in the plots with a high nitrogen level, according to these authors, was caused exclusively by a higher egg production; no effect on the rate of development could be observed.

The same authors also mention a correlation between the increase and decrease of the mite population and the seasonal rise and fall of the nitrogen content of the leaves. According to them, there was no distinct correlation to be observed between the increase in the mite population and the potassium, phosphorus, calcium, and magnesium contents of the leaves.

KUENEN (1949) similarly demonstrated the effect of the condition of the host plant, i.e. the apple, pear, and plum tree, on the population increase of *M. ulmi:* egg production was much higher on leaves of trees in well-kept orchards than in neglected orchards. He also found a wide difference in the injury to various varieties of plum and to one variety on various rootstocks. There was a distinct correlation between the thickness of the cuticle of the pear and plum and the injury: the thicker the cuticle the less the injury.

RODRIGUEZ (1958) used pot experiments lasting two years to investigate the effect of three nitrogen and three phosphorus levels on the development of *Panonychus ulmi* (= *M. ulmi*) and *T. telarius*, the potassium level being held constant. For both species there was a positive correlation between the quantity of absorbed nitrogen and the density of the mite population. At the highest nitrogen level (800 ppm) a decrease in the mite population appeared during the second year of the experiments, especially in the case of *T. telarius*, in relation to the lower nitrogen levels (20 and 200 ppm). The correlation of the population of *P. ulmi* and *T. telarius* with the absorbed phosphorus was variable.

Compared with the literature concerning the effect of the natural enemies and nutrition on the development of the phytophagous mites, relatively little has been published on the effect of climatic and weather conditions on their populations. Climate determines whether a species can be expected in a given region, and weather factors strongly influence the degree to which a population can develop.

According to ROESLER (1953), the increase in a great number of (xerophilic and thermophilic) insect species in central Europe during the last ten years is to be ascribed to the predominantly dry and warm climate which has prevailed in this period. This holds for, among others, *Capua reticulana* Hb., *Psylla pyri* L., and *P. pyricola* Först. The spider mites have also grown in importance in this period and, according to this author, the prolonged warmth and dryness have unquestionably contributed to their marked increase. In his opinion, the extent to which these weather factors have exerted a direct influence on the population increase of the fruit tree red spider mite or have worked indirectly through radical changes in the concentration and composition of the plant juices is not of essential importance. Nevertheless, the occasionally catastrophic increase is not to be explained exclusively by climatic and weather conditions. Modern culture methods, in his opinion, are also of great importance. In the spindles with open crowns, more light and therefore also more heat can penetrate than in the closed crowns of the standard trees; in addition, the temperature in the modern orchard, where the soil is often clean-cultivated, will rise to higher levels. Both cultural methods thus favour the increase of the mite. ROESLER is of the opinion that these two factors adequately explain the extreme increase of the fruit tree red spider mite, '*sodass kein Grund für weitere Spekulationen besteht*'.

MÜLLER (1959) also thinks that the increase of the fruit tree red spider mite in central Europe is due to the changed climatological conditions in this region. From the first larval stage to the depositing of the first summer eggs the mite, according to him, is most strongly dependent on the weather conditions. In this period, i.e. around the month of May, the temperature in central Europe has risen appreciably between 1941 and 1950.

Temperature measurements made in Vienna from 1775 to 1950 indicate, according to PSCHORN-WALCHER (1954 a, b), that since the first quarter of the twentieth century and especially since 1940 a more continental climate has developed in central Europe. The effect of climate is of great importance for the distribution of those thermophilic insect species whose northern border lies in central Europe. For various injurious species of beetle such as *Ceutorrhynchus napi* Gyll., *Tropinota hirta* Poda, *Acanthoscelides obsoletus* Say., etc. he assumes a causal relationship between climatic changes and changes in the area of distribution and population increase, but for each individual species this of course requires substantiation. According to this author, it is not improbable that the increase in insects which are injurious to plants is also in general promoted by the changes in the climate of central and northern Europe. The effect of the natural variations in climate are, probably, more important than the effect exerted on the fauna by man in the form of monoculture, chemical control, etc. This would then, in his opinion, relieve man of a part of his responsibility for the damage caused by exaggerated methods of culture.

Field observations made by KUENEN (1946) and others indeed indicate a favourable influence from higher temperatures on the development of *M. ulmi*, while rain and wind, especially when combined with low temperatures, reduce the population density. It is also known from practical orchard experience that in warm, dry summers *M. ulmi* is more likely to develop a serious outbreak.

Investigations made by ANDERSEN (1948) also indicate the favourable effect of a rise in temperature both on the embryonic and larval development of the mite. The depositing of eggs is, according to him, also promoted by dry, warm weather.

The effect of temperature on the mite is thus quite evident. However, to demonstrate the accuracy of the theories of ROESLER, MÜLLER, and PSCHORN-WALCHER it would be necessary to establish just when the increase of *M. ulmi* and the injurious insects began. For *M. ulmi* this was long before 1940, which in no sense agrees with ROESLER and MÜLLER's theories. In addition, these temperature increases apply to central Europe. In the western European countries there has also been a sharp increase in harmful organisms, but here no distinct changes in climatic conditions are demonstrable. In order to study the effect of climate and weather conditions on a mite or insect population, the effect of other factors such as, for example, changes in the composition of their food, must certainly be excluded. The increase of the harmful organisms which affected plant culture in the period mentioned above, dating from 1920, shows just as strongly a correlation with the extension of plant breeding investigation in this period and the application of the results from this work in the field of culture and nutrition. Whether there is a causal relationship between the two can, however, only be demonstrated experimentally.

Thus, various attempts have been made to approach the problem of the large-scale multiplication of the phytophagous mites. In this work much attention has been given to the role played by the elimination of natural enemies in this multiplication. Concerning the relationship between population development and the nutritional position of the phytophagous mites, however, relatively little has been published, and such studies have to a very large extent been done under laboratory or greenhouse conditions. In only a few isolated cases has the investigation been concentrated on *M. ulmi.*

Although weather conditions can temporarily strongly favour or limit population increase, these factors are not on the whole considered to have decisive importance for the catastrophic increase of the phytophagous mites in both Europe and America. In the investigations discussed above, in general only one factor was selected from the entire complex of influencing factors and its effect on the population development studied. In the present field study, the direct and indirect effects of the cultural measures applied in fruit growing on the population development of *M. ulmi* and its predators are investigated, i.e. the effect of soil cultivation, fertilization, and pruning separately or in combination with the effect of chemical control. This approach makes it possible to compare the significance of these two groups of factors.

3. THE BIOLOGY OF TWO PHYTOPHAGOUS MITES

3.1. SOME ASPECTS OF THE BIOLOGY OF *Metatetranychus ulmi* KOCH

So many publications have appeared concerning the biology of *M. ulmi* (e.g. ANDERSEN, 1948; BLAIR & GROVES, 1952; GÜNTHART, 1945; KUENEN, 1946, 1949; WIESMANN, 1940; WYBOU, 1951) that it will be sufficient here to report only the most important data concerning the development of the mite in western Europe.

The mites hibernate in the egg stage. The eggs are deposited in the autumn on the undersides of branches and twigs. They are bright red, slightly flattened, radially striated, and are provided with a small, protruding 'hair'. Towards the end of April and the beginning of May (before the trees bloom) the first larvae hatch. The hatching process of the winter eggs lasts about three weeks. Both the time at which they hatch and the period of hatching are dependent on the prevailing conditions. The colour of the newly-emerged larva is bright red; in the course of the mite's development the colour becomes darker as a result of ingested food.

The development from egg to adult passes through three active stages (one larval and two nymphal) and three quiescent stages (chrysalid): egg – larva (hexapod) – protochrysalis – protonymph (octopod) – deutochrysalis – deutonymph – teleiochrysalis – adult. The development from egg to egg takes approximately four weeks; from larva to adult about fourteen days. In the warmest summer period these values are about three weeks and ten days respectively.

The development from larva to mature male is about one day shorter than from larva to mature female (e.g. ANDERSEN, 1948; BLAIR & GROVES, 1952; KUENEN, 1946; and the author's observations). GEYSKES (1938), GÜNTHART (1945), and WIESMANN (1940) were of the opinion that the more rapid development of the male is caused by the absence of the deutonymphal and teleiochrysalid stages. According to ANDERSEN (1948), this is caused by the fact that the deutonymphal stage of the male is about one day shorter than that of the female.

The summer eggs are deposited primarily on the leaves. The 1st and 2nd generation of mites deposit only summer eggs, the 3rd and 4th generation summer and winter eggs. The number of winter eggs increases with each successive generation; in the 5th generation only winter eggs are deposited. The condition of the leaf is one of the factors which determines the start of the production of winter eggs: when the condition of the leaf is poor, for instance as a result of severe mite injury, production will begin earlier (BLAIR & GROVES, 1952; GASSER, 1957; KUENEN, 1946, 1949; WIESMANN, 1940). The total number of eggs is largest in the first generation and drops off after that (ANDERSEN, 1948). On the average, the production per day is one to two eggs per female. The maximal total number of eggs per female is 45 according to ANDERSEN (1948), 46 according to BLAIR & GROVES (1952), and 37 according to KUENEN (1946) for the Netherlands, the locale of the present study.

The longevity of a female is on the average about two weeks, while that of the male is slightly shorter. The duration of the stages of the mite, of the entire life cycle and the number of eggs which are deposited are all strongly dependent on prevailing climatic conditions. In the Netherlands, five generations of mites per year is the average.

3.2. SOME ASPECTS OF THE BIOLOGY OF *Bryobia rubrioculus* SCHEUTEN

Since in the orchards *B. rubrioculus* follows *M. ulmi* in importance (see p. 42), the most significant biological data for this mite will also be given here.

B. rubrioculus also hibernates in the egg stage. The eggs are found especially on very rough surfaces, in cracks, etc., preferentially on the undersides of the older branches and on the transition zone of the new growth. The eggs are dark red and cylindrical. The winter eggs hatch about two weeks earlier than those of *M. ulmi*. The hatching rate is strongly dependent on temperature, precipitation, and relative humidity in that period.

Like *M. ulmi*, there are three active stages which alternate with three quiescent stages. The total development of the mite lasts from 29 to 37 days (GÄBELE, 1959). KREMER's laboratory investigation (1956) demonstrates the strong influence of temperature on the rate of development of this mite.

The summer eggs are deposited on the branches as well as on leaves, the winter eggs on branches only. The 1st generation deposits only summer eggs, the 2nd generation summer and winter eggs, the 3rd generation only winter eggs (GÄBELE, 1959; KREMER, 1956). According to GÄBELE a total of 25 to 30 eggs is deposited per female. The longevity of a female is on the average 23 to 28 days (there are no males). The number of generations per year is dependent on the climatic conditions; in the Netherlands three generations are observed.

4. FIELD STUDY

4.1. INTRODUCTION

The problem of the excessive increase of injurious mites and insects affecting fruit culture can be approached in two ways. The first is to determine correlations between the population density of the injurious organism and the situation as to food or natural enemies in which these densities occur. This approach provides not only qualitative but also quantitative data when the observations can be carried out over a series of years in a number of appropriate orchards. The second approach is experimental; the variations in the conditions are produced deliberately, and on the basis of the results an attempt is made to reach a conclusion concerning the significance of each factor for the development of the populations. Here, two further possibilities are conceivable: *a*) proceeding from the conditions in a completely neglected orchard and disturbing the existant situation by applying cultural measures, or *b*) proceeding from such a disturbed situation in a well-kept and sprayed orchard and suspending treatment so that the original situation is restored.

Since at the start of the investigation in 1952 no orchard was available in which the experimental method could be used, the first approach was followed until 1954. During this initial period the observations were carried out in three completely neglected orchards and three well-kept standard-tree orchards which had been planted 25 to 30 years previously. Within the two groups of orchards, however, there were rather large variations, for instance in the profile and management of the soil. In the well-kept orchards, also, the extent of the management varied widely as to fertilization, pruning, and chemical control. Finally, the disastrous floods of February 1953 caused the loss of several fields, which had to be replaced by others. It is clear that with this approach the number of variables was too large to permit reliable determination of correlations between the population densities of the fruit tree red spider mite and the circumstances under which these densities occur. In addition, the observation period was too short for this purpose. The remarks concerning this initial period are therefore intended only to convey a few results obtained from these orientational observations. The methods used for these observations are treated on page 17, where the main investigation is discussed.

The inventories made in this initial period showed that the population densities of *M. ulmi* in the neglected plots were very low, while *B. rubrioculus* occurred in greater but not very injurious numbers. In the well-kept plots, by contrast, the *M. ulmi* populations reached high densities and those of *B. rubrioculus* remained very limited. The number of predacious mites and predacious

FIG. 1. General view of the experimental field at Eversdijk. Plot I: untreated.
Overzicht van het proefveld te Eversdijk. Perceel I: onbehandeld.

FIG. 2. Experimental field at Eversdijk. Looking from Plot II towards Plots III and IV.
Proefveld te Eversdijk. Vanuit Perceel II gezien naar Perceel III en IV.

insects in the neglected plots was large in relation to the number in the well-kept plots, where it was almost zero.

Leaf analyses showed that the total nitrogen contents of the leaves from the well-kept plots on the average lay distinctly higher than those of the leaves from the neglected plots. No consistent differences in the potassium, magnesium, and phosphate content of the leaves was found between the well-kept and neglected plots.

The high population densities of *M. ulmi* were thus found in the well-kept orchards, in which, besides the absence of the phytophagous mite *B. rubrioculus* and of predators, a higher nitrogen content of the leaves was observed.

In 1954 the investigation obtained the use of an orchard which made it possible to apply the experimental method.

4.2. EXPERIMENTAL FIELD AT EVERSDIJK

4.2.1. *Introduction*

In March 1954, the Agricultural Research Council, T.N.O., put at our disposal part of a farm orchard leased in Eversdijk-Biezelinge (Zeeland), about 1.2 hectare in size, which had never been sprayed. The rented area was bordered on the North and West by the rest of the farm orchard and on the East and South by a hawthorn hedge. It was planted predominantly with standard apple trees on seedling rootstocks, 20 to 40 years of age, and comprised 22 different varieties of which Boskoop and Bellefleur were the most important. On the South side there was one row, composed predominantly of pear trees, which was not included in the experiment.

The orchard was surveyed by the Soil Section of the Research Station for Outdoor Fruit Growing at Wilhelminadorp; the soil was found to consist of a silt loam with a clay pan at a depth of $\pm$ 50 cm on the South side: since the row of fruit trees on the South side was not used for the observations, this created no difficulties.

As an experimental field, this somewhat heterogeneous standard-tree orchard (Figs. 1 and 2[1]) was certainly not ideal. In a fruit-growing area such as Zeeland, however, it is very difficult to find an unsprayed orchard and still more so one in which experimental treatment may be applied freely.

4.2.2. *Arrangement of the experimental field*

As we have pointed out (p. 12), the influence of the cultivation methods used in fruit growing on the development of the mite and insect pests can be studied in various ways. In the standard-tree orchard in Eversdijk we applied the experimental method as described ad *a*): in part of the completely neglected orchard the existing conditions were disturbed by the application of the methods required for economically sound fruit growing, and subsequent development of the mite and insect populations was followed. At the same time, a study was made of the effect of these measures on the physiological condition and development of the fruit trees.

Because of the available number of observation trees suitable for the investigation, we could achieve only single examples of the various treatments. The

[1]) All photographs were taken by the Ministry of Agriculture.

orchard was therefore divided into 4 plots for the study of the effect of the various treatments on the development of the mite and insect populations. The division was as follows:

Plot I – untreated
Plot II – soil cultivation, fertilization, pruning
Plot III – soil cultivation, fertilization, pruning and chemical control
Plot IV – chemical control.

The following abbreviations are used throughout:
–sfp: without soil cultivation, fertilization and pruning
+sfp: with soil cultivation, fertilization and pruning.

The object of the study was thus to investigate to what extent the excessive multiplication of the fruit tree red spider mite is due to the chemical control which causes the elimination of regulation by predators, or to the other treatments, i.e. soil cultivation, fertilization, and pruning which improve the nutritional position of the phytophagous mite, or whether it is caused by a combination of these two factors.

The first of these factors is represented in Plot IV, in which the chemical control was applied. Soil cultivation, fertilization, and pruning are carried out in combination in fruit growing for the improvement of the physiological condition of the fruit tree, which represents factor 2 (Plot II). The effect of these two factors combined on the development of *M. ulmi* was studied in Plot III.

For the observations, 6 Boskoop and 6 Bellefleur trees were chosen per plot. In Plot I, however, there were only 3 Boskoop trees; in 1954 in the surrounding unsprayed orchard 3 more Boskoop trees were used for the insect inventories. From 1955 on the number of insects was collected only on the 3 experimental trees and calculated for 6 trees.

4.2.3. *Cultural program*

4.2.3.1. Soil cultivation

Because of the sensitivity of many Zeeland soils to drought, the ground in most of the orchards in this region is clean-cultivated from spring until about the end of July. For this reason we clean-cultivated the soil in Plots II and II. In Plots I and IV the grass cover was maintained and was regularly mowed only for the convenience of the observations. The cut grass was removed in order to promote quicker depletion of the soil.

4.2.3.2. Fertilization

Among the observations in the three well-kept and three neglected orchards, the leaf analyses showed that only in the total nitrogen content of the leaves was there a distinct difference between the two types of orchard. The potassium, magnesium, and phosphate contents showed no consistent differences. We then attempted to bring the nitrogen content of the leaves in the +sfp plots up to the level found in the well-kept orchards by means of nitrogen dressing. Beginning in 1954, at about the end of March each year Plots II and III were fertilized with 300 kg of ammonium nitrate, the equivalent of ± 100 kg of pure nitrogen per hectare.

4.2.3.3. Pruning

In March 1954 a radical rejuvenation pruning was carried out in order to produce growth in the trees; in the following years only normal pruning was applied. No fruit thinning was performed.

4.2.3.4. Chemical control

In Plots III and IV a conventional spray program was used. The effect of the pesticides was not studied for each chemical separately; rather, we investigated the total effect of a control program such as is normally applied in fruit culture against phytophagous mites and their predators. The spraying was usually done with a low volume spraying machine and the concentrations used were 10 times the usual spray concentrations. In a few cases a high volume sprayer was used, for example in winter control with tar oil sprays and for the control of the woolly aphid (see Table I).

a. Fungicides

An attempt was made to combat apple scab (*Venturia inaequalis*) preventatively: with copper oxychloride, dinitrothiocyanobenzene, or ziram before blossoming. When necessary, a curative control, carried out only before blossoming, was done with an organomercury compound. After blossoming, several sprayings were done with ziram, followed by thiram or captan. In 1956 in August a commercial mixture of thiram and sulphur (AApirsul) was used for the simultaneous control of apple mildew (*Podosphaera leucotricha*) which had begun to appear on Boskoop.

b. Acaricides, insecticides, etc.

In April 1954 and 1955 tar oil winter washes were performed to control the injurious organisms which hibernate on or under the tree bark: eggs of the green apple aphid (*Aphis pomi* De G.) and the winter moth (*Operophtera brumata* L.); the woolly aphid (*Eriosoma lanigerum* Hausm.); the scale (*Lepidosaphes ulmi* L.); larvae of tortricids, etc. In addition, these sprays rid the trees of epiphytes.

Before blossoming in 1954 and 1955 a DDT spray was also applied against the larvae of such tortricids as *Spilonota ocellana* Sch. and *Adoxophyes reticulana* Hb., and the apple blossom weevil (*Anthonomus pomorum* L.). Since for *A. pomorum* the results were satisfactory, no separate control with DDT was required. At the end of June 1954 and the beginning of July 1955, DDT was also sprayed to control the tortrix species *S. ocellana* and *A. reticulana*, and the codling moth (*Enarmonia pomonella* L.). In view of the heavy increase of *M. ulmi* in 1955, no DDT was used after blossoming, the organophosphorus compounds diazinon and parathion being substituted. When many winter eggs of *M. ulmi* were present, spraying was done in the following years just before or after blossoming with the ovolarvicide chlorbenside mixed with diazinon. A further attempt was made to keep the fruit tree red spider mite population below the injurious level by summer spraying with diazinon or parathion, and at the end of July 1959, Kelthane was also used.

E. lanigerum was controlled with a high concentration of diazinon and another organophosphorus compound, Phosdrin; for *A. pomi* isolan was used.

TABLE 1. Spraying programs in Plots III and IV, 1954–1959. The pesticides were applied in the usual concentrations.

INSECTICIDES:	1954	1955	1956
March	tar oil [1])+		
April	DDT	tar oil+ DDT diazinon	
May		diazinon	diazinon (2×) chlorbenside [4]) + diazinon+
June	DDT	diazinon	
July	diazinon (2×)	DDT + diazinon	diazinon + isolan (2×) isolan
August	diazinon (2×)	diazinon (2×)+	isolan
September			parathion
FUNGICIDES: March			
April	copper oxychloride (2×) [2])	copper oxychloride dinitrothiocyanobenzene [3])	organomercury compound dinitrothiocyanobenzene
May	organomercury compound ziram	ziram (2×)	dinitrothiocyanobenzene ziram (2×)
June	ziram (2×)	ziram	ziram (2×)
July		ziram thiram	ziram (2×) thiram
August	thiram		AApirsul [5])
September			

[1]) *vruchtboomcarbolineum*
[2]) *koperoxychloride*
[3]) *dinitrorhodaanbenzeen*
[4]) *chloorparacide*

The complete spraying program is given in Table 1 and the chemical composition of the sprays is given in Table 2.

It should also be remarked that spraying could not always be done at the proper time because the apparatus was not always available. However, this again showed clearly that the application of a control method can be effective only if it is applied at the right moment.

Bestrijdingsschema's in de Percelen III en IV, 1954–1959. De middelen zijn in de gebruikelijke concentraties toegepast.

1957	1958	1959	INSECTICIDES:
parathion			March
	DDT + malathion +	parathion (2×) chlorbenside + parathion	April
diazinon	chlorbenside +	chlorbenside + parathion	May
diazinon + isolan (2×)		Phosdrin+	June
diazinon + isolan	diazinon + isolan	Kelthane	July
	diazinon + diazinon	Gusathion	August
diazinon+	diazinon +		September
			FUNGICIDES:
organomercury compound[6])		copper oxychloride	March
dinitrothiocyanobenzene ziram	copper oxychloride +	copper oxychloride organomercury compound ziram	April
ziram (2×)	organomercury compound ziram	ziram (2×)	May
thiram (2×)	captan (2×)	thiram	June
thiram	thiram	thiram	July
	thiram		August
thiram			September

[5]) contains sulphur + thiram / *bevat spuitzwavel + thiram*
[6]) *organische kwikverbinding*

+ high volume spray / *verspoten met motorspuit*

4.2.4. *Methods used for the inventory of mites and predators*

Mites:

For the determination of the population density of the mites, every 2 to 3 weeks in the early morning hours a sample of 100 leaves, arbitrarily distributed per plot and per variety, was collected and the mites and eggs on them counted in the laboratory with a binocular microscope. The leaves were transported in

TABLE 2. Common names and chemical names of the pesticides.
Chemische samenstelling der bestrijdingsmiddelen.

Common name: *Naam:*	Chemical name: *Scheikundige naam:*
chlorbenside *chloorparacide*	4-chlorobenzyl 4-chlorophenyl sulphide
DDT	1,1,1-trichloro-2,2-di-(4-chlorophenyl) ethane
diazinon	diethyl 2-isopropyl-6-methyl-4-pyrimidinyl phosphorothionate
Gusathion	0,0-dimethyl S-(4-oxo-benzotriazino-3-methyl) phosphorodithionate
isolan	1-isopropyl-3-methyl-5-pyrazolyl-dimethyl-carbamate
Kelthane	1,1,1-trichloro-2-hydroxy-2,2-di-(4-chlorophenyl) ethane
malathion	S-(1,2-di(ethoxycarbonyl)ethyl)dimethyl phosphorothiolothionate
parathion	diethyl 4-nitrophenyl phosphorothionate
Phosdrin	dimethyl-(1-methyl-2-carbomethoxyvinyl)-phosphate
captan	N-trichloromethylthio-4-cyclohexene-1,2-dicarboxyimide
dinitrothiocyanobenzene *dinitrorhodaanbenzeen*	2,4-dinitro-thiocyanobenzene
Karathane	dinitro-(1-methylheptyl)-phenyl crotonate
organomercury compound *organische kwikverbinding*	organomercury preparation
thiram	bis(dimethylthiocarbamoyl) disulphide
ziram	zinc dimethyldithiocarbamate

glass preserving jars to the laboratory, where they were immediately put in a refrigerator at ± 5°C so that the mites would remain on the leaves and the leaves stay fresh. It has been demonstrated by KUENEN (1946) that for the statistical significance of observations concerning *M. ulmi* a sample of 100 leaves of a given variety is sufficient. The number of leaves per tree and their total surface influences the error of the sample (HUECK, 1953), and in comparing the population density of the mites on pruned and unpruned trees of the same variety this factor could have affected the results to some extent. Although we were aware of the fact that the sampling was in this respect not completely adequate, time limitations made this method unavoidable.

In general, this method of sampling is adequate for mites which remain on the leaf through their entire summer cycle. *B. rubrioculus*, however, deposits its eggs on branches as well and especially on the older, rougher branches of the short shoots. The migration from branch to leaf is, however, according to KREMER (1956), strongly dependent on temperature and humidity. Because the samples were always gathered in the early hours of the morning, in our opinion the inventorying of a random sample of leaves provided us with a satisfactory measure of the population density of *B. rubrioculus*. In our investigation, correlation of the population density with various cultural measures is more important than the absolute numbers. In addition, this is the only means of determining the ratios of the *B. rubrioculus* to the *M. ulmi* populations.

In 1958 and 1959 time became available for a separate inventory of the *B. rubrioculus* population on both leaves and branches. Approximately every 14

FIG. 3. Inventory of predacious insects.
Inventariseren van roofinsekten.

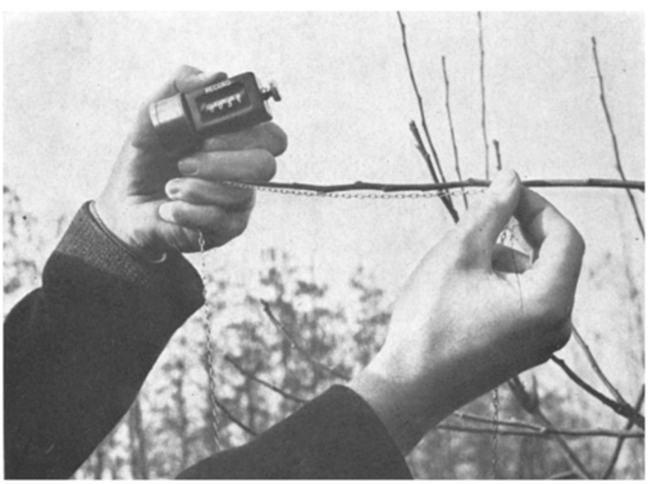


FIG. 4. Apparatus for measuring branch length.
Apparaat voor het meten van taklengte.

days a sample was taken consisting of 24 short shoots with leaves per variety per plot, 12 from the inside of the crown and 12 from outside the crown. Since there was considerable mutual difference among the samples as to number of leaves and length of the shoot, an average had to be sought for processing the data. It was found that the short shoots had an average of about one leaf per centimetre of shoot, so that for comparison of the densities in the unsprayed plots the number of mites and eggs per observation was calculated for the number per 10 cm of shoot + 10 leaves.

The time of sampling could not always be strictly maintained; when as a result of rain or mist the leaves were still wet in the morning, no samples were taken.

Predators:

The predatory mites were registered at the same time as the phytophagous mites. Predatory insects were collected by means of 'tapping' (see Fig. 3): in the early morning, between 6:30 and about 8:30, the lower branches of the standard trees were struck with a stick wound with a strip of rubber and the falling insects caught in a net. This net consisted of a 1 × 1 m wooden frame on which white cheesecloth was stretched. The predatory insects, both larvae and adults, were sorted by species into tubes to be counted and recorded in the laboratory. Unknown larvae and pupae were cultivated. The observations in 1951 and 1952 had shown that these inventories must be made early in the morning when the insects are not yet active and do not fly when the branch is tapped, although on very warm days this difficulty is of course not easily to avoid. Spiders were collected only qualitatively.

These inventories were also done every three weeks; in 1959 the assistance available and the favourable weather made it possible to sample every fortnight.

The numbers of insects collected do not, of course, provide absolute values. In the standard trees it was impossible to determine what percentage of the insect population was collected by tapping. The percentage of branches tapped was ± 20% for the unpruned and ± 30% for the pruned trees.

4.2.5. *Methods used for observations pertaining to the development of the fruit trees*

The determinations made for the fruit trees were:

a. mean total shoot length per 10 m of branch
b. mean number of fruit buds and leaf buds per 10 m of branch
c. percentage of fruit setting
d. quantity of fruit
e. mean fruit weight
f. nitrogen, potassium, calcium, and magnesium content of the leaves
g. moisture content of the leaves
h. mean leaf area
i. anatomical structure of the leaves.

a. Measurement of the number of centimetres of young shoots formed in the preceding season was made on 10 metres length of branch on the North, East, South, and West sides of the trees, thus on 40 metres of branch per tree.

From 1954 through 1956 this was done with a measuring rod. From 1957 on an apparatus designed by BUTIJN & VAN DER BOON (1957) was used (FIG. 4): with this apparatus the branch length is taken with an unwinding chain which operates a counter simultaneously; this counter gives the branch length in centimetres after a simple calculation.

b. The number of fruit buds and the number of leaf buds were counted for the combined 40 metres length of branch per tree. The measurements and counts for *a* and *b* were, of course, done before pruning.

c. On the same four sides of the tree 10 flower clusters, i.e. about $4 \times 50 = 200$ flower buds, were marked in the green-bud to pink-bud stages. The number of set fruit was counted after a few weeks, before June drop.

d. The yield of the fruit trees and the total fruit weight were determined.

e. For the picked apples the mean fruit weight was calculated.

f. For the determination of the nitrogen, potassium, calcium, magnesium, and phosphate content of the leaves of the experimental trees, a leaf sample comprising 100 leaves per plot was taken in the months of June through September.

For the interpretation of the data obtained from leaf analyses it is, according to MASON (1958), important to take into consideration the phenomenon that the concentration of the elements found in the leaves is strongly dependent on the position of the leaf on the shoot, the type of shoot, and the time of year in which the sampling is done. MULDER (1951), with this in mind, emphasized the importance of using leaves of long shoots in sampling because the short shoot shows most of the symptoms of any nutritional disturbance less clearly than the long shoots. When observations were begun in 1954, however, no long shoots were present in any of the plots, and after one year they were found only in the pruned plots during the entire season. In order to obtain as constant a sample as possible, we collected and analysed only leaves from the short shoots in all the plots.

The leaves were dried, ground, and analysed according to SCHUFFELEN et al. (1961), the total content of the various elements being determined in the dry matter.

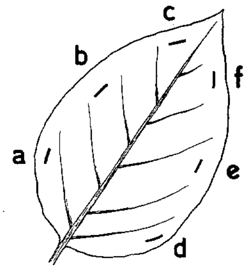
g. The moisture content of the leaves was determined as percentage of the fresh weight of the leaves.

h. The area per leaf was determined by tracing the outlines of the fresh leaves on paper, measuring the resulting figures by means of a planimeter, and calculating the mean of the values.

i. For a comparison of the anatomy of the leaves, measurements were done on the variety Bellefleur. Eight leaves from the fertilized Plot II were compared with 8 leaves from the untreated Plot I. The leaves were collected in August and held in 70% alcohol. In each leaf duplicate determinations were made at 6 different places (a–f). The six sites were chosen such that they fell about 1 cm from the leaf margin between two lateral veins (Fig. 5). The sections were cut by hand. For good transparency they were boiled in the following solution:

98% acetic acid	630 ml
distilled water	270 ml
HNO_3 (SG = 1.4)	60 ml
trichloroacetic acid	24 g.

FIG. 5. Diagram of leaf, indicating origin of samples used for anatomical observations.
Overzicht van de plaats der sneden op het blad gebruikt voor het anatomisch onderzoek.



For each dimension measured, the mean of the 12 observations in one leaf was calculated.

4.2.6. *Observations and results*

4.2.6.1. Introduction

A list is given below of all the mite species observed and the insects which our own observations and the literature indicate as predators on phytophagous mites.

ACARI			
Phytophagous:			
	Trombidiformes	Tetranychidae	*Metatetranychus ulmi* Koch
			Bryobia rubrioculus Scheuten
			Eotetranychus pomi Sep. [1]
		Phytoptipalpidae	*Brevipalpus oudemansi* Geyskes
		Tydeidae	*Tydeus* spp.
		Eriophyidae	Unknown
		Tarsonemidae	Unknown
	Sarcoptiformes	Czenspinskiidae	*Czenspinskia transversostriata* Oudms. [2]
Predacious:			
	Mesostigmata	Phytoseiidae	*Typhlodromus aberrans* Oudms. [3]
			Typhlodromus tiliae Oudms.
			Typhlodromus tiliarum Oudms.
			Typhlodromus finlandicus Oudms.
			Phytoseius macropilis Banks

[1] The Tetranychid reported in the publications of POST, 1954, 1956, and 1958 as *Schizotetranychus* sp. was at that time considered by VAN EYNDHOVEN as belonging to the genus *Schizotetranychus* Trägardh. Further investigation showed, however, that this mite must belong to the genus *Eotetranychus* and agrees with the species *E. pomi* published by SEPASGOSARIAN (1955).

[2] As far as can be deduced from the description and Figures given by NESBITT (1946), in VAN EYNDHOVEN's opinion this mite agrees not with the species *Czenspinskia lordi* Nesbitt 1946, reported for apple orchards, but with the species *Dondorffia transversostriata* Oudms. 1931. Since BAKER & WHARTON (1952) reported that *Czenspinskia* and *Dondorffia* are synonomous, *C. transversostriata* Oudms. would thus be the most exact name. Only females have been observed as yet. Material from DOSSE conveys the impression that males also occur; if this is indeed so, it will be necessary to consider whether the species is identical with *C. heterocomus* Michael 1903.

[3] The predatory mite species *Kampimodromus elongatus* Oudms. and *Typhlodromus vitis* Oudms. mentioned in previous publications (POST, 1954, 1956, 1958, 1959a) are according to CHANT (1955) the winter and summer forms of one species, *Typhlodromus* (*Amblyseius*) *aberrans* Oudms. For the predatory mite *Phytoseius spoofi* Oudms., VAN EYNDHOVEN gave the species name with reservations; on further study this species appears to be *P. macropilis* Banks.

Trombidiformes	Raphignatidae	*Mediolata mali* Ewing
	Anystidae	*Anystis* sp.
	Trombidiidae	*Allothrombium fuliginosum* Herm.
HEXAPODA		
Hemiptera-Heteroptera	Miridae	*Phytocoris tiliae* Fab.
		Phytocoris reuteri Saund.
		Pilophorus perplexus D. & S.
		Pilophorus clavatus L.
		Heterotoma meriopterum Scop.
		Malacocoris chlorizans Pz.
		Atractotomus mali M.D.
		Blepharidopterus angulatus Fall.
		Deraeocoris olivaceus F.
	Anthocoridae	*Anthocoris nemorum* L.
		Anthocoris nemoralis F.
		Anthocoris confusus Reut.
		Anthocoris gallarum-ulmi De G.
		Orius minutus L.
		Orius majusculus Reut.
		Orius niger Wolff
	Nabidae	*Nabis apterus* F.
		Nabis myrmecoides C.
		Nabis ferus L.
Neuroptera	Chrysopidae	*Chrysopa carnea* Steph.
		Chrysopa septempunctata Wesm.
	Hemerobiidae	*Micromus variegatus* Fabr.
		Hemerobius humulinus L.
	Coniopterygidae	*Conwentzia* sp.
Coleoptera	Coccinellidae	*Exochomus quadripustulatus* L.
		Adalia bipunctata L.
		Coccinella septempunctata L.
		Coccinella decempunctata L.
		Coccinella undecimpunctata L.
		Coccinella quinquepunctata L.
		Propylaea quatordecimpunctata L.
Diptera	Syrphidae	*Syrphus ribesii* L.
		Syrphus vitripennis Mg.
		Epistrophe balteata DeG.
		Lasiopticus selenicus Mg.
		Lasiopticus pyrastri L.

During the inventories of the predators, spiders were qualitatively collected because according to some authors small and immature spiders prey upon the fruit tree red spider mite (see also p. 37). No observations on this point were done in this study, however. A list of the species observed is available to those who are interested.

4.2.6.2. Development of *Metatetranychus ulmi* Koch

The inventories carried out in 1954 in the unsprayed part of the orchard confirmed the results of the inventories made in the three neglected orchards in 1952 and 1953. *M. ulmi* was present only sporadically; *B. rubrioculus* was much more strongly represented, and a great number of predatory mites and insects were also found.

Figures 6, 7, 8 and 9 give the development of the *M. ulmi* population on Boskoop and Bellefleur in the unsprayed and sprayed plots in the years 1954

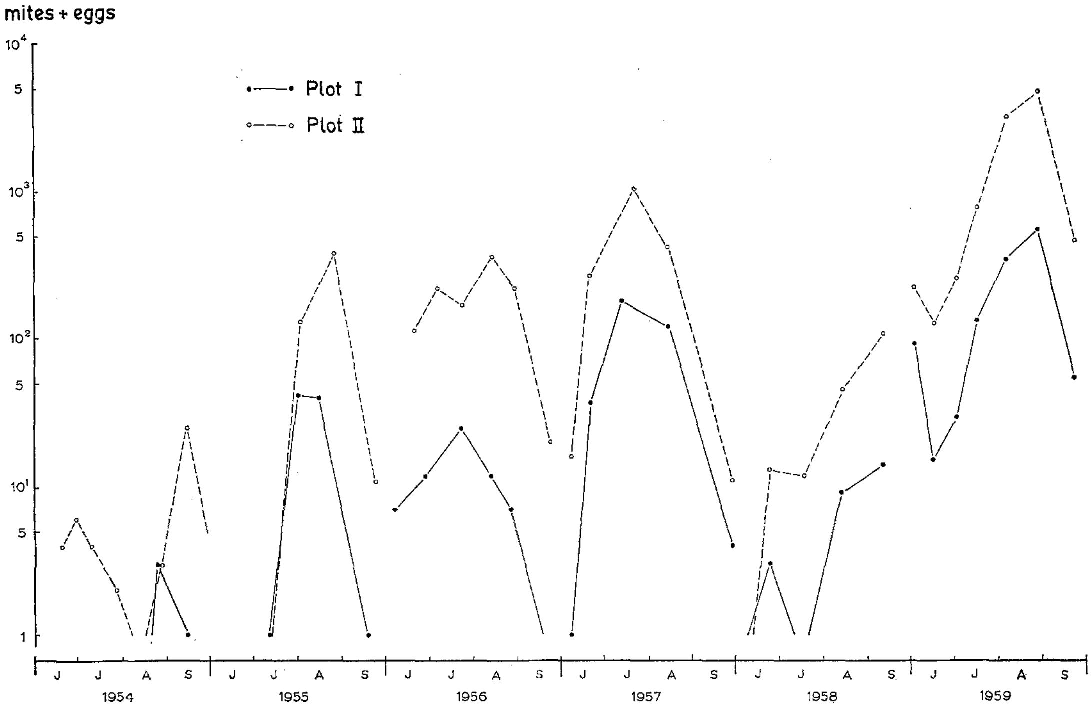


FIG. 6. Development of the *M. ulmi* population on Boskoop in the unsprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plot I: –sfp; Plot II: +sfp.
Populatie ontwikkeling van M. ulmi *op Schone van Boskoop in de onbespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Perceel I: –sfp; Perceel II: +sfp.*

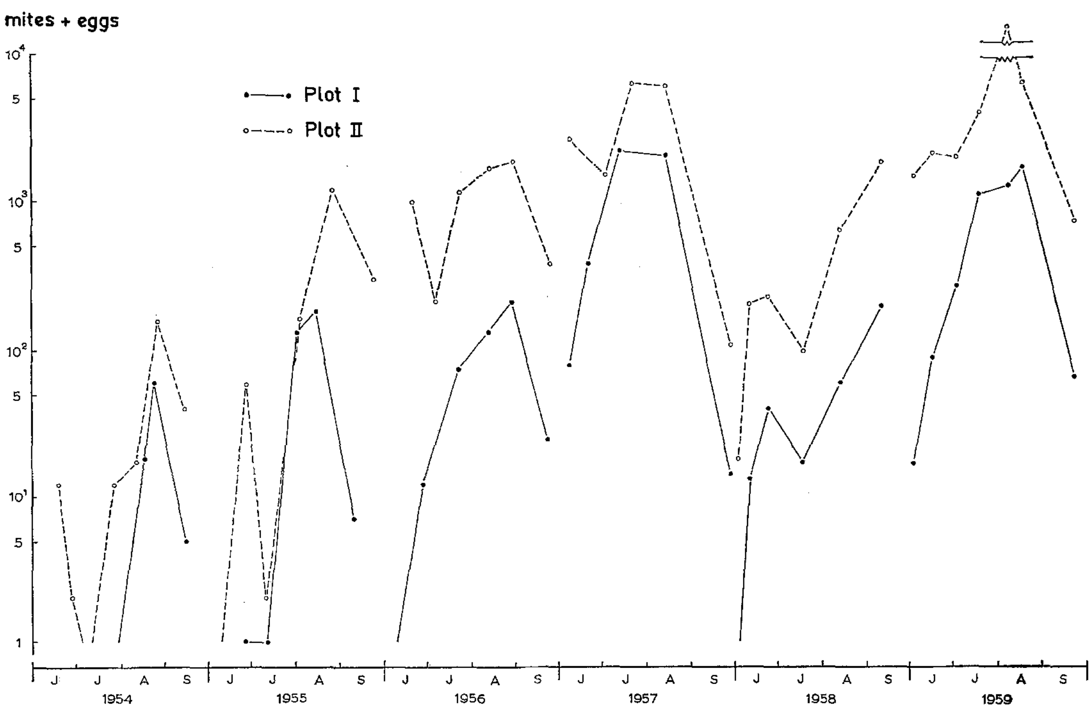


FIG. 7. Development of the *M. ulmi* population on Bellefleur in the unsprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plots as in Fig. 6.
Populatie ontwikkeling van M. ulmi *op Bellefleur in de onbespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Percelen als in fig. 6.*

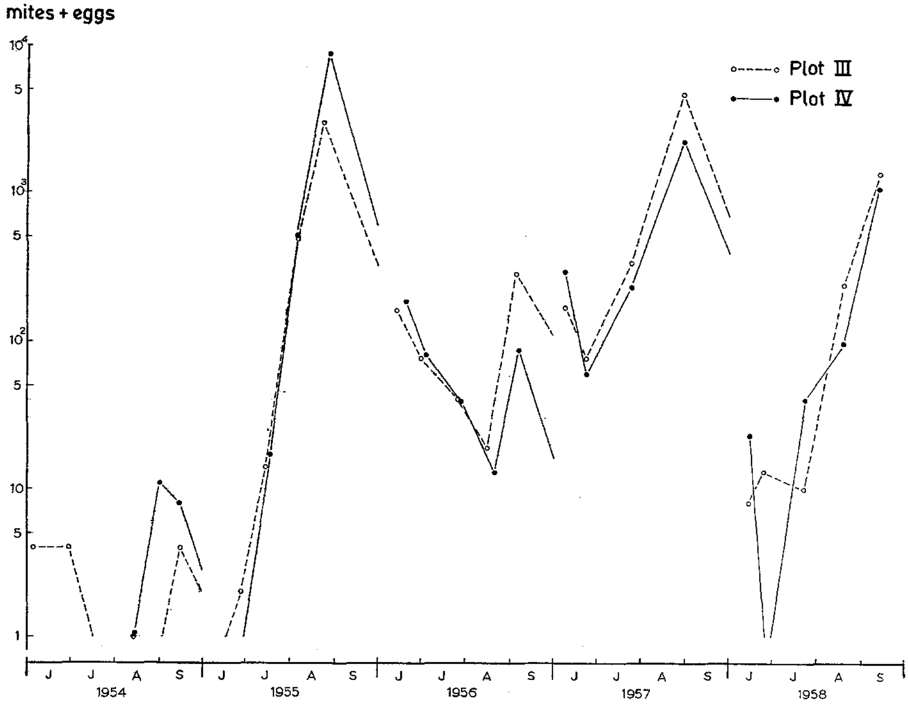


FIG. 8. Development of the *M. ulmi* population on Boskoop in the sprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plot III: +sfp; Plot IV: -sfp.
Populatie ontwikkeling van M. ulmi *op Schone van Boskoop in de bespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Perceel III: +sfp; Perceel IV: -sfp.*

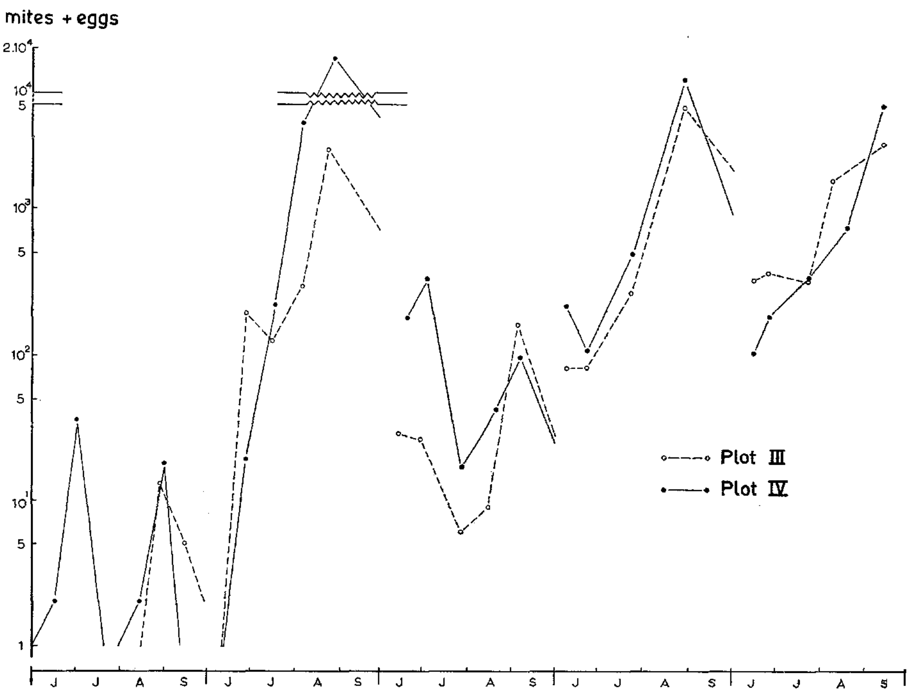


FIG. 9. Development of the *M. ulmi* population on Bellefleur in the sprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plots as in Fig. 8.
Populatie ontwikkeling van M. ulmi *op Bellefleur in de bespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Percelen als in fig. 8.*

through 1959. The numbers of mites and eggs per 100 leaves are plotted on a logarithmic scale against time in linear units.

Unsprayed section (Plots I and II):

As early as the second half of 1954 a large increase in the *M. ulmi* population in the +sfp Plot II was observed. In the succeeding years the density in the +sfp plot increased sharply, especially on Bellefleur (Figs. 6 and 7). The development of the mite population per year varied greatly as a result of the very variable weather conditions. In the –sfp Plot I the density of *M. ulmi* also increased somewhat over the years but this increase was relatively much smaller (for further discussion see p. 32).

Sprayed section (Plots III and IV):

Starting with the second year of the application of chemical control in Plots III and IV, which during the first few years was directed especially towards control of the larvae of the tortricids, apple blossom weevil, and apple scab, *M. ulmi* showed a sharp increase in both plots (Figs. 8 and 9). Only by intensive chemical control could this increase be held below a dangerous level, but the density nevertheless remained consistently higher than in the unsprayed plots.

In the sprayed plots the effect of soil cultivation, fertilization, and pruning was not clear. For Boskoop only, in a few of the years, the population density of *M. ulmi* in the +sfp Plot III lay higher than in the –sfp Plot IV (see p. 47).

4.2.6.3. Factors affecting the population density of *M. ulmi*

a. Nutrition

The condition of the tree, i.e. *M. ulmi*'s food source, was estimated according to the results of the observations reported on page 19. Figures 10–16 and Tables 3–6, give the results of these observations.

The cultural measures were first carried out in 1954. It can be seen from Figure 10 that even in 1955 there was a great difference in growth between the +sfp and –sfp plots. Because these differences were so spectacular, the growth measurements were suspended after 1957. In the –sfp plots the growth of the trees in the sprayed section was stronger than in the unsprayed section, with the exception of Boskoop in 1955.

In Boskoop the phenomenon of fruiting and non-fruiting years is clearly expressed in both the relative number of fruit buds in the –sfp plots (Fig. 11) and the percentage of fruit setting (Fig. 12) and, of course, especially in the yield (Fig. 13). The mean weight per apple in Boskoop in the 'on' years was on the average higher than in the 'off' years (Fig. 14). In Bellefleur the phenomenon of the 'on' years can be observed only in the yield.

It can also be seen from Figure 13 that in both varieties the yield in the +sfp plot is appreciably lower than in the –sfp plot, especially in Bellefleur. The radical pruning in 1954 and the following years caused the loss of a large proportion of the fruiting spurs in these old trees, and within the rather short period of the study they had not yet been able to recover.

The percentage of fruit setting is based on the number of healthy flower buds. The larvae of the apple blossom weevil and several tortricid species, particularly *S. ocellana* and *Recurvaria leucatella* Cl., caused the destruction in the unsprayed plots of a more or less large number of flower buds, and these

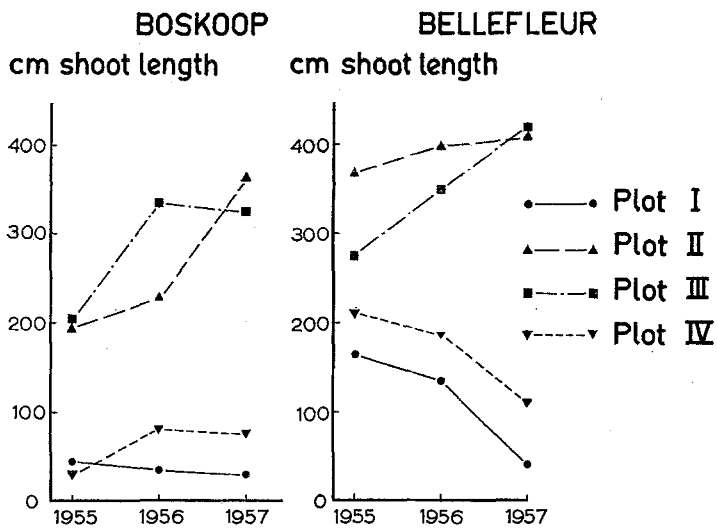


FIG. 10. Relation between total shoot length per plot and the treatment used in 1955–1957. Mean total shoot length in centimetres per 10 metre branch.
Plot I: unsprayed −sfp — Plot III: sprayed +sfp
Plot II: unsprayed +sfp — Plot IV: sprayed −sfp
Invloed van de cultuurmaatregelen op de totale scheutlengte per perceel in 1955–1957. Gemiddelde totale scheutlengte in cm per 10 m taklengte.
Perceel I: onbespoten −sfp — Perceel III: bespoten +sfp
Perceel II: onbespoten +sfp — Perceel IV: bespoten −sfp

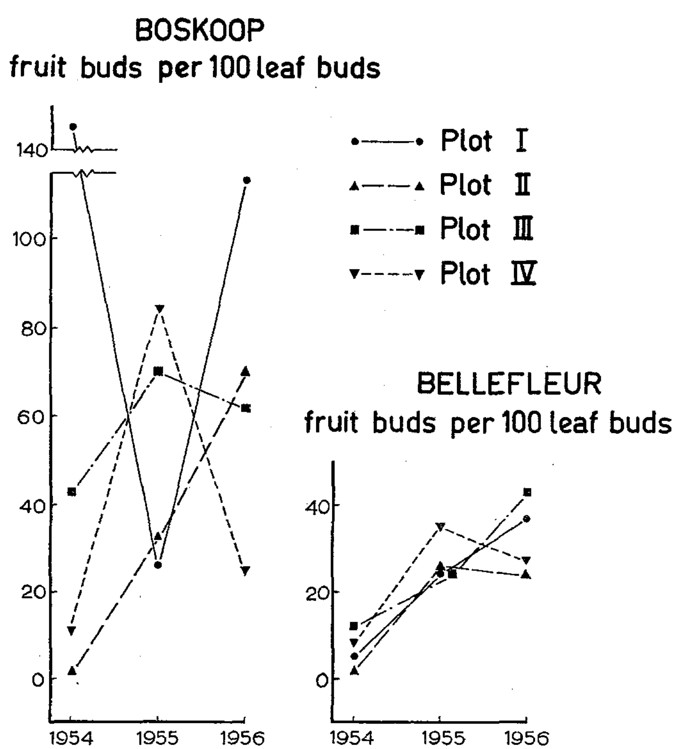


FIG. 11. Relation between number of fruit buds and leaf buds per plot and the treatment used in 1954–1956. Mean number of fruit buds per 100 leaf buds. Plots as in Fig. 10.
Invloed van de cultuurmaatregelen op het aantal gemengde knoppen en bladknoppen in 1954–1956. Gemiddeld aantal gemengde knoppen per 100 bladknoppen. Percelen als in fig. 10.

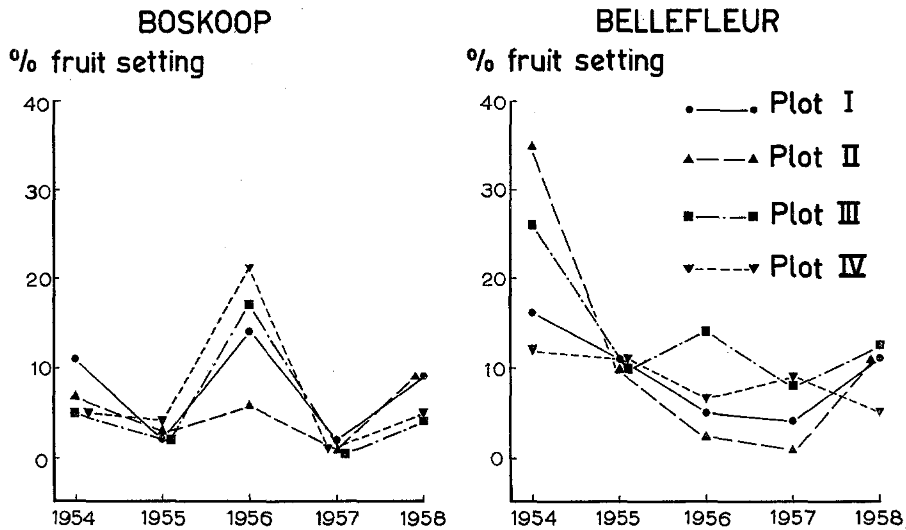


FIG. 12. Relation between fruit setting per plot and the treatment used in 1954–1958. Mean percentage of fruitsetting. Plots as in Fig. 10.
Invloed van de cultuurmaatregelen op de vruchtzetting per perceel in 1954–1958. Gemiddeld percentage vruchtzetting. Percelen als in fig. 10.

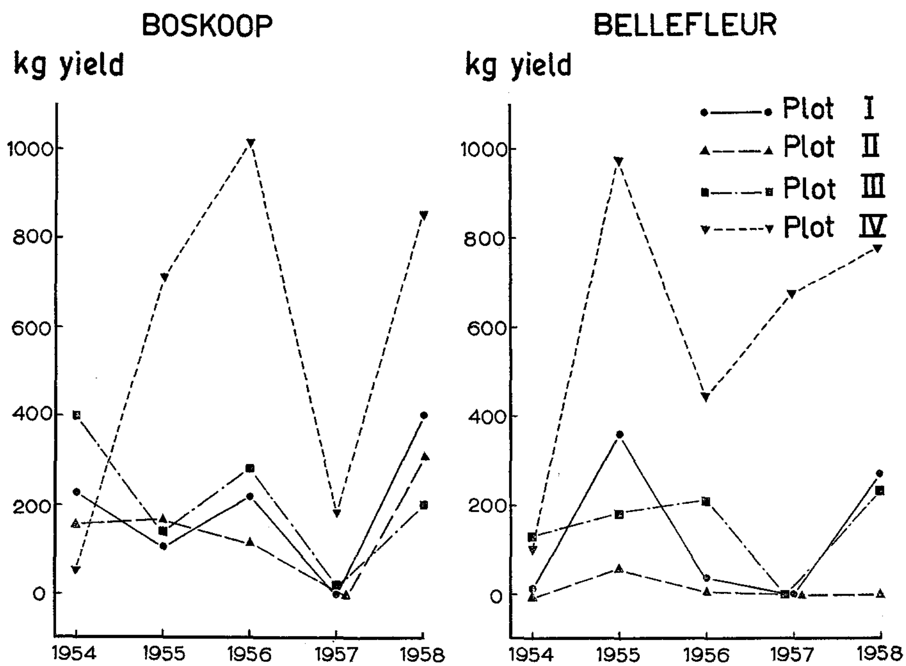


FIG. 13. Relation between total yield per plot and the treatment used in 1954–1958. Yield in kilogram. Plots as in Fig. 10.
Invloed van de cultuurmaatregelen op de totale opbrengst per perceel in 1954–1958. Opbrengst in kilogram. Percelen als in fig. 10.

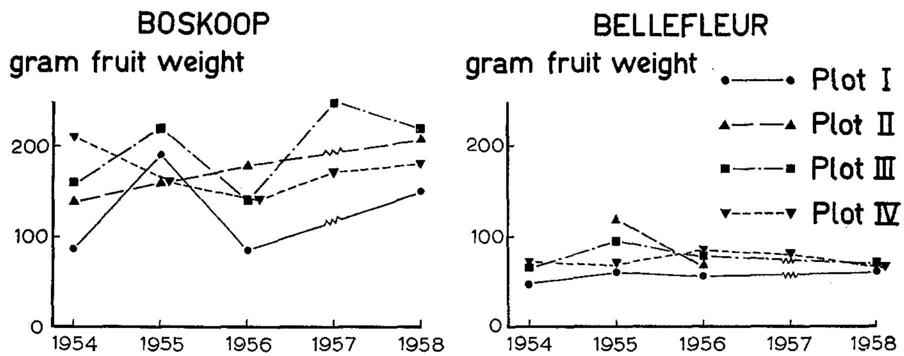


FIG. 14. Relation between fruit weight per plot and the treatment used in 1954–1958. Mean fruit weight in gram. Plots as in Fig. 10.
Invloed van de cultuurmaatregelen op het gewicht per appel per perceel in 1954–1958. Gemiddeld gewicht per appel in gram. Percelen als in fig. 10.

were therefore not included in the calculation of the percentage of fruit setting. The year 1957 was an exception to this: the number of flower buds damaged by *A. pomorum* (so-called 'capped' blossoms) could no longer be determined because they had dropped before the count was made.

Chemical composition of the leaves:

Figures 15 and 16 give the results of the nitrogen determinations done in 1954 through 1959. Tables 3–6 give the means of the potassium, calcium, magnesium, and phosphate contents in June, July, and August of these years.

TABLE 3. Mean potassium content of the leaves in meq per 100 gram dry matter during June, July and August, 1954–1959.
Gemiddeld kaliumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1954–1959.

	Boskoop				Bellefleur			
	unsprayed *onbespoten*		sprayed *bespoten*		unsprayed *onbespoten*		sprayed *bespoten*	
	–sfp	+sfp		–sfp	–sfp	+sfp		–sfp
Plots: *Percelen:*	I	II	III	IV	I	II	III	IV
1954	40.8	50.4	42.4	40.6	52.8	47.9	50.6	48.4
1955	45.0	46.7	43.1	40.4	61.2	55.9	53.9	53.2
1956	46.1	50.5	47.2	46.0	50.7	55.7	56.1	47.6
1957	42.3	30.4	48.4	26.6	52.7	55.2	51.1	48.9
1958	47.4	48.6	45.3	47.2	47.9	50.8	48.0	45.7
1959	47.7	46.9	–	–	54.0	55.9	–	–

Plots I & IV: without soil cultivation, fertilization, and pruning.
Plots II & III: with soil cultivation, fertilization, and pruning.

Perceel I & IV: zonder grondbewerking, bemesting en snoei.
Perceel II & III: met grondbewerking, bemesting en snoei.

TABLE 4. Mean calcium content of the leaves in meq per 100 gram dry matter during June, July and August, 1954–1959.
Gemiddeld calciumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1954–1959.

	Boskoop				Bellefleur			
	unsprayed *onbespoten*		sprayed *bespoten*		unsprayed *onbespoten*		sprayed *bespoten*	
	–sfp	+sfp		–sfp	–sfp	+sfp		–sfp
Plots: *Percelen:*	I	II	III	IV	I	II	III	IV
1954	66	64	63	58	50[1])	60[2])	55	56
1955	65	63	67	66	60	65	59	61
1958	70	65	68	71	66	69	62	61
1959	67	58	–	–	67	58	–	–

1) June and July only — 1) *Alleen juni en juli*
2) July and August only — 2) *Alleen juli en augustus*

TABLE 5. Mean magnesium content of the leaves in meq per 100 gram dry matter during June, July and August, 1954–1959.
Gemiddeld magnesiumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1954–1959.

	Boskoop				Bellefleur			
	unsprayed *onbespoten*		sprayed *bespoten*		unsprayed *onbespoten*		sprayed *bespoten*	
	–sfp	+sfp		–sfp	–sfp	+sfp		–sfp
Plots: *Percelen:*	I	II	III	IV	I	II	III	IV
1954	33.6	31.6	30.3	29.5	30.6	29.5	30.8	30.0
1955	20.8	22.0	21.7	20.9	21.4	23.1	20.8	18.9
1958	18.5	18.5	20.4	18.9	19.9	20.5	17.7	18.2
1959	19.3	20.6	–	–	20.8	21.9	–	–

TABLE 6. Mean phosphate content of the leaves in mmol per 100 gram dry matter during June, July and August, 1954–1959.
Gemiddeld fosfaatgehalte der bladeren in mgmol per 100 gram droge stof gedurende juni, juli en augustus, 1954–1959.

	Boskoop				Bellefleur			
	unsprayed *onbespoten*		sprayed *bespoten*		unsprayed *onbespoten*		sprayed *bespoten*	
	–sfp	+sfp		–sfp	–sfp	+sfp		–sfp
Plots: *Percelen:*	I	II	III	IV	I	II	III	IV
1954	4.9	4.3	4.3	4.5	5.8	5.6	4.8	5.3
1955	4.2	6.0	5.9	5.3	8.5	8.4	7.9	8.4
1958	4.2	4.8	4.7	5.1	6.4	6.1	5.1	5.8
1959	3.9	4.9	–	–	5.3	4.9	–	–

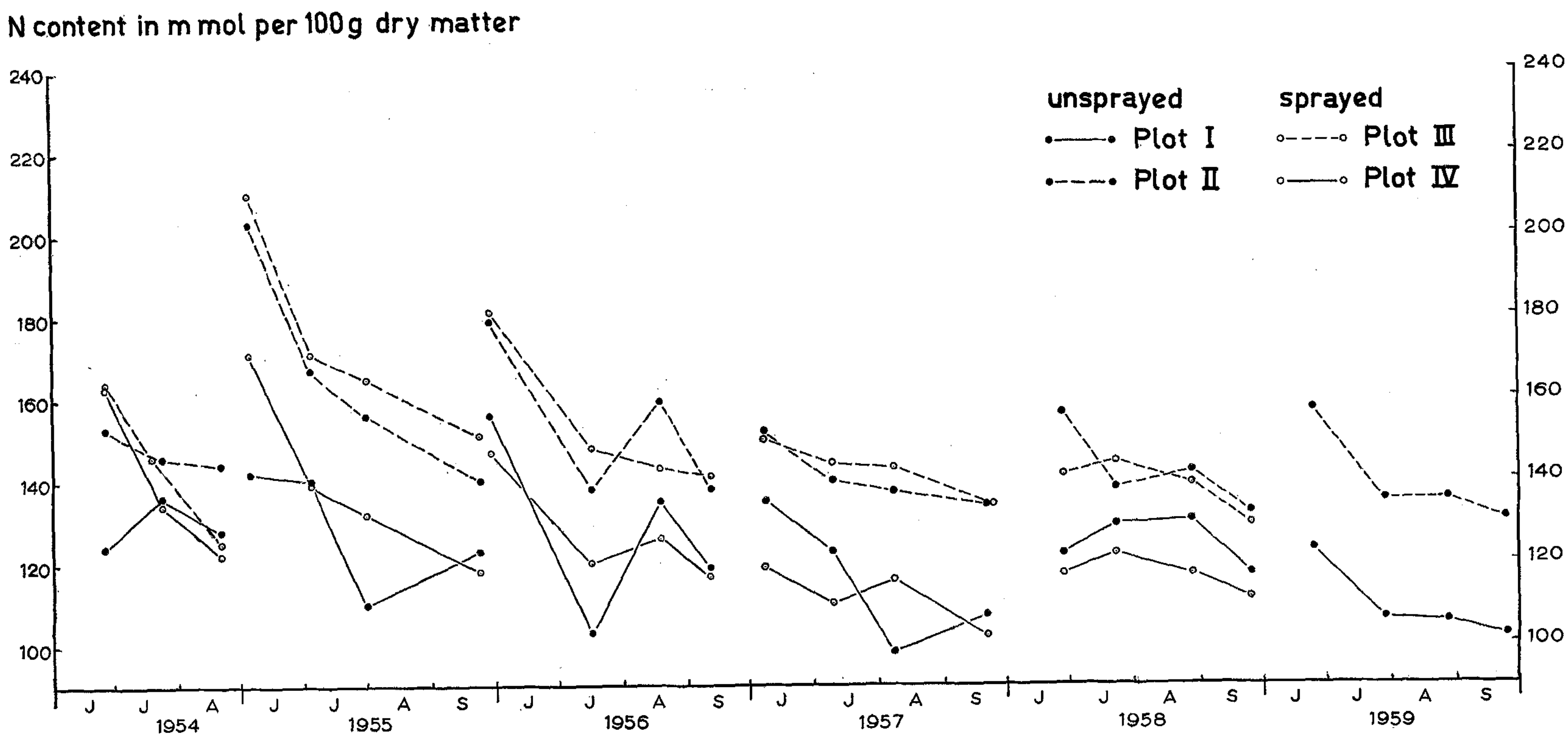


FIG. 15. Relation between total nitrogen content of the leaves of Boskoop and the treatment used during 1954–1959. Nitrogen content in mmol per 100 gram dry matter. Plots as in Fig. 10.

Invloed van de cultuurmaatregelen op het totale stikstofgehalte der bladeren van Schone van Boskoop gedurende 1954–1959. Stikstofgehalte in mgmol per 100 gram droge stof. Percelen als in fig. 10.

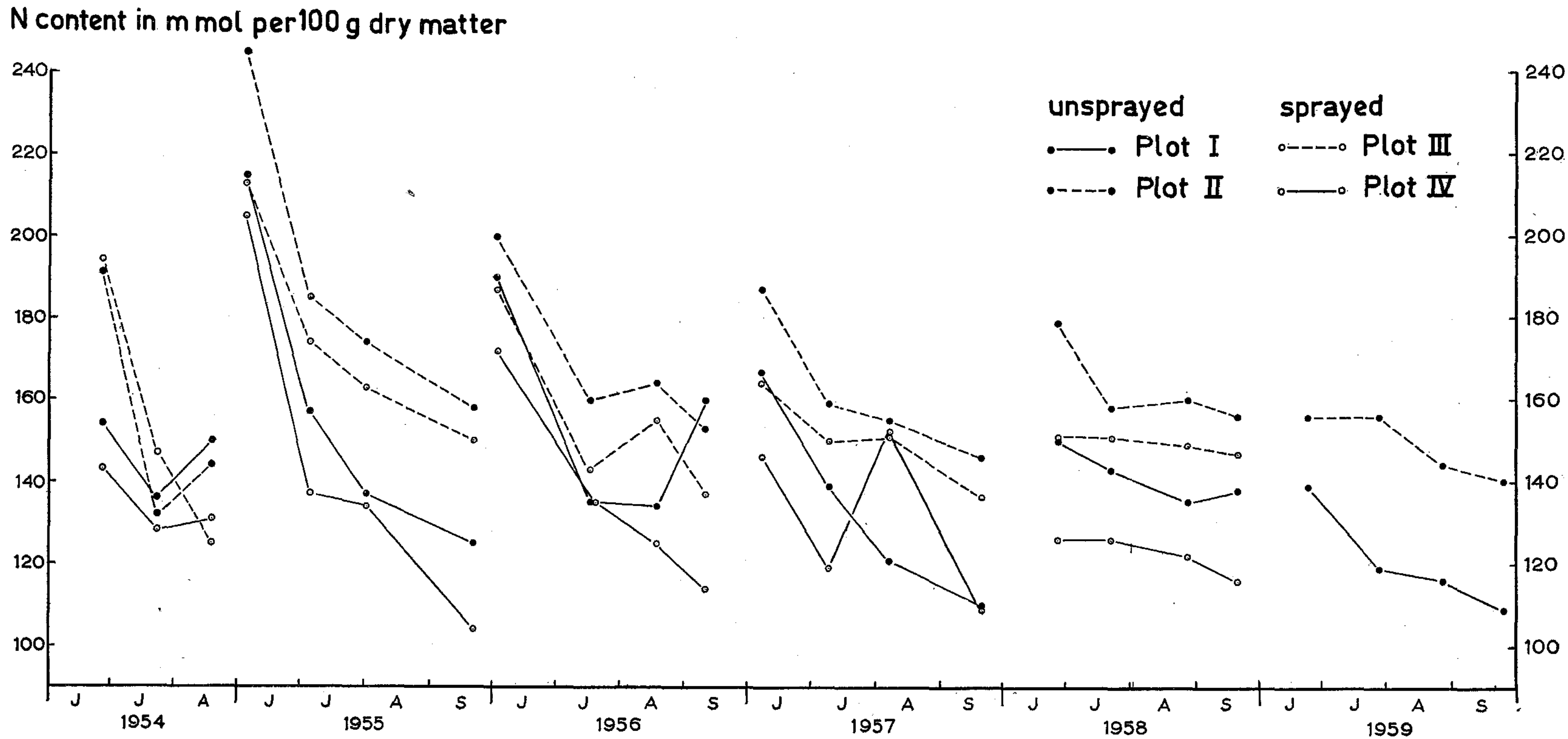


FIG. 16. Relation between total nitrogen content of the leaves of Bellefleur and the treatment used during 1954–1959. Nitrogen content in mmol per 100 gram dry matter. Plots as in Fig. 10.
Invloed van de cultuurmaatregelen op het totale stikstofgehalte der bladeren van Bellefleur gedurende 1954–1959. Stikstofgehalte in mgmol per 100 gram droge stof. Percelen als in fig. 10.

Figures 15 and 16 indicate that in the +sfp Plots II and III, even in 1954, changes in the total nitrogen content appear as a result of the treatment applied, although the values still overlap to some extent. From 1955 on, however, the values differ widely, with the exception of several isolated cases (e.g. in Bellefleur in August 1957). These exceptions are in all probability to be attributed to an error in sampling. The nitrogen contents in the corresponding sprayed and unsprayed plots differ somewhat now and then, but no distinct trend can be distinguished.

No consistent differences in the potassium, calcium, magnesium, and phosphate contents of the leaves could be found between the two treatments. In 1956 and 1957 no analyses of the calcium, magnesium, and phosphate content could be carried out.

The increase in the population density of *M. ulmi* in the unsprayed +sfp plot (Figs. 6 and 7) runs parallel with the increase in the total nitrogen content of the leaves in this plot following cultivation, fertilization, and pruning (Figs. 15 and 16). The widely varying weather conditions caused the levels of both to vary greatly from one year to another. At the same time, the stronger development of *M. ulmi* on the Bellefleur variety in relation to Boskoop was accompanied by a higher total nitrogen content of the former. An etiological connection seems obvious here. In the sprayed plots there was no correlation between the density of *M. ulmi* and the total nitrogen content of the leaves.

It has been mentioned that in addition to the strong increase of *M. ulmi* in the unsprayed +sfp plot there was also a small increase in the –sfp plot. Because of the limited number of experimental trees per plot, it became necessary to include in the study trees bordering the fertilized plot; the chance that these trees were affected by factors from adjacent plots was thus large. To examine this effect, the population density of the fruit tree red spider and predatory mites per tree (50 leaves per tree) and the total nitrogen content of the leaves were determined in a uniform row of Bellefleurs. Of this row of Bellefleurs, trees nos. 1, 2, and 3 were in the unfertilized plot and tree no. 4 in the fertilized plot. Table 7 gives the total mean numbers of mites + eggs of the fruit tree red spider mite and the predatory mites per 100 leaves, as well as the mean nitrogen content of the leaves during the months of July, August, and September, given in mmol per 100 gram of dry matter.

Table 7 indicates that there is indeed a 'border' effect. This effect may have been caused by an effect on the trees in the –sfp plot by fertilization in the adjacent plot and by migration of mites from the plot with the highest mite population density to the plot with a lower density.

In Table 7 it can be seen that the increase of the population density on the trees from the –sfp towards the +sfp plot parallels the increase in the average nitrogen content of the leaves. The mean densities per 50 leaves sampled per month also show in most cases a correlation with the nitrogen content of the same month (Table 8).

The drop in the population densities of *M. ulmi* from the +sfp plot towards the –sfp plot is roughly proportional to a drop in the nitrogen contents of the trees from no. 4 towards no. 2.

For September this is not the case: in connection with the high population densities in the +sfp plot *M. ulmi* probably began earlier to deposit winter eggs on the spurs, where they remained outside our observations (see p. 11).

FIG. 26. Infestation of the leaf by *E. pomi*. Right: upper surface of the leaf. Left: under surface of the leaf.
Aantasting van blad door E. pomi. *Rechts: bovenkant van het blad. Links: onderkant van het blad.*

FIG. 17. Apparatus for determining the number of mites transported by wind.
Apparaat ter bepaling van het aantal met de wind verplaatste mijten.

TABLE 7. Mean population density of *M. ulmi* and predacious mites per 100 leaves and the mean total nitrogen content of the leaves in the unsprayed plots from July to September, 1959.
Gemiddelde populatiedichtheid van M. ulmi *en roofmijten per 100 bladeren en gemiddeld totaal stikstofgehalte der bladeren in de onbespoten percelen van juli tot septeuber, 1959.*

Bellefleur	West / *West* ←			→ East / *Oost*
mites + eggs *mijten + eieren*	I –sfp			II +sfp
tree no.: *boom no.:*	1	2	3	4
M. ulmi	641	801	1245	3274
predacious mites/*roofmijten* .	115	119	143	281
mmol N/*mgmol N*	110	110	123	142

TABLE 8. Mean population density of *M. ulmi* per 50 leaves and the total nitrogen content of the leaves in July, August and September, 1959.
Gemiddelde populatiedichtheid van M. ulmi *per 50 bladeren en het totale stikstofgehalte der bladeren in de maanden juli, augustus en september, 1959.*

tree no.: *boom no.:*	July		August		September	
	N	M + E	N	M + E	N	M + E
–sfp 1	118	104	106	583	106	14
2	119	83	103	719	109	82
3	131	203	126	1081	112	126
+sfp 4	155	1122	140	2698	132	30

N: N content in mmol per 100 gram dry matter.
M + E: Number of mites + eggs of *M. ulmi.*
N: *N-gehalte in mgmol per 100 gram droge stof.*
M + E: *Aantal mijten + eieren van* M. ulmi.

A certain effect must also be ascribed to transportation of the mites by the wind from the +sfp to the –sfp plot (ANDERSEN, 1948; KUENEN, 1946; MARLÉ, 1951). During the period of the observations described below, in the summer of 1959, there was a prevailing dry East wind which could have blown mites from the densely populated +sfp plot to the –sfp plot lying to the West. These numbers were, however, small, as shown by the orientational counts of mites and eggs on vaseline-covered slides. These slides were clamped between two wooden laths covered with foam plastic which were placed on poles at the height of the crown of the trees between the –sfp and +sfp plots (Fig. 17). The total surface of the vaseline-covered slides was 2025 cm^2. The numbers are very small compared to those reported by ANDERSEN (1948): minimum, 17 per hour per m^2 on 1 August; maximum, 400 per hour per m^2 on 6 October (Table 9).

It should also be noted that 1959 was an exceptional summer by Dutch standards, with a strongly predominating warm, dry East wind. Normally, there are generally prevailing moist West winds which would have severely limited an increase of the fruit tree red spider mite population in the –sfp plots caused

TABLE 9. Number of *M. ulmi* mites on the vaseline mite trap.
Aantal M. ulmi *mijten op de totale glasoppervlakte.*

period *periode*	number of mites *aantal mijten*
16/6–30/6	10
2/7–14/7	8
20/7– 5/8	8
7/8–27/8	111
31/8–11/9	24

by wind-borne mites from the heavily populated adjacent +sfp plot lying East of it.

The population density of the predatory mites increases with the population density of the phytophagous mites (Table 7). The sharp increase in the harmful mites can thus not be ascribed here to a reduction in the number of predatory mites.

The chances for an effect on the mite population in the –sfp plot from the fertilization in the adjacent plot is, therefore the most probable factor.

Moisture content of the leaves:

The leaves of trees from well-kept orchards give the impression of being more turgescent than those from trees in neglected orchards. The investigations carried out by KENNEDY & BOOTH (1959) and KENNEDY, LAMB & BOOTH (1958) among others, have brought out the effect of the moisture content of the host plant on the development and reproduction of the aphid *Aphis fabae* Scop. Since the moisture content of the leaves may also be important for the development of the phytophagous mites, the moisture content of the leaves on which the mites were counted was determined in percents of the fresh weight of the leaves. The results of these observations indicate that there are no differences between the moisture contents of the leaves from the +sfp and –sfp plots or between the sprayed and unsprayed plots. This factor can therefore have had no effect on the differences in the development of *M. ulmi* in the +sfp and the –sfp plots.

Leaf area:

In order to determine whether there was any difference between the mean area of the leaves from the +sfp and –sfp plots, a leaf sample of 100 leaves was taken each week in 1954 and 1955 during the summer months and the leaf area determined. From 1956 through 1959 the areas of the mite-sample leaves were measured. No difference was observed, and there was a great deal of variation during the course of the season. In taking the sample the chance for picking young and therefore smaller leaves was greater in the +sfp plots because during the first half of the season many new leaves are formed in these plots.

In the –sfp plots the formation of young shoots with leaves was much smaller (Fig. 10, p. 26). In August there is little growth, so that the differences in growth between the +sfp and –sfp plots give less trouble. The leaf area measurements from August in the various years were therefore used for comparison. These areas also showed no consistent differences caused by the various treatments. If the area of the leaves is taken into consideration in determining the population density of the mites, it can have no effect on our conclusion concerning the difference in development in the +sfp and –sfp plots. Because the Bellefleur leaf is smaller than that of Boskoop, the differences in population density of *M. ulmi* on the two varieties which are shown on page 23 become even greater (Table 10).

TABLE 10. Mean population density of *M. ulmi* per 100 cm² of leaf area in August.
Gemiddelde populatiedichtheid van M. ulmi *per 100 cm² bladoppervlakte in augustus.*

	Boskoop				Bellefleur			
mites + eggs *mijten + eieren*	unsprayed *onbespoten*		sprayed *bespoten*		unsprayed *onbespoten*		sprayed *bespoten*	
	–sfp	+sfp		–sfp	–sfp	+sfp		–sfp
Plots: *Percelen:*	I	II	III	IV	I	II	III	IV
1956	0	10	1	0	6	72	0	2
1957	5	14	20	86	90	271	235	336
1958	0	2	9	4	3	34	71	35
1959	17	163	–	–	101	1193	–	–

Anatomical structure of the leaves:

Work done by BALDINI (1960) has shown that fertilization of apple trees by means of urea foliar sprays increases the chlorophyll and nitrogen content of the leaves and thickens the mesophyll, especially the spongy mesophyll. Because of the possibility that the anatomical structure of the leaf affects the development of the *M. ulmi* population, the measurements of various parts of the leaf were determined. The method used has already been discussed (see p. 20).

Measurements done on Bellefleur leaves from the unsprayed plots showed that between the +sfp and –sfp plots there was a difference in the total thickness of the leaf and in the width of the palisade mesophyll. In the +sfp plot these measurements were significantly larger (at the 5% level) than in the –sfp plots.

This is in complete agreement with the observations in the Lombartscalville variety in the Kuenen's Hof experimental field (see p. 62). Because the results of the measurements of the cuticle of the leaves from the Eversdijk and Kuenen's Hof experimental fields differed essentially, they could not be used without further investigation.

Thus, in the unsprayed plots the highest population density of *M. ulmi* occurs in the +sfp plot where the leaves, in addition to a higher total nitrogen content, have a thicker palisade mesophyll. In the +sfp plots there was also a more vigorous growth of the trees than in the –sfp plots. In the sprayed plots the relationship between population development of *M. ulmi* and the cultural practices of soil cultivation, fertilization, and pruning is not expressed.

b. Predators

Only the predators are considered as natural enemies of the fruit tree red spider mite. It is known from the literature (MUNGER et al., 1959; SMITH et al., 1959) that a virus disease can be responsible for high mortality in the citrus mite (*Panonychus citri* McG.). STEINHAUS (1959) assumes, on the basis of his obser-

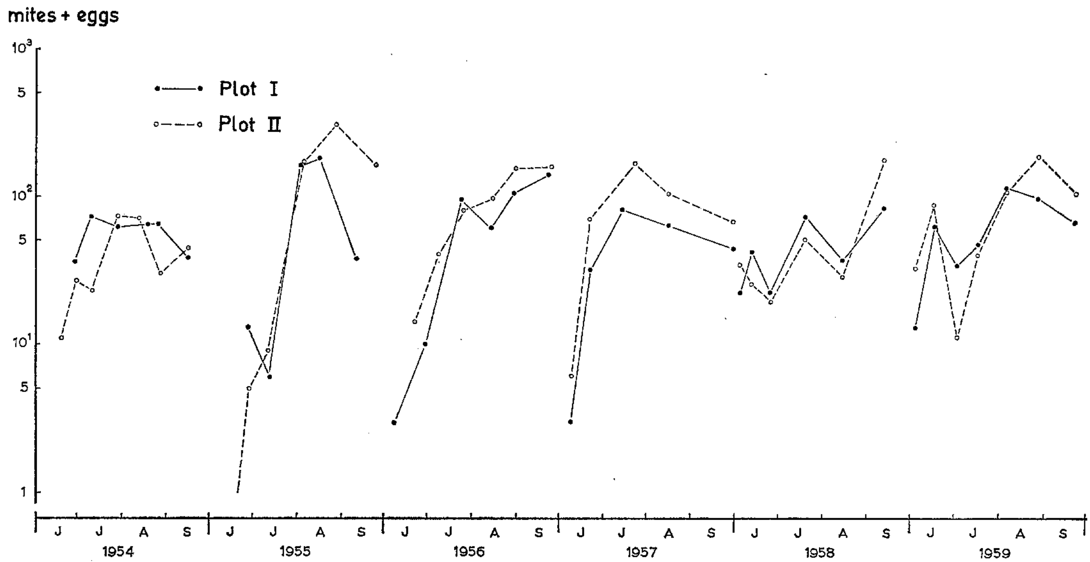


FIG. 18. Population density of predacious mites on Boskoop in the unsprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plot I: –sfp; Plot II: +sfp.
Populatiedichtheid der roofmijten op Schone van Boskoop in de onbespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Perceel I: –sfp; Perceel II: +sfp.

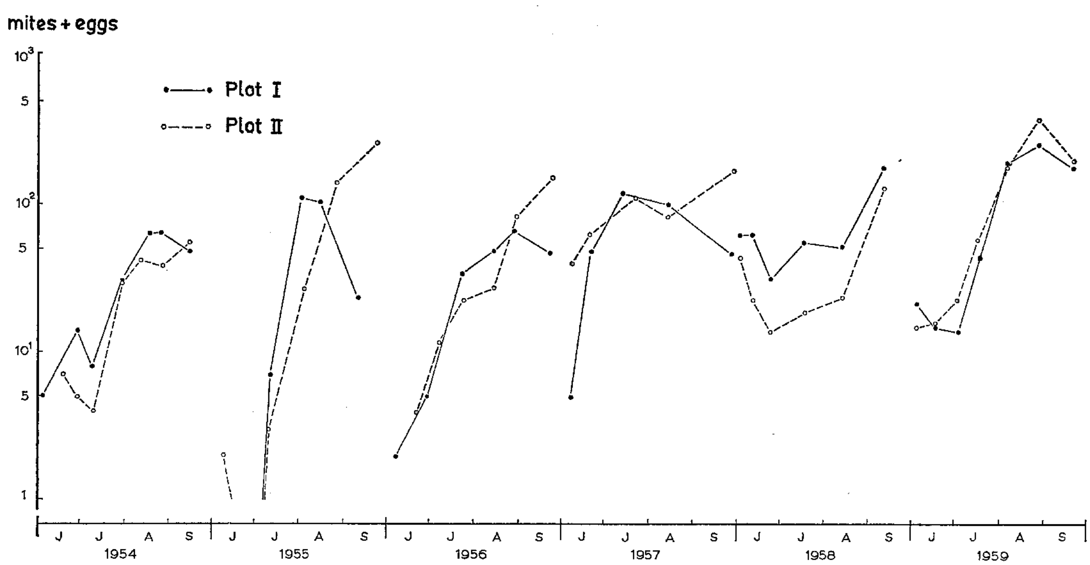


FIG. 19. Population density of predacious mites on Bellefleur in the unsprayed plots during 1954–1959. Number of mites + eggs per 100 leaves. Plots as in Fig. 18.
Populatiedichtheid der roofmijten op Bellefleur in de onbespoten percelen gedurende 1954–1959. Aantal mijten + eieren per 100 bladeren. Percelen als in fig. 18.

vations, the presence of a virus disease in *Panonychus ulmi* on nut trees in California. In the Netherlands there have been no findings of any virus disease for *M. ulmi*, however.

Among the predators there are both mite and insect species. Of the predatory insects, the predatory Heteroptera are the most numerous; the other predatory insects belong to the Neuroptera, Coleoptera, and Diptera (see p. 22). The data concerning the predatory mites and Heteroptera in the unsprayed plots on Boskoop and Bellefleur are given in Figures 18, 19, 20, and 21. Since the predatory insects other than predatory Heteroptera seldom prey on the fruit tree red spider mite, these are not included in the Figures but are reported in Table 11 and 13.

Unsprayed plots

Predatory mites:

It can be seen in Figures 18 and 19, beginning in 1955, the population densities of the predatory mites in the unsprayed plots, both +sfp and –sfp, lie on about the same level early in the season. From July onward, however, the densities, with the exception of Bellefleur in 1958, are highest in the +sfp plots in which the high population densities of *M. ulmi* occur. In the winter season the predatory mites are reduced in number, after which several months are required before they increase to any extent. Over the years there is no great variation. The species observed are given on pages 21, 22. A large proportion of the mites belong to the species *Typhlodromus aberrans* (Phytoseiidae). In 1959 the mite *Mediolata mali* suddenly appeared in larger numbers; from 1954 to 1959 it was rarely seen.

Predatory Heteroptera:

The predatory Heteroptera (and the other predatory insects as well) in general also do not reach a population density of any importance until full summer. The differences between the +sfp and –sfp plots are very irregular.

The most frequent species were, on the whole, *Phytocoris tiliae*, *P. reuteri*, *Nabis apterus*, and *Anthocoris nemorum*. In 1956 at the end of July in the +sfp plot there were a great many adults and larvae of *Pilophorus* species; in 1959 in addition to large numbers of the above-mentioned species, a number of adults and larvae of *Orius* species were found at the end of August on the Bellefleur trees in Plot II. Of the remaining species listed on page 22, only very small numbers were present.

Other predacious insects:

In Table 11 the mean numbers of predatory insects other than the predatory Heteroptera are given per sample. The differences in the mean population density between the unsprayed +sfp and –sfp plots are small. For Boskoop the numbers in the +sfp plots, in which there was a severe increase of *M. ulmi* and aphids, lie somewhat higher. For Bellefleur this correlation was not found.

Spiders:

The importance of spiders as natural enemies of harmful organisms is, according to SPECHT & DONDALE (1960), often neglected. Because certain species of spiders are present from early in the spring until late in the autumn, they may

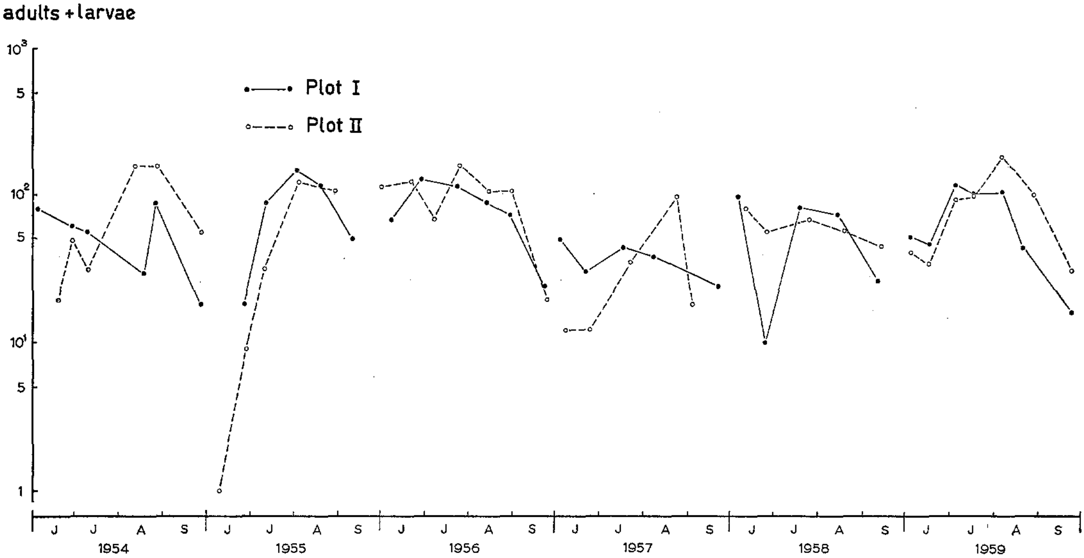


FIG. 20. Population density of predacious Heteroptera on Boskoop in the unsprayed plots during 1954–1959. Number of predacious Heteroptera per sample. Plots as in Fig. 18.
Populatiedichtheid van roofwantsen op Schone van Boskoop in de onbespoten percelen gedurende 1954–1959. Aantal roofwantsen per monster. Percelen als in fig. 18.

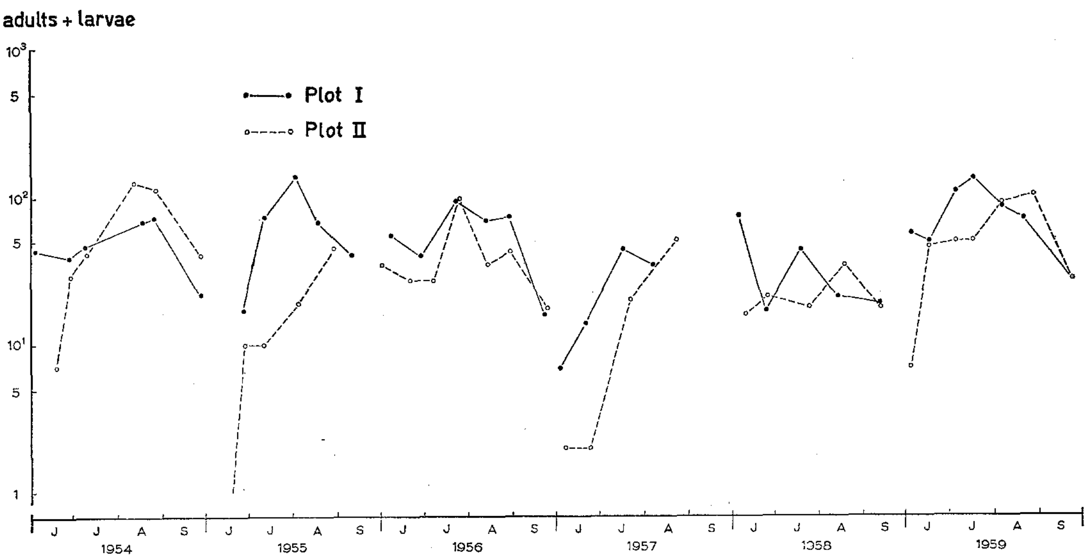


FIG. 21. Population density of predacious Heteroptera on Bellefleur in the unsprayed plots during 1954–1959. Number of predacious Heteroptera per sample. Plots as in Fig. 18.
Populatiedichtheid van roofwantsen op Bellefleur in de onbespoten percelen gedurende 1954–1959. Aantal roofwantsen per monsters Percelen als in fig. 18.

TABLE 11. Mean population density of the other predacious insects per sample in the unsprayed plots.
Gemiddelde populatiedichtheid van de overige roofinsekten per monstername in de onbespoten percelen.

adults + larvae *imago's + larven*	Boskoop		Bellefleur	
	I -sfp	II +sfp	I -sfp	II +sfp
1954	13	19	17	13
1955	18	26	22	14
1956	23	34	9	10
1957	27	40	25	37
1958	30	36	22	15
1959	16	15	16	14

be of greater importance than other predators which consume more within a short period (CHANT, 1956). In addition, these spiders are often extremely polyphagous. According to CHANT, it is especially the small and immature spiders which prey on *M. ulmi*; the larger species are more likely to attack insects such as the caterpillars of the winter moth, apple sucker, aphids, and a number of carnivorous insects. As has already been reported, the spiders were only collected qualitatively.

Sprayed plots

Predatory mites:

Due to the chemical control applied in these plots, predatory mites were found only sporadically. Many authors have reported the unfavourable effect of the chemicals used on the predatory mites (see literature review by REDENZ-RÜSCH, 1959). Only a few species were observed even sporadically, principally *Typhlodromus tiliae*. This is in agreement with COLLYER's report (1956) that *T. tiliae* is the only species found in great numbers in sprayed apple orchards in southeastern England. GÜNTHART (1959) also reports that *T. tiliae* and both *T. tiliarum* and *T. finlandicus* are sometimes seen on sprayed trees; *T. aberrans*, to the contrary, is rarely found on sprayed trees, a fact which, according to this author, is related to the nutritional requirements of these predatory mites.

Predatory Heteroptera:

In the sprayed plots even in the first year of the investigation winter spraying with tar oils, followed by DDT, immediately killed most of the predatory Heteroptera which hibernate either as eggs or adults. The remaining numbers were too small to have much value for graphical purposes; therefore, only the mean number of predatory Heteroptera per sample is given in Table 12.

The most frequent species was *A. nemorum;* for the rest, a few specimens of *O. minutus*, *P. tiliae*, *P. reuteri*, and *N. apterus* were observed. It is known from the literature (STEINER, 1956, 1959; REDENZ-RÜSCH, 1959) that the predatory Heteroptera are sensitive to most insecticides. In all probability those which were observed originated in the adjacent unsprayed plots, while regular spraying prevented them from building up a population.

Other predacious insects:

Due to the chemical control the number of the other insects was also very much reduced (Table 13).

TABLE 12. Mean population density of the predacious Heteroptera per sample in the sprayed plots.
Gemiddeld aantal roofwantsen per monstername in de bespoten percelen.

adults + larvae *imago's + larven*	Boskoop		Bellefleur	
	III +sfp	IV -sfp	III +sfp	IV -sfp
1954	6	2	1	3
1955	1	1	1	0
1956	3	0	1	0
1957	4	1	18	1
1958	5	1	1	1

TABLE 13. Mean population density of the other predacious insects per sample in the sprayed plots.
Gemiddelde populatiedichtheid van de overige roofinsekten per monstername in de bespoten percelen.

adults + larvae *imago's + larven*	Boskoop		Bellefleur	
	III +sfp	IV -sfp	III +sfp	IV -sfp
1954	2	2	1	1
1955	2	1	3	0
1956	3	1	3	1
1957	2	1	6	4
1958	3	1	2	1

Spiders:
In the plots in which chemical control was applied, the population density of the spiders was greatly reduced. CHANT (1956) observed a reduction of the spider population in apple orchards in southeastern England after winter spraying and the use of lime sulphur sprays. STEINER (1956) also reports the effect of chemical control on the population density of spiders. According to SPECHT & DONDALE (1960), their modified spray program using ryania, lead arsenate, and nicotine bentonite reduced the spiders only to a small extent, but they also remark that the sprays affect 'hunting' spiders more strongly than 'web-builders'.

Summarizing, it may be said that the population density of the predators does not reach any appreciable proportions until the middle of the summer. Only for the predatory mites in the +sfp plots in which there was a heavier increase of *M. ulmi* was there regularly a somewhat larger number present than in the -sfp plots. In the sprayed plots the predators were observed only sporadically. Counts of *M. ulmi* indicate that this cannot be attributed to a shortage of food (Fig. 8 and 9).

c. Competition
In discussing the possibilities for competition with *M. ulmi* by other organisms, intraspecific competition should be mentioned first, but for the present study, which sought the cause of the heavy increase of *M. ulmi*, this intraspecific competition is not of importance.

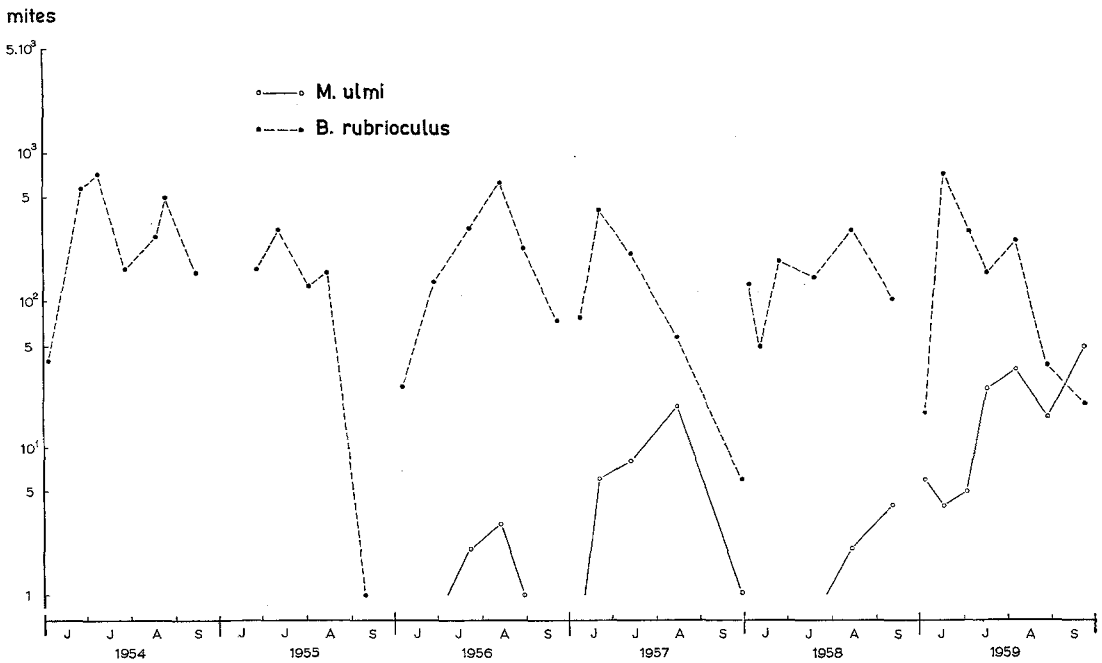


FIG. 22. Development of the *M. ulmi* and *B. rubrioculus* populations on Boskoop in Plot I during 1954–1959. Number of mites per 100 leaves. Plot I: unsprayed –sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *op Schone van Boskoop in Perceel I gedurende 1954–1959. Aantal mijten per 100 bladeren. Perceel I: onbespoten –sfp.*

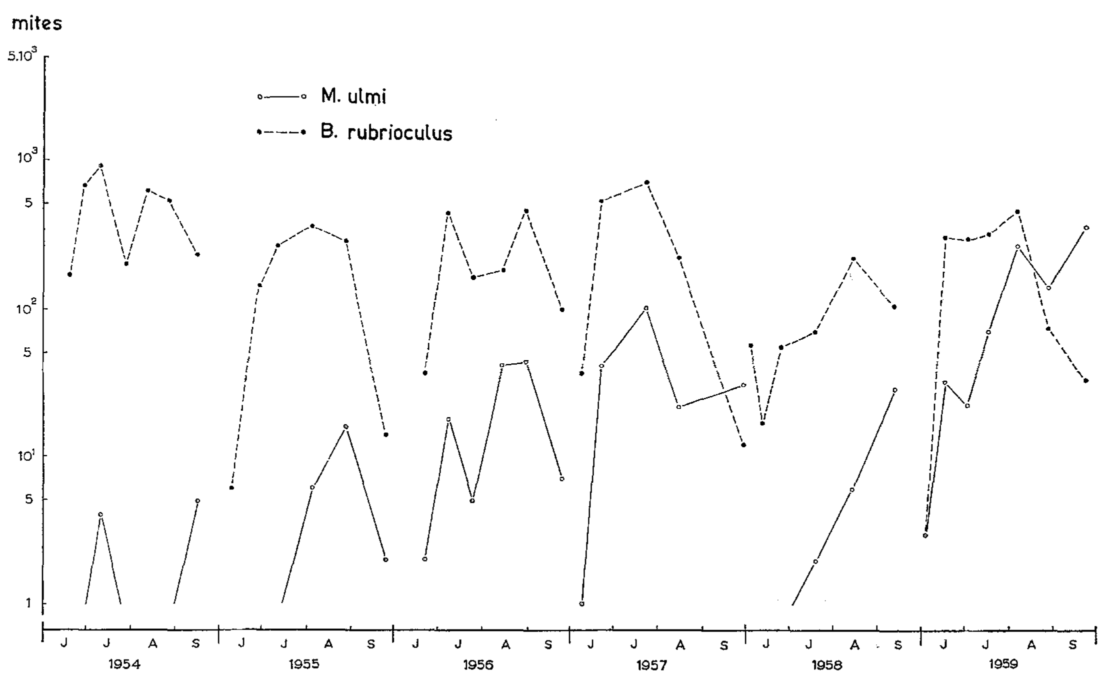


FIG. 23. Development of the *M. ulmi* and *B. rubrioculus* populations on Boskoop in Plot II during 1954–1959. Number of mites per 100 leaves. Plot II: unsprayed +sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *op Schone van Boskoop in Perceel II gedurende 1954–1959. Aantal mijten per 100 bladeren. Perceel II: onbespoten +sfp.*

Concerning interspecific competition in relation to *M. ulmi*, the organisms of most importance are the phytophagous mites *Bryobia rubrioculus*, *Eotetranychus pomi*, and *Brevipalpus oudemansi*. The remaining phytophagous mites belonging to the Tydeidae, Eryophyidae, and Tarsonemidae are seen only sporadically, even in the unsprayed plots. Of these, the Tydeidae are the most numerous, but even their mean population density per leaf is only about one mite or less.

In addition, in the unsprayed plots the following organisms might also appear as competing factors: the pear leaf blister moth (*Leucotricha scitella* Zell.) and the apple scab fungus (*V. inaequalis*).

Bryobia rubrioculus Scheuten

As mentioned on page 22, at the beginning of the observations in 1954 there was only a very small population density of *M. ulmi* in the unsprayed plots of the neglected orchard, while that of *B. rubrioculus* was of more importance. This phenomenon is well known. SUMMERS & BAKER (1952) demonstrated the relationship between the appearance of *B. praetiosa* Koch (= *B. rubrioculus* Scheuten) and the roughness of the branches: trees with rough, irregular bark were affected most severely. This type of tree is found in neglected orchards, and especially in neglected standard-tree orchards.

UNTERSTENHÖFER (1955), KREMER (1956), and MÜLLER (1958) also investigated the presence of *B. praetiosa* and *P. pilosus* in connection with the shape of the tree and the management of the orchard. They found *B. praetiosa* present mainly in the standard-tree orchard and *P. pilosus* in the bush and spindle types. Due to management of the trees (under which pruning and chemical control are understood) the injury from *B. praetiosa* dropped, while that from *P. pilosus* increased.

According to KREMER (1956), the mortality of *B. praetiosa* on the smooth branches of the open crown in the well-kept bush and spindle orchards caused by rain and wind is much larger than that of *P. pilosis* which lives especially on the lower surface of the leaves. *B. praetiosa* is much more active and spends part of its life on branches, in addition to being much more sensitive to rain and chemicals than *M. ulmi* (KREMER, 1956; MASSEE, 1955a). Besides the effect of chemical control, the absence of rough, irregular bark should thus be considered as one of the factors which causes the very limited numbers of *B. rubrioculus* in the well-kept Plots III and IV. Figures 22–25 show the population densities of *M. ulmi* and *B. rubrioculus* in the various years.

It can be seen from Figure 22 that the population density of *B. rubrioculus* on Boskoop, expressed in the number of mites per 100 leaves, remained about the same in the unsprayed –sfp plot in the various years. In this plot the population density of *M. ulmi* increased in some degree, as a result of which the differences between the densities of the phytophagous mites became somewhat smaller. In the +sfp Plot II the increase of *M. ulmi* was much stronger (Fig. 23). Apart from annual variations in the *B. rubrioculus* population due to weather conditions, the level of this mite remains more or less the same. Only in the last year could any inhibiting effect from *M. ulmi* on the development of *B. rubrioculus* be considered, in terms of the relatively low population density of *B. rubrioculus* in spite of the favourable weather conditions.

On Bellefleur *M. ulmi* developed more favourably and *B. rubrioculus* less

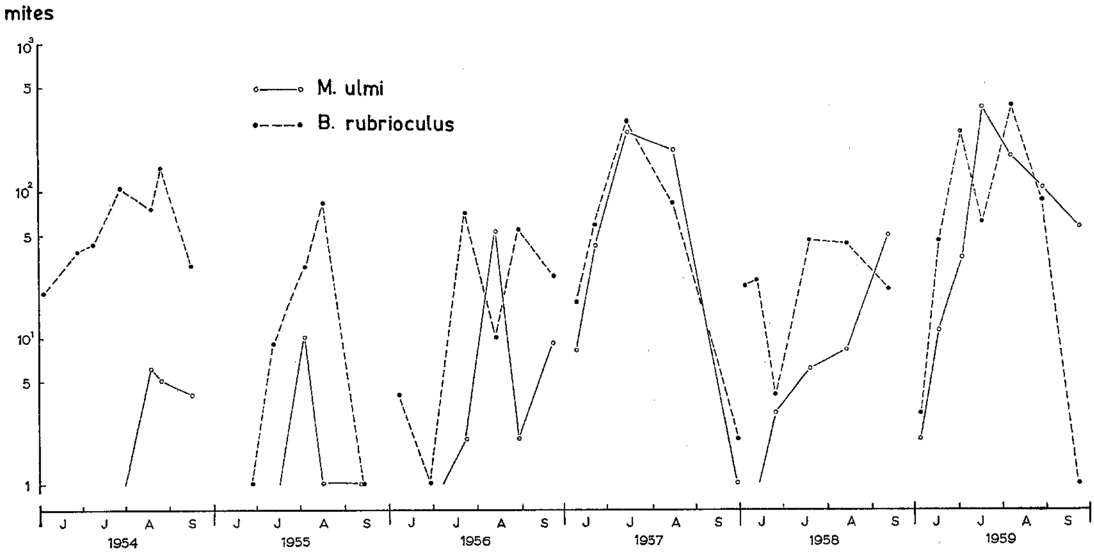


FIG. 24. Development of the *M. ulmi* and *B. rubrioculus* populations on Bellefleur in Plot I during 1954–1959. Number of mites per 100 leaves. Plot I: unsprayed –sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *op Bellefleur in Perceel I gedurende 1954–1959. Aantal mijten per 100 bladeren. Perceel I: onbespoten –sfp.*

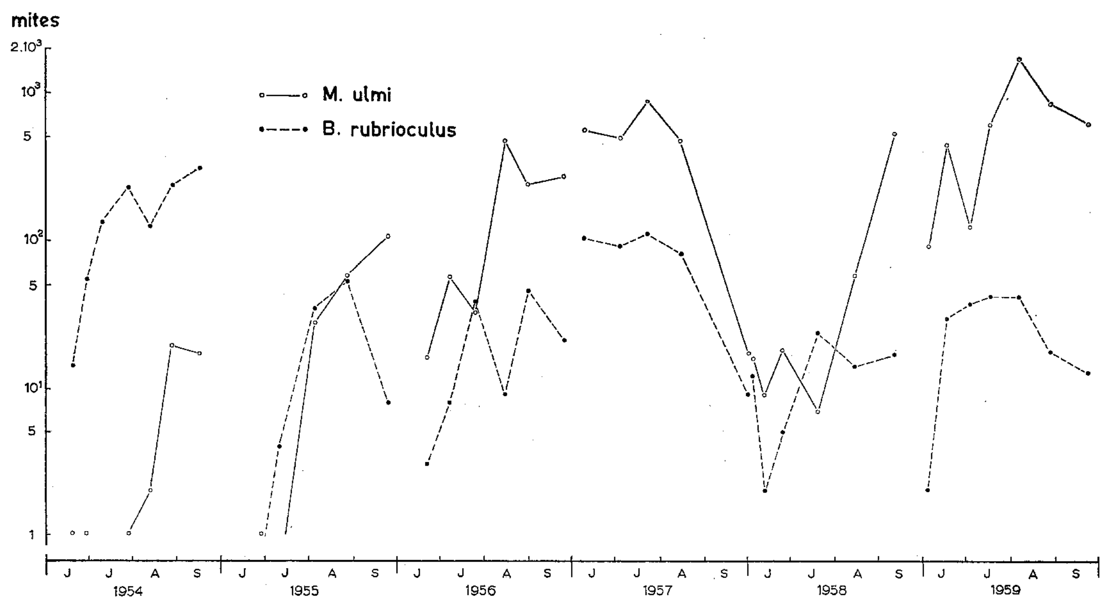


FIG. 25. Development of the *M. ulmi* and *B. rubrioculus* populations on Bellefleur in Plot II during 1954–1959. Number of mites per 100 leaves. Plot II: unsprayed +sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *op Bellefleur in Perceel II gedurende 1954–1959. Aantal mijten per 100 bladeren. Perceel II: onbespoten +sfp.*

favourably than on Boskoop, as can be seen in Figures 24 and 25. The population density of *B. rubrioculus* lies on a much lower level, while *M. ulmi* shows an even higher increase on the -sfp Bellefleur than on Boskoop. In the +sfp Plot II the strong increase of *M. ulmi* is paralleled by a decrease in *B. rubrioculus*. In contrast to the situation at the beginning of the observations, in 1954 the density of the *M. ulmi* population lies much higher than that of *B. rubrioculus*. This heavy increase of *M. ulmi* appeared as a result of soil cultivation, fertilization, and pruning.

In *B. rubrioculus* a distinct reaction to the improved condition of the fruit tree could not be found either in laboratory or semi-field experiments or from population counts in Eversdijk, as shown in Table 14. In connection with our impression of the distribution of the separate observations, the differences in the densities between the +sfp and -sfp plots are unimportant. According to RODRIGUEZ (1958), however, SNETSINGER did observe an effect of the condition of the host plant (apple) on the development of *B. praetiosa*: on leaves with a high nitrogen content the average egg production per mite was higher than on those with a low nitrogen content.

TABLE 14. Mean population density of *B. rubrioculus* on Boskoop per 10 cm of branch + 10 leaves, in the unsprayed plots.
Gemiddelde populatiedichtheid van B. rubrioculus *op Schone van Boskoop per 10 cm tak + 10 bladeren in de onbespoten percelen.*

	I -sfp			II +sfp		
	mites *mijten*	eggs *eieren*	total *totaal*	mites *mijten*	eggs *eieren*	total *totaal*
1958	28	76	104	38	75	113
1959	41	127	160	40	141	181

In view of the increase of the *M. ulmi* population under the influence of cultivation, fertilization, and pruning while the population density of *B. rubrioculus* in Eversdijk was not observably affected by the same treatment, it seems obvious to assume that the reduction in the population density of *B. rubrioculus* over the years in the unsprayed plots was caused by competition with an increasing *M. ulmi* population. KUENEN found in experiments with two-year old apple trees that the presence of *B. rubrioculus* interferes with the growth of the *M. ulmi* population: the pure populations reached a far higher density than the mixed ones. According to this author, the effect of *B. rubrioculus* on *M. ulmi* was less strong than the reverse effect (KUENEN & POST, 1958). Laboratory experiments by POST (1959b) gave the impression that *M. ulmi* reduced the population density of *B. rubrioculus*. Under the prevailing experimental conditions the density of *M. ulmi* was not affected by infection with *B. rubrioculus*. It should nevertheless be mentioned that the mean number of *Bryobia* mites in relation to *M. ulmi* in these laboratory experiments lay lower than in the field. Under field conditions, such as those in the neglected plot in Eversdijk, it is not excluded that *B. rubrioculus* simultaneously exerts a somewhat inhibitory effect on the development of the *M. ulmi* population.

Eotetranychus pomi Sepasgosarian

E. pomi is found on the lower surface of the leaf, where the mites deposit the eggs along the midvein and the lateral veins, and spin a fine web over the leaf (Fig. 26). In the unsprayed plots the mites were found in large numbers. Because of lack of time, only orientational observations could be made; in 1954 and 1955 the number of mites (M) per 100 leaves was counted and in 1956 and 1958 the number of mites + eggs (M + E). The results are given in Table 15, where it can be seen, that in the +sfp plots the population density was much lower on both Boskoop and Bellefleur than in the –sfp plots. No laboratory experiments have yet been done to determine the cause of this severe reduction in the +sfp plots.

TABLE 15. Mean population density of *E. pomi* per 100 leaves in the unsprayed plots.
Gemiddelde populatiedichtheid van E. pomi *per 100 bladeren in de onbespoten percelen.*

June – September	Boskoop		Bellefleur	
	I –sfp	II +sfp	I –sfp	II +sfp
1954 M [1]	13	11	189	62
1955 M	110	30	271	13
1956 M (E) [2]	460 (698)	22 (42)	1244 (1196)	42 (80)
1958 M (E)	21 (15)	12 (24)	127 (154)	57 (41)

[1] M: mites — [1] *M: mijten*
[2] M (E): mites (eggs) — [2] *M (E): mijten (eieren)*

In the development of *M. ulmi* in well-kept, unsprayed plots *E. pomi* probably plays no role as food competitor; in the totally neglected plots it certainly might influence the population density of *M. ulmi*. No experiments on this problem were carried out, however. We did note that with a severe *E. pomi* infestation on the lower surfaces of the leaves *M. ulmi* mites were found only on the upper surfaces. An investigation done by NEWCOMER & YOTHERS (1929) demonstrated that an increase of another webbing mite, *Tetranychus urticae* Koch was accompanied by a reduction in the number of *M. ulmi* mites. According to them, *M. ulmi* is unable to move in the webs and will be destroyed. KUENEN & DEN BOER (unpublished) also observed a reduction in the population density of *B. rubrioculus* and *M. ulmi* in conjunction with a strong increase of the spinning mite *Epitetranychus urticae* (= *Tetranychus urticae*). Thus, a reduction of *M. ulmi* may also be expected by an infestation with *E. pomi*.

Brevipalpus oudemansi Geyskes

In the unsprayed plots these mites are found in more or less large numbers but not, under our conditions, in injurious numbers. DOSSE (1955a), to the contrary, reports that in the neighbourhood of Stuttgart-Hohenheim *B. oudemansi* so severely damaged the apple trees that control experiments were instituted in 1954. BÖHM (1957) observed a minor infection on apple trees in Austria in neglected orchards and plantings along roads. The mites are found on the lower surfaces of the leaves, in particular close to the midvein, and they also deposit their eggs there.

TABLE 16. Mean population density of *B. oudemansi* per 100 leaves in the unsprayed plots. *Gemiddelde populatiedichtheid van* B. oudemansi *per 100 bladeren in de onbespoten percelen.*

June – September	Boskoop		Bellefleur	
	I –sfp	II +sfp	I –sfp	II +sfp
1954 M [1]	126	42	74	24
1955 M	109	181	71	44
1956 M (E) [2]	198 (81)	132 (57)	45 (39)	7 (4)
1958 M (E)	123 (185)	100 (77)	19 (20)	15 (12)

[1] and [2] as in Table 15
[1] *en* [2] *als in tabel 15*

In 1954 and 1955 the number of mites (M) per 100 leaves was determined; in 1956 and 1958 the number of mites + eggs (M + E) (Tabel 16).

According to these observations, the mean population density of *B. oudemansi* in the cultivated, fertilized, and pruned plots generally lay lower than in the –sfp plots without chemical control, as was also seen for *E. pomi*. For *B. oudemansi*, 1955 Boskoop was an exception to this. The mean population densities are, however, also small in the –sfp plots, so that in unsprayed plots *B. oudemansi* in any case plays no important role as a competitor of *M. ulmi*. This was, however, not demonstrated experimentally. In contrast to *E. pomi*, *B. oudemansi* showed a stronger development on Boskoop than on Bellefleur; no study was made of which factors determine this difference in development.

It should also be noted that in the unsprayed plots the galleries of *L. scitella* appeared in such large numbers as to eliminate a large proportion of the leaves as a food source for *M. ulmi*. In addition, in the unsprayed plots parts of the leaves were rendered inedible by scab infestation. Thus, fungi also reduce the quality and quantity of the phytophagous mites' food supply (GILLIATT, 1935; KUENEN, 1949).

The problem of the small numbers of *M. ulmi* in neglected plots is not explained by the factor of competition, however. Laboratory experiments are required for further investigation of the effect of each of these competing organisms on the development of *M. ulmi*.

A difference in predation was also investigated as a possible cause of the small numbers of *M. ulmi* compared to *B. rubrioculus* in neglected orchards. Laboratory experiments showed that the predatory Heteroptera showed no preference for either of the two species but the predatory mites did show a preference. In the young stages of both species there was no preference; in the older stages there was a preference for *M. ulmi* (see p. 78).

In the sprayed plots the population density of *B. rubrioculus* was very low, because this species is very sensitive to most of the chemicals used in control. Our observations also showed that, in contrast to the mites of *M. ulmi*, it rarely survives even exposure to water. *E. pomi* was also severely reduced by spraying, and even in the first year of the study was observed only sporadically. The total number of mites from the –sfp plot and the +sfp plot on the 9 leaf samples of 100 leaves of Boskoop in 1954 was 0 and 4 respectively; for Bellefleur, 20 and 3. For *B. oudemansi* these numbers are still smaller: on Boskoop 5 and 2 and on Bellefleur, 1 and 0 respectively. The remaining phytophagous mites, belonging to the Tydeidae, Eriophyidae, Tarsonemidae, etc., were almost completely eliminated.

These results indicate that in the plots in which chemical control was applied the phytophagous mites other than *M. ulmi* were for the most part or entirely destroyed. *L. scitella* was found in very small numbers and scab injury to the leaves was negligible, as shown by the percentage of affected fruit harvested (0–2%).

d. Chemical control

Because of the low density of the initial population of *M. ulmi* in 1954 it seemed possible to use DDT in the sprayed plots in June to control the caterpillars of *Adoxophyes reticulana* and *Enarmonia pomonella:* observations by HUECK et al. (1952) and LÖCHER (1957), among others, have shown that the egg production of *M. ulmi* increases sharply under the influence of DDT. After a repeated spraying in July of 1955 with DDT to control the tortricids, the first marked increase in the density of *M. ulmi* occurred (Figs. 8 and 9). Consequently, at the beginning of June 1956 we sprayed with the ovolarvicide chlorobenside and diazinon, which gave very good results; not until the end of August did *M. ulmi* begin to increase appreciably again. Because the number of winter eggs was not very large, an attempt was made in 1957 to keep the mite population down with diazinon; in the second half of July and August no spraying was done because of circumstances. As a result, in 1958 it was necessary to spray with chlorbenside before blossoming. Because that spring was extremely cold and rainy, the mite population remained at a low level; only in August and September, when the weather was much improved, did the population increase heavily In 1959 no observations on the mite population were done in the sprayed plots, but *M. ulmi*, was controlled in order to protect the unsprayed plots from infection from these severely affected plots.

In spite of the chemical control, the population density of *M. ulmi* increased sharply and lay on a much higher level than in the untreated Plot I (Figs. 8 and 9). Per year the densities vary greatly, depending upon the effect of control and upon the weather.

In the discussion of the effect of cultivation, fertilization, and pruning on the development of *M. ulmi* it was pointed out that this effect did not stand out clearly in the sprayed +sfp Plot III in contrast to the unsprayed +sfp Plot II. On these grounds the population development of *M. ulmi* in the sprayed plots was more closely analysed. In 1957 in Plots III and IV the numbers of mites and eggs were counted on 50 leaves per tree instead of on a sample of 100 leaves per plot per variety. Table 17 gives the mean number of mites and eggs per leaf.

TABLE 17. Mean number of mites + eggs of *M. ulmi* per tree per leaf in the sprayed plots. *Gemiddeld aantal mijten + eieren van* M. ulmi *per boom per blad in de bespoten percelen.*

1957	Boskoop						Bellefleur					
tree no.: *boom no.:*	1	2	3	4	5	6	1	2	3	4	5	6
III + sfp	6.9	7.4	18.4	4.0	2.3	5.9	9.4	4.9	13.4	6.9	9.5	10.8
IV – sfp	5.8	3.9	1.3	2.8	7.0	3.9	13.3	11.9	16.6	13.6	12.5	1.7

The population density of *M. ulmi* appears to be very variable per tree. The high densities are found primarily on the high, large, heavily foliated trees. In establishing the size of the tree, the height and the crown projection must be taken into account. (The crown projection can be determined from the product of π R1 $\times$ R2 (VAN DER BOON & BUTIJN, 1958), in which R1 and R2 are the diameters of the tree, which we preferably measured North-South and East-West). Except for +sfp Bellefleur, there was a significant correlation (at the 5% level) between the density of the *M. ulmi* population and the height or crown projection of the tree. This correlation is probably caused by the difference in the effectiveness of the spraying which results from the lack of uniformity of the trees. In smaller and especially in pruned trees (such as +sfp Bellefleur) spraying, and particularly low volume spraying, gives a better penetration of the tree and is more lethal to the mite. Thus in the pruned Plot III control was more effective and cancelled out the favourable effect of cultivation, fertilization, and pruning on the development of *M. ulmi* which was to be expected on the basis of the results in the unsprayed plots.

Further, in the –sfp Plot IV, as in the –sfp Plot I, a small increase in the density of *M. ulmi* may be ascribed to an effect from the bordering trees in the –sfp plot through the fertilization applied in the adjacent +sfp plot (p. 32).

4.3. EXPERIMENTAL FIELD 'KUENEN'S HOF'

4.3.1. *Introduction*

With the expansion of the Research Station in the autumn of 1952, 0.5 ha of agricultural land was put at the disposal of the investigation; in the spring of 1953 Lombartscalville M I trees were planted. This variety was chosen because of its low susceptibility to apple scab. Later on it was observed to be very susceptible to mildew, which gave great difficulties in the plots which obtained no chemical control. The trees were planted at 5 $\times$ 5 m. At the end of 1954 new planting was done between the trees in the rows, so that the distance between trees became $2\frac{1}{2}$ and 5 m.

In Kuenen's Hof soil borings were carried out and a soil map was made by the Soil Section of the *Rijkstuinbouwconsulentschap* (Horticultural Advisory Service) at Goes, which showed that the topsoil consists of a silt loam or clay loam overlying to a depth of 40–80 cm a sandy subsoil. Owing to this subsoil the moisture supply of this profile is limited and the growth of the Lombartcalvilles is consequently retarded, especially in the eastern Plots Ia and IIa, compared to the trees in the rest of the experimental field.

Until the spring of 1956, or for 3 years, pruning, fertilization, and chemical control were applied in the entire field so that normal trees were raised. During this time crops were grown under the young trees (onions and sugar beets).

Where in the Eversdijk experimental field the starting point was the situation in a neglected orchard, in Kuenen's Hof it was the situation in a well-kept orchard. In the latter, the biocoenosis is continuously disturbed by the necessary cultural measures (method 2*b*, p. 12). Starting in 1956, these practices were partially or entirely suspended in part of the field and a comparative study was made of the development of the mite and insect fauna in this section and in the section in which the treatment was maintained.

4.3.2. *Arrangement of the experimental field*

This arrangement was essentially the same as that of the standard-tree orchard in Eversdijk but in Kuenen's Hof the plots were in duplicate (Fig. 27).

Plots Ia & Ib – untreated
Plots IIa & IIb – soil cultivation, fertilization, pruning
Plots IIIa & IIIb – soil cultivation, fertilization, pruning, and chemical control
Plots IVa & IVb – chemical control.

For purposes of chemical control and the limitation of wind transportation of the chemicals, the plots receiving chemical control were chosen next to each other.

On the North and South the plots were bordered by an alder hedge (*Alnus glutinosa*) and on the East and West by a hedge of Italian poplars (*Populus nigra* var. *italica*). Thus the 8 plots were separated from each other by alder hedges and a 'buffer' row of Lombartscalville, while the experimental field was divided into two halves by a poplar hedge. In this way each plot was bordered on three sides by an alder hedge and on the fourth side by a poplar hedge. In each plot the 16 trees planted in 1953 were used for the observations; the trees planted later were not included.

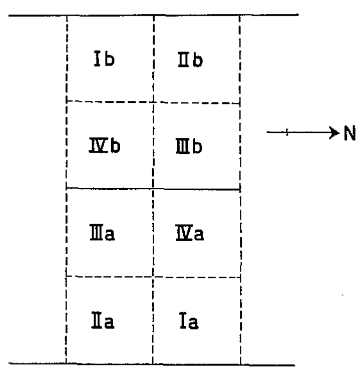


FIG. 27.
Diagram of the experimental field Kuenen's Hof.
Plot Ia & Ib: untreated
Plot IIa & IIb: soil cultivation, fertilization, pruning
Plot IIIa & IIIb: soil cultivation, fertilization, pruning, and chemical control
Plot IVa & IVb: chemical control.

------ *Alnus glutinosa*
—— *Populus nigra* var. *italica*

Overzicht van het proefveld Kuenen's Hof.
Perceel Ia & Ib: onbehandeld
Perceel IIa & IIb: grondbewerking, bemesting, snoei
Perceel IIIa & IIIb: grondbewerking, bemesting, snoei en chemische ziektebestrijding
Perceel IVa & IVb: chemische ziektebestrijding.

4.3.3. *Cultural program*

4.3.3.1. Soil cultivation

In 1956 soil cultivation was carried out for the last time in all plots. In 1957 grass was sown in the –sfp Plots I and IV; these plots were mowed when necessary and the cut grass removed. The +sfp Plots II and III were clean-cultivated until about August.

4.3.3.2. Fertilization

Starting in 1956 no further fertilization was applied in Plots I and IV. Plots II and III were fertilized each year with 100 kg sulphate of ammonia, i.e. the equivalent of 80 kg of pure nitrogen per hectare. Since the nitrogen content decreased over a period of years, 150 kg was applied in 1961 (= 120 kg pure nitrogen per ha). Kuenen's Hof is situated in a young polder (150 years old), and as a consequence the soil is still rich in calcium, potassium, magnesium, and phosphate. Because of the crops grown under the trees, potassium was supplied until 1956, after which only a nitrogen fertilizer was used.

4.3.3.3. Pruning

After determination of the relative length of the one-year old shoots and the number of fruit buds and leaf buds per unit of branch length, the trees in Plot II and III were pruned.

4.3.3.4. Chemical control

As in Eversdijk, in this experimental field the object was to study the effect of a normal control program on the development of harmful and beneficial organisms. The spraying was usually done with a knapsack low volume sprayer. The spraying program is given in Table 18, the chemical composition of the pesticides in Table 2.

a. Fungicides

The apple scab (*V. inaequalis*) control program was principally identical with that used in Eversdijk. Here, however, a great deal of attention had to be paid to the control of apple mildew (*P. leucotricha*). In August 1956 a commercial mixture of sulphur and thiram (AApirsul) was sprayed for the simultaneous control of scab and mildew. In 1957, 1958, and 1959 the mildew was controlled by spraying from May on every fortnight with AApirsul or SM 55 (a commercial mixture of captan and sulphur) and Karathane. In 1960 starting in April, SM 55 was sprayed weekly in a weaker concentration.

b. Acaricides, insecticides, etc.

The pre-blossom spray for control of the rosy apple aphid (*Dysaphis plantaginea* Pass.), green apple aphid (*A. pomi*), and tortricids was done with organophosphorous compounds. These chemicals also controlled the fruit tree red spider mite.

In 1958 just before blossoming, and in 1959 and 1960 before and after it, spraying was also done with the ovolarvicide chlorbenside and an organophosphorous compound, which killed not only the various mite stages but also the summer eggs. In 1959 and 1960 2 sprayings with Kelthane were also applied, at the end of July and beginning of August.

E. lanigerum was controlled with a strong concentration of diazinon or Phosdrin; *A. pomi* with diazinon, isolan, or Phosdrin.

4.3.4. *Methods used for the inventory of mites and predators*

In principle, the same method was used as in Eversdijk. Because of the different shape of the trees, however, a few modifications were introduced.

Predators:

Instead of tapping with a stick, the branches at about 1 metre from the ground were shaken over a net by hand, because tapping with a stick often damages the trees. With this technique ± 40% of the branches were sampled. To determine what percentage of the insects we obtained by this method, several

TABLE 18. Spraying programs in Plots III and IV, 1956–1960. The pesticides were applied in the usual concentrations.
Bespuitingsschema's in de Percelen III en IV, 1956–1960. De middelen zijn in de gebruikelijke concentraties toegepast.

	1956	1957	1958	1959	1960
INSECTICIDES:					
March		parathion			
April			malathion	parathion (2×)	chlorbenside^{+}
				chlorbenside + malathion	
May	parathion	isolan	chlorbenside [3]	chlorbenside + diazinon	chlorbenside + diazinon^{+}
					Phosdrin
June	diazinon (2×)	isolan (2×)	diazinon + isolan	Phosdrin^{+}	Phosdrin
				parathion	Gusathion
July	diazinon + isolan	diazinon + isolan	parathion	Kelthane^{+}	Gusathion
August	diazinon + isolan	diazinon	diazinon	Kelthane^{+}	Gusathion
	isolan			parathion^{+}	
September	parathion	diazinon	diazinon		
FUNGICIDES:					
March		dinitrothiocyanobenzene		copper oxychloride	SM 55
April		dinitrothiocyanobenzene	copper oxychloride	copper oxychloride	SM 55 (3×)
		ziram		organomercury compound	
				SM 55	
May	dinitrothiocyanobenzene [1] (2×)	ziram	SM 55 (3×) [4]	SM 55 (3×)	SM 55 (4×)
June	ziram (3×)	AApirsul (2×)	SM 55 (2×)	SM 55 (3×)	SM 55 (4×)
July	ziram	AApirsul	SM 55 (3×)	captan + Karathane	SM 55 (2×)
August	AApirsul [2]	thiram		captan + Karathane	SM 55 (3×)
September		thiram			

1) *dinitrorhodaanbenzeen*
2) contains sulphur + thiram / *bevat spuitzwavel + thiram*
3) *chloorparacide*
4) contains sulphur + captan / *bevat spuitzwavel + captan*
+) high volume spray / *verspoten met motorspuit*

buffer trees in the +sfp Plot II with the highest density of insect populations were shaken in the usual way, then sprayed with a quick-acting chemical (pyrethrum), after which the entire tree was shaken again. Before spraying, a groundsheet of cheesecloth was spread under the tree to catch the fallen insects. Observations made in August 1952 with 2 buffer trees showed that our usual sampling method provided per tree only 12.5% and 13.9% of the total number of predatory insects. In 1960 the percentages were again determined at the end of July for 4 trees. The results were 24.5%, 24.0%, 20.6%, and 23.1%, which is somewhat better. Because with this 'knock-down' method also there is no certainty that all the insects in the tree have been caught, MUIR & GAMBRILL (1960) made a check test by releasing marked insects (adult *Blepharidopterus angulatus*) and found that the efficiency of the method varied between 47.8 and 77.3%. Many dead insects probably remain on the tree.

4.3.5. *Methods used for observations pertaining to the development of the fruit trees*

Only deviations from the method used in Eversdijk will be reported here (see p. 19).

a. From 1958 on, the total shoot growth averaged per 10 metre length of branch was determined as described, but in 1957 the total growth of young shoots was measured in relation to the total branch length of the young trees. These values were then calculated for 10 metre branch length. The same holds for

b. the number of fruit buds and leaf buds averaged per 10 metre of branch.

4.3.6. *Observations and results*

4.3.6.1. Development of *Metatetranychus ulmi* Koch

In comparison with the situation in Eversdijk, the population density of *M. ulmi* at the beginning of the observations was rather high. From the time the trees were planted in 1953 until the field was put into use in 1956, a normal spray program was applied in the orchard. As a result, the number of phytophagous mites, with the exception of *M. ulmi*, was just about zero. Figures 28 and 29 give the numbers of *M. ulmi* mites and eggs averaged per 100 leaves for the years 1956 through 1961.

At the conclusion of chemical control in 1955 in Plots I and II, there was a very heavy *M. ulmi* increase in these plots compared to Plots III and IV. As will be discussed further below, the physiological condition of the trees was still very favourable for the development of the mites, while other phytophagous organisms and predators were almost entirely absent in these years. The differences in the population density of *M. ulmi* between the duplicate plots were rather large, particularly in the first years of the study.

Beginning in 1957, a difference in the development of *M. ulmi* between the +sfp and -sfp plots started to appear, in both the sprayed and unsprayed parts of the experimental field. The mean population density of *M. ulmi* during 1957 was higher in the +sfp plots than in the -sfp plots, although the differences were at first still small. However, while in the -sfp plots in 1958 and 1959 *M. ulmi* no longer appeared in harmful numbers, in the unsprayed +sfp plots a bronzing of the leaves occurred due to the severe infestation. In the sprayed section the population in the +sfp plots recovered very rapidly after each spraying.

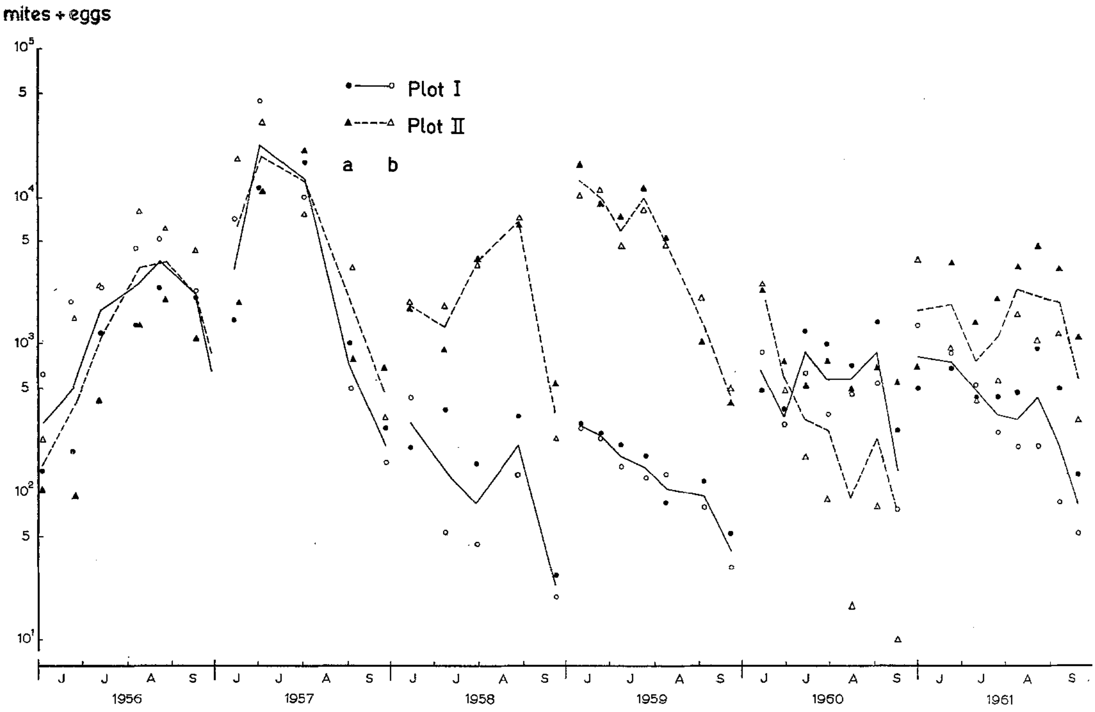


FIG. 28. Development of the *M. ulmi* population in the unsprayed plots during 1956–1961. Number of mites + eggs per 100 leaves.
Plot Ia & Ib: – sfp; Plot IIa & IIb: +sfp.
Populatie ontwikkeling van M. ulmi *in de onbespoten percelen gedurende 1956–1961. Aantal mijten + eieren per 100 bladeren.*
Perceel Ia & Ib: –sfp; Perceel IIa & IIb: +sfp.

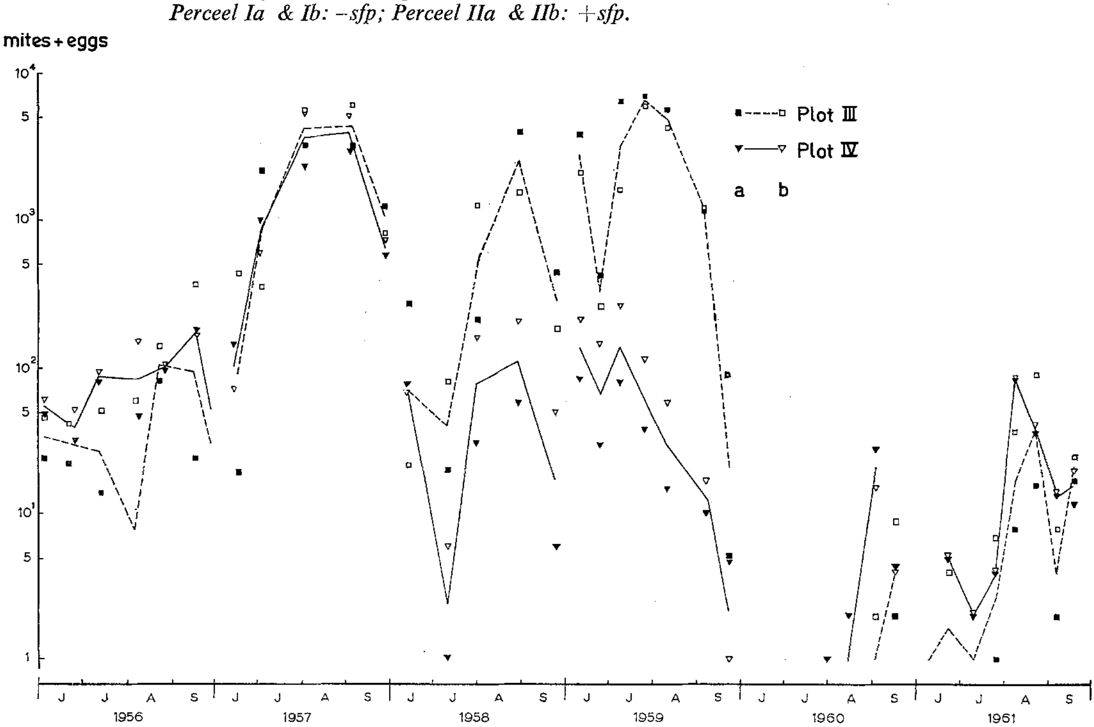


FIG. 29. Development of the *M. ulmi* population in the sprayed plots during 1956–1961. Number of mites + eggs per 100 leaves.
Plot IIIa & IIIb: +sfp; Plot IVa & IVb: –sfp.
Populatie ontwikkeling van M. ulmi *in de bespoten percelen gedurende 1956–1961. Aantal mijten + eieren per 100 bladeren.*
Perceel IIIa & IIIb: +sfp; Perceel IVa & IVb: –sfp.

As the observations show, from 1957 and 1958 on a more or less severe deterioration of the physiological condition of the trees occurred in the –sfp plots. The reduction in the population density of *M. ulmi* corresponds with this.

As shown in Figure 28, the population density of *M. ulmi* in the very rainy summer of 1960 in the +sfp Plots IIa and IIb was, until about the beginning of July, also higher than in the –sfp plots. After the beginning of the very rainy period, however, the density in the –sfp plots rises to above that in the +sfp plots. The ratio of the maximum densities in the +sfp and –sfp plots is negligibly small compared to those in 1958 and 1959. The increase in the population density of the mites in the –sfp plots was again proportional to an increase in the nitrogen content of the leaves: due to the fruiting year of the biennially-bearing trees and the rainy weather the nitrogen content of the leaves could reach a higher level than in 1959. The number of predators and competitors was small in these –sfp plots compared to the +sfp plots, permitting the population to increase in spite of the bad weather. In the +sfp plots the large numbers of predators which were present, especially in the beginning of the summer, amplified the unfavourable effect of the bad weather.

In 1961 from the middle of July onward the population densities of *M. ulmi* in the unsprayed +sfp plots again lay higher than those in the –sfp plots.

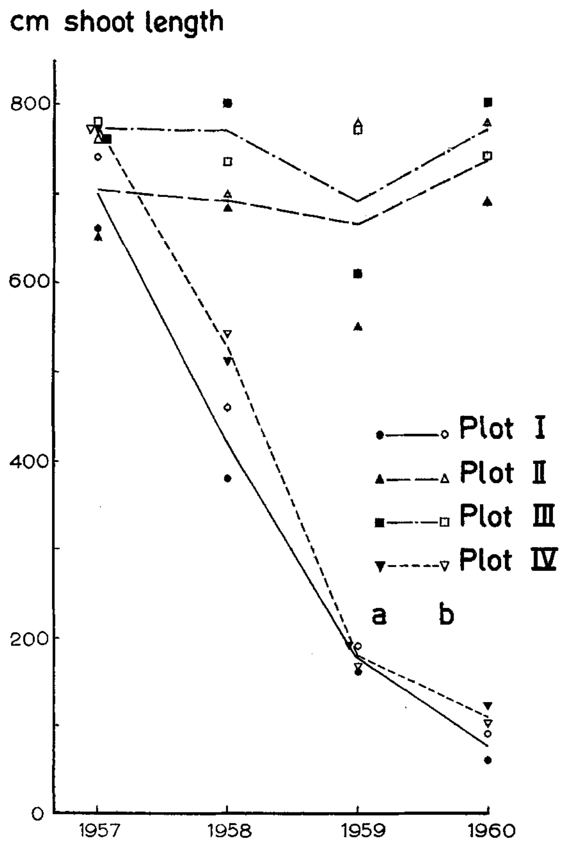


FIG. 30.

Relation between total shoot length per plot and the treatment used in 1957–1960.
Mean shoot length in centimetres per 10 metre branch.

Plot Ia & Ib: unsprayed –sfp
Plot IIa & IIb: unsprayed +sfp
Plot IIIa & IIIb: sprayed +sfp
Plot IVa & IVb: sprayed –sfp

Invloed van de cultuurmaatregelen op de totale scheutlengte per perceel in 1957–1960.
Gemiddelde totale scheutlengte in cm per 10 m taklengte.

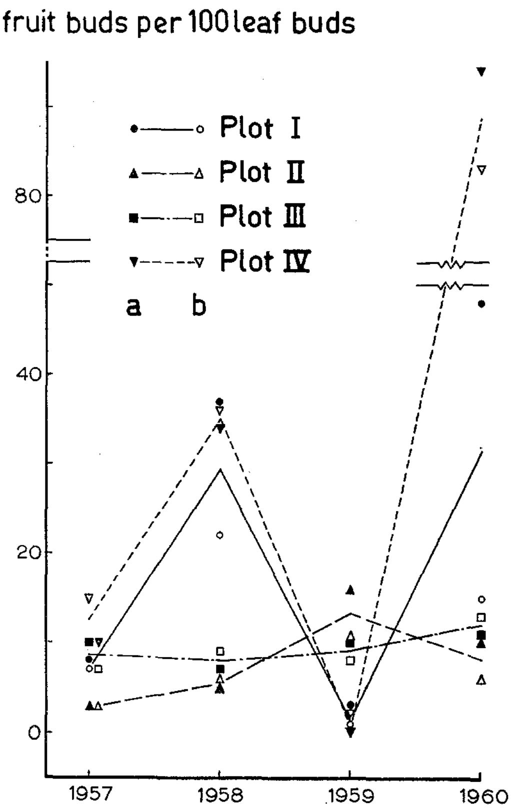
Perc. Ia & Ib: onbespoten – sfp
Perc. IIa & IIb: onbespoten + sfp
Perc. IIIa & IIIb: bespoten + sfp
Perc. IVa & IVb: bespoten – sfp

FIG. 32. Kuenen's Hof, 1958.
Plot I: untreated. / *Perceel I: onbehandeld.*

FIG. 33. Kuenen's Hof, 1958.
Plot III: soil cultivation, fertilization, pruning, and chemical control.
Perceel III: *grondbewerking, bemesting, snoei en chemische ziektebestrijding.*

FIG. 31.
Relation between number of fruit buds and leaf buds per plot and the treatment used in 1957–1960. Mean number of fruit buds per 100 leaf buds. Plots as in Fig. 30.

Invloed van de cultuurmaatregelen op het aantal gemengde knoppen en bladknoppen in 1957–1960. Gemiddeld aantal gemengde knoppen per 100 bladknoppen. Percelen als in fig. 30.



In the sprayed plots no pronounced difference in development was observed.

For 1961, only the population densities of *M. ulmi* are given (in Figs. 28 and 29); the data for the other mites and the insects could not be prepared in time for this publication.

4.3.6.2. Factors affecting the population density of *M. ulmi*

a. Nutrition

As in Eversdijk, an attempt was made to determine the physiological condition of the mite's source of food, i.e. the fruit tree. The following observations were made, the results being shown in Figures 30, 31, 34, 37, and 38.

In the winter of 1955/1956 Plots I and IV were pruned for the last time, and in 1957 the length of the one-year old shoots was first measured. Beginning in 1958, thus actually starting in the season of 1957, there was a distinct difference in the formation of young shoots between the trees in the fertilized and unfertilized plots (Fig. 30).

The phenomenon of biennial bearing, which the Lombartscalville variety shows to some extent, is clearly demonstrated in Figure 31. In the +sfp plots the good management of the trees suppressed the phenomenon somewhat, so that in these plots the differences in fruit bud formation are small between the years. In the –sfp plots the differences are very large; in 1958 (Figs. 32, 33) and

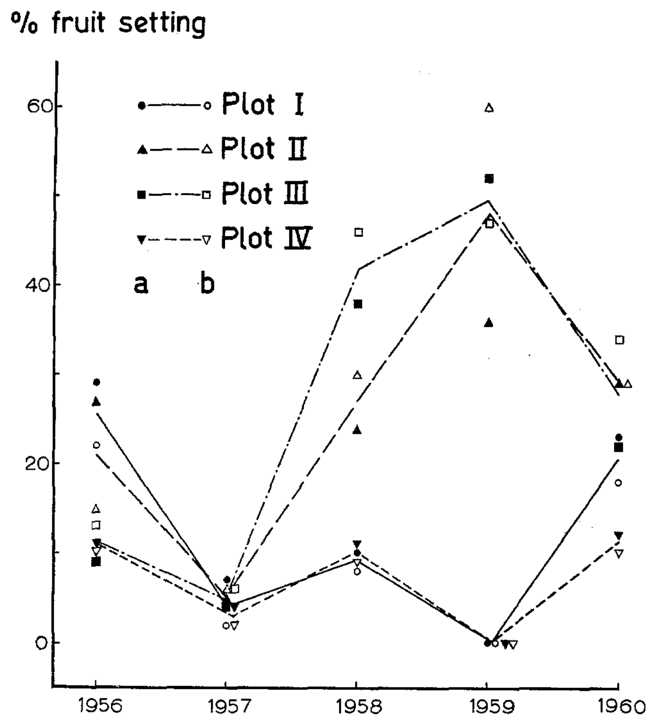


FIG. 34. Relation between fruit setting per plot and the treatment used in 1956–1960. Mean percentage of fruit setting. Plots as in Fig. 30.
Invloed van de cultuurmaatregelen op de vruchtzetting per perceel in 1956–1960. Gemiddeld percentage vruchtzetting. Percelen als in fig. 30.

1960 the trees blossomed profusely: in 1959 only a few sporadic fruit buds were formed.

It can be seen from Figure 34 that the mean percentage of fruit setting per plot from 1957 onward is higher in the +sfp plots than in the –sfp plots in both the sprayed and unsprayed section. In 1956 and 1960 in the unsprayed –sfp Plots Ia and Ib there was a high percentage of fruit setting compared to the sprayed Plots IVa and IVb. In the +sfp plots this phenomenon appeared only slightly in 1956. The high percentage of fruit setting in the unsprayed plots occurred in the years in which the trees were severely affected by *D. plantaginea*. Abundant fruit setting with an infestation of this aphid is a well-known phenomenon; in all probability the aphid infestation prevents the early fruit drop so that a larger than normal number of fruits occur per cluster, although they remain small and very malformed (Fig. 35). The rosy apple aphid additionally causes a serious deformation of the branches (Fig. 36).

Fig. 37 also clearly shows the occurrence of biennial years in which the differences in yield between the years in the –sfp plots are the largest. From 1957 onward, the yield in kilogram in the sprayed Plots III and IV was higher than in the unsprayed Plots I and II (except Plot Ib, 1958 and Plot II, 1959).

Starting in 1958, the mean fruit weight in the +sfp plots was larger than that

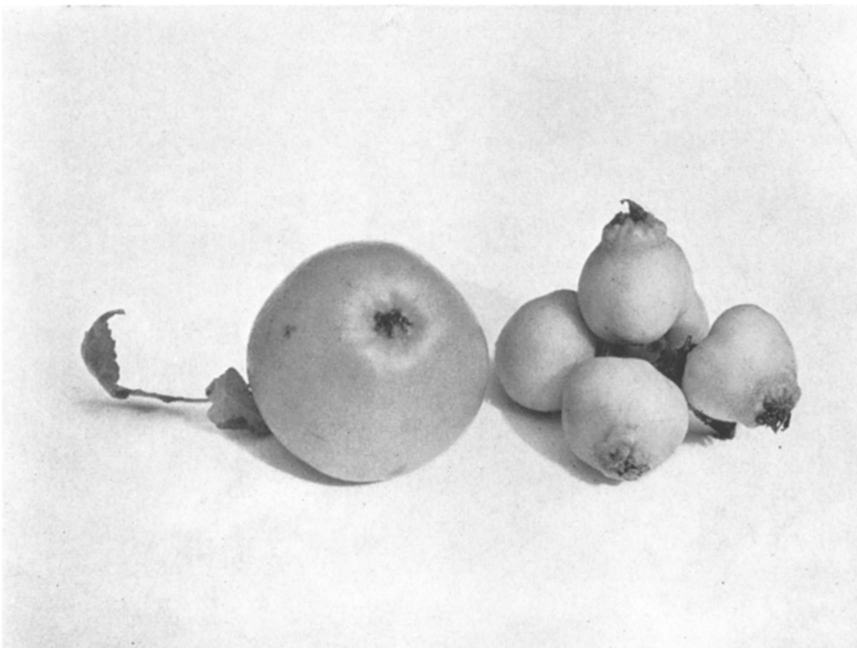


FIG. 35. Fruit deformed by *D. plantaginea* (right) and normal fruit (left).
Door D. plantaginea *beschadigde appels* (*rechts*) *en normale appel* (*links*).

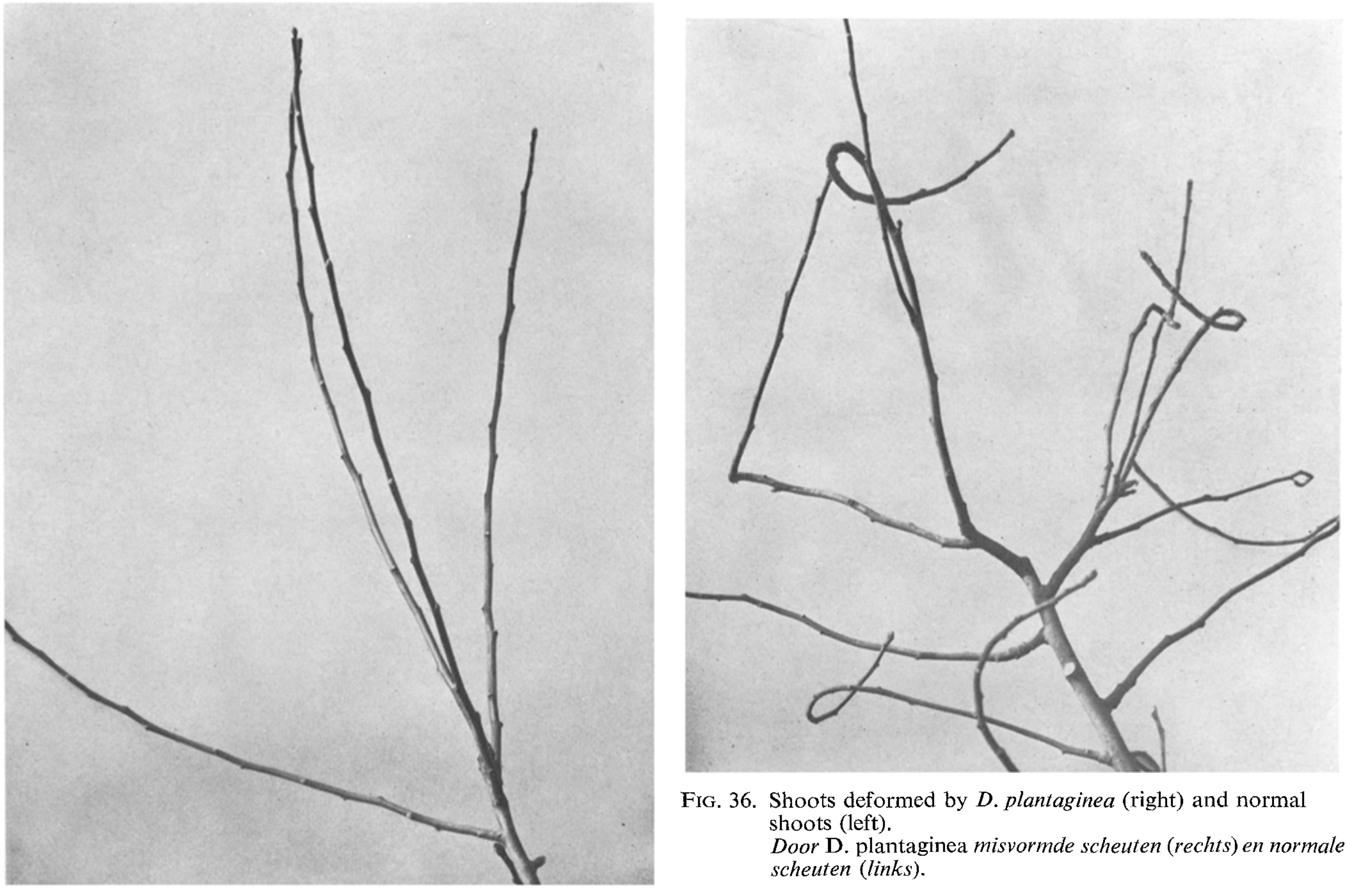


FIG. 36. Shoots deformed by *D. plantaginea* (right) and normal shoots (left).
Door D. plantaginea *misvormde scheuten* (*rechts*) *en normale scheuten* (*links*).

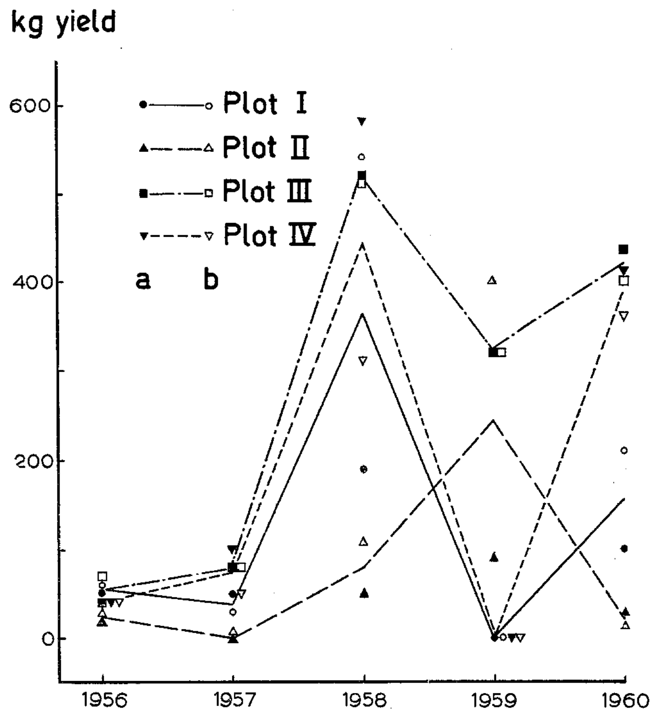


FIG. 37. Relation between total yield per plot and the treatment used in 1956–1960. Yield in kilogram. Plots as in Fig. 30.
Invloed van de cultuurmaatregelen op de totale opbrengst per perceel in 1956–1960. Opbrengst in kilogram. Percelen als in fig. 30.

in the –sfp plots, while in 1959 and 1960 the fruit weight in the sprayed plots was in both the +sfp and –sfp plots higher than in the corresponding unsprayed plots.

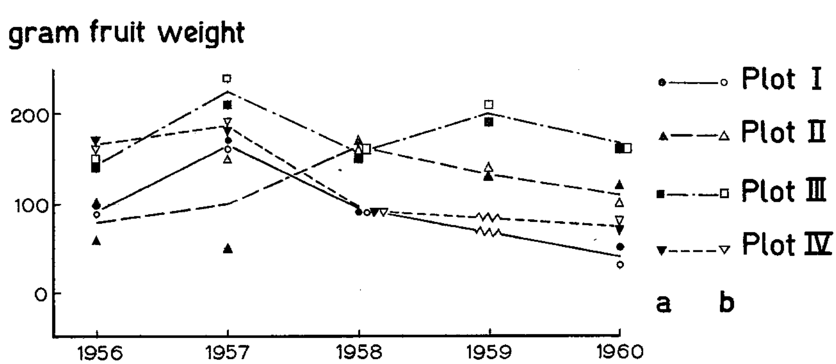


FIG. 38. Relation between fruit weight per plot and the treatment used in 1956–1960. Mean fruit weight in gram. Plots as in Fig. 30.
Invloed van de cultuurmaatregelen op het gewicht per appel per perceel in 1956–1960. Gemiddeld gewicht per appel in gram. Percelen als in fig. 30.

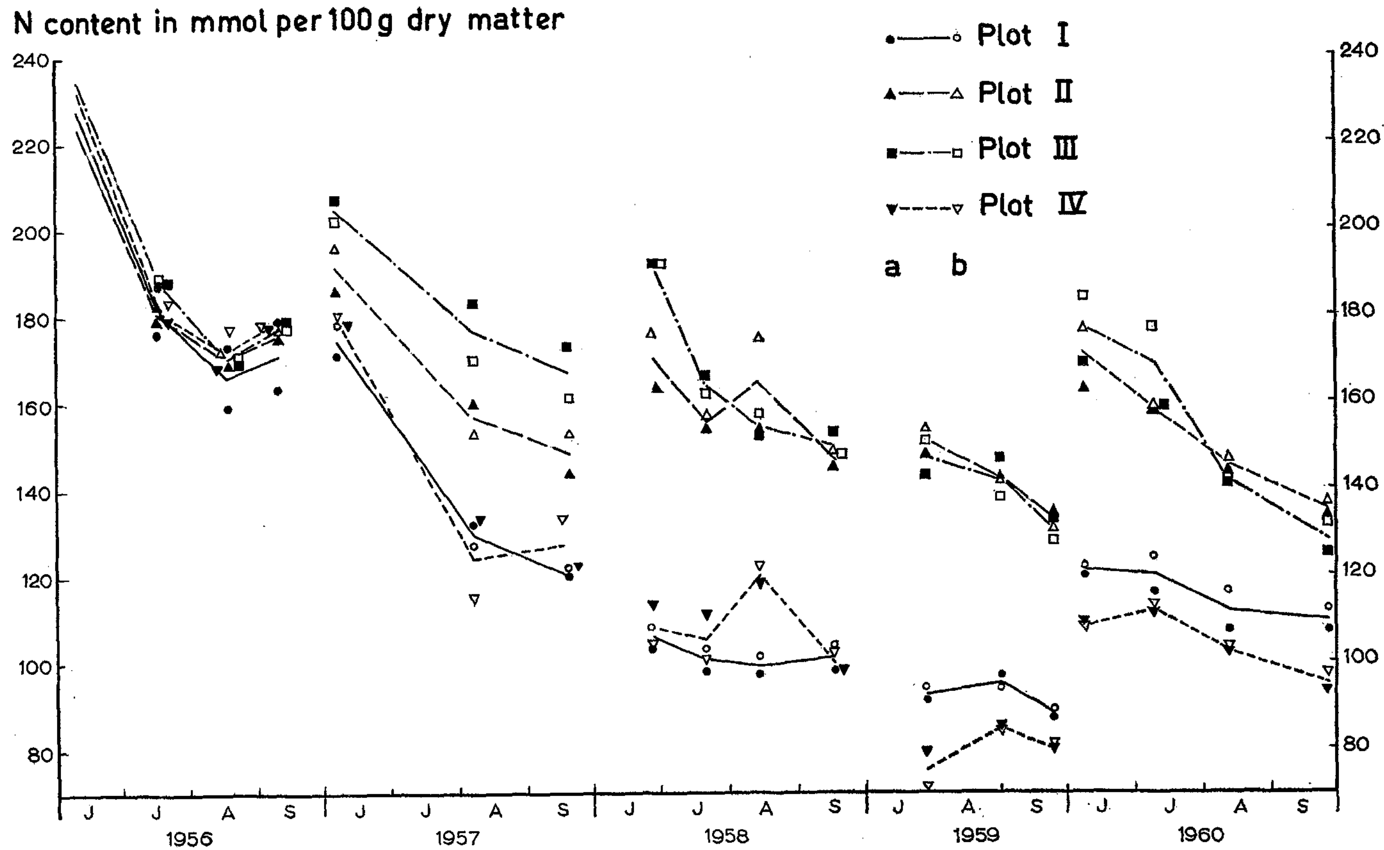


FIG. 39. Relation between total nitrogen content of the leaves and the treatment used during 1956–1960. Nitrogen content in mmol per 100 gram dry matter. Plots as in Fig. 30.
Invloed van de cultuurmaatregelen op het totale stikstofgehalte der bladeren gedurende 1956–1960. Stikstofgehalte in mgmol per 100 gram droge stof. Percelen als in fig. 30.

Chemical composition of the leaves:

In Figure 39 the nitrogen content of the leaves is given for the course of the season in the years 1956 through 1960. Tables 19–22 give the means per year of the potassium, calcium, magnesium, and phosphate contents of the leaves. In these Tables the uppermost figures give the mean contents of the leaves in each of the duplicate plots, the lowermost figures the means of these values.

In 1956 the values for the nitrogen contents of the leaves from the 4 +sfp and 4 –sfp plots were in complete agreement; beginning in 1957 these values showed consistently less agreement. In the –sfp plots there was a sharp drop due to the suspension of fertilization. The small drop in the +sfp plots over the years is attributable to the increase in the size of the tree. In 1960 the content in both the +sfp and the –sfp plots is higher than in the previous year. In the fruiting years of biennially-bearing trees the nitrogen content of the leaves is generally higher than in the non-fruiting year (MASON, 1955; BUTIJN, 1961b). This phenomenon is probably responsible for the high nitrogen content of the leaves in 1960 (fruiting year) in relation to 1959 (non-fruiting year). Moreover, the nitrogen take-up from the soil was also certainly promoted by the heavy rainfall in 1960 (BUTIJN, 1961a).

TABLE 19. Mean potassium content of the leaves in meq per 100 gram dry matter during June, July and August, 1956–1960.
Gemiddeld kaliumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1956–1960.

	unsprayed *onbespoten*				sprayed *bespoten*			
	–sfp		+sfp				–sfp	
	I		II		III		IV	
	a	b	a	b	a	b	a	b
1956	33.3	35.0 [1]	35.8	37.7	48.3	35.6	35.1	38.4
	34.2 [2]		36.8		41.9		36.7	
1957	28.3	25.9	32.4	31.1	32.1	30.9	27.4	24.0
	27.1		31.7		31.5		30.7	
1958	55.8	35.8	31.8	34.6	27.6	26.9	36.2	40.3
	45.8		33.2		27.3		38.3	
1959	55.2	53.3	36.4	37.0	30.9	26.2	49.2	53.0
	54.2		36.7		28.6		51.1	
1960	48.3	44.7	32.9	34.5	27.7	26.2	48.5	48.9
	46.5		33.7		26.9		48.7	

[1] mean content of the duplicates separately
[2] mean of the duplicates combined
[1] *gemiddelde gehalte in ieder der duplo percelen*
[2] *gemiddelde van de bovenste waarden*

Difference in the mean potassium content of the leaves from the +sfp and –sfp plots began to occur in 1957. In 1958 and the following years the figures from the analyses of the leaves in the +sfp plots are all lower than those from the –sfp plots. In the +sfp plots with a high nitrogen content, thus, a low potassium content occurred, which agrees with the observations of BUTIJN (1961a), among others.

In the sprayed +sfp Plots IIIa and IIIb, the contents in 1958, 1959, and 1960 were somewhat higher than in the unsprayed Plots IIa and IIb. No differences were found between the sprayed and unsprayed –sfp plots.

TABLE 20. Mean calcium content of the leaves in meq per 100 gram dry matter during June, July and August, 1958–1960.
Gemiddeld calciumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1958–1960.

<table>
<tr><th rowspan="4"></th><th colspan="4">unsprayed
onbespoten</th><th colspan="4">sprayed
bespoten</th></tr>
<tr><th colspan="2">–sfp</th><th colspan="4">+sfp</th><th colspan="2">–sfp</th></tr>
<tr><th colspan="2">I</th><th colspan="2">II</th><th colspan="2">III</th><th colspan="2">IV</th></tr>
<tr><th>a</th><th>b</th><th>a</th><th>b</th><th>a</th><th>b</th><th>a</th><th>b</th></tr>
<tr><td>1958</td><td>98</td><td>103 [1]</td><td>136</td><td>151</td><td>154</td><td>167</td><td>109</td><td>140</td></tr>
<tr><td></td><td colspan="2">101 [2]</td><td colspan="2">143</td><td colspan="2">160</td><td colspan="2">124</td></tr>
<tr><td>1959</td><td>101</td><td>98</td><td>139</td><td>165</td><td>188</td><td>184</td><td>101</td><td>99</td></tr>
<tr><td></td><td colspan="2">99</td><td colspan="2">152</td><td colspan="2">186</td><td colspan="2">100</td></tr>
<tr><td>1960</td><td>100</td><td>106</td><td>109</td><td>128</td><td>129</td><td>147</td><td>97</td><td>99</td></tr>
<tr><td></td><td colspan="2">103</td><td colspan="2">118</td><td colspan="2">138</td><td colspan="2">98</td></tr>
</table>

[1]) and [2]) as in Table 19
[1]) *en* [2]) *als in tabel 19*

The mean calcium content of the leaves in 1958, 1959, and 1960 were higher in the +sfp plots than in the –sfp plots. The values of the monthly analyses of the +sfp plots were all above those in the –sfp plots. In the sprayed +sfp Plots IIIa and IIIb these values were also somewhat higher than in the unsprayed Plots IIa and IIb. In the –sfp plots there were no consistent differences in the calcium content of the leaves from the sprayed and unsprayed plots.

TABLE 21. Mean magnesium content of the leaves in meq per 100 gram dry matter during June, July and August, 1958–1960.
Gemiddeld magnesiumgehalte der bladeren in mgaeq per 100 gram droge stof gedurende juni, juli en augustus, 1958–1960.

<table>
<tr><th rowspan="4"></th><th colspan="4">unsprayed
onbespoten</th><th colspan="4">sprayed
bespoten</th></tr>
<tr><th colspan="2">–sfp</th><th colspan="4">+sfp</th><th colspan="2">–sfp</th></tr>
<tr><th colspan="2">I</th><th colspan="2">II</th><th colspan="2">III</th><th colspan="2">IV</th></tr>
<tr><th>a</th><th>b</th><th>a</th><th>b</th><th>a</th><th>b</th><th>a</th><th>b</th></tr>
<tr><td>1958</td><td>10.2</td><td>11.5 [1]</td><td>15.3</td><td>18.0</td><td>23.4</td><td>23.6</td><td>10.5</td><td>9.0</td></tr>
<tr><td></td><td colspan="2">10.8 [2]</td><td colspan="2">16.7</td><td colspan="2">23.5</td><td colspan="2">9.7</td></tr>
<tr><td>1959</td><td>7.0</td><td>8.6</td><td>17.6</td><td>18.6</td><td>22.8</td><td>26.2</td><td>9.3</td><td>8.9</td></tr>
<tr><td></td><td colspan="2">7.8</td><td colspan="2">18.1</td><td colspan="2">24.5</td><td colspan="2">9.1</td></tr>
<tr><td>1960</td><td>8.8</td><td>10.3</td><td>15.8</td><td>18.0</td><td>19.7</td><td>21.4</td><td>9.2</td><td>8.2</td></tr>
<tr><td></td><td colspan="2">9.6</td><td colspan="2">16.9</td><td colspan="2">20.6</td><td colspan="2">8.7</td></tr>
</table>

[1]) and [2]) as in Table 19
[1]) *en* [2]) *als in tabel 19*

Symptoms of magnesium deficiency were first seen in 1958 in the –sfp plots. The results of the analyses showed that, as in the following years 1959 and 1960, the magnesium content was very low in these plots and far below the level of the +sfp plots. In the sprayed +sfp plots this level was higher. In the –sfp plots no difference was observed in the magnesium content of the leaves from the sprayed and unsprayed plots.

TABLE 22. Mean phosphate content of the leaves in mmol per 100 gram dry matter during June, July and August, 1958–1960.
Gemiddeld fosfaatgehalte der bladeren in mgmol per 100 gram droge stof gedurende juni, juli en augustus, 1958–1960.

	unsprayed *onbespoten*						sprayed *bespoten*					
	–sfp			+sfp						–sfp		
	I			II			III			IV		
	a	b	mean	a	b	mean	a	b	mean	a	b	mean
1958	6.4	6.4 [1]	6.4 [2]	7.0	7.6	7.3	7.2	8.0	7.6	6.5	6.4	6.4
1959 [3]	17.0	14.7	15.8	5.1	5.3	5.2	5.5	5.6	5.5	13.4	14.1	13.7
1960	12.8	12.0	12.4	5.9	6.4	6.2	6.4	6.9	6.6	10.3	10.0	10.2

[1]) and [2]) as in Table 19
[3]) in July, August, and September
[1]) *en* [2]) *als in tabel 19*
[3]) *in juli, augustus en september*

In 1958 the differences in the mean phosphate content of the leaves from the +sfp and –sfp plots were still very small. In 1959 and 1960, however, the phosphate content in the +sfp plots was appreciably lower than in the –sfp plots. In the sprayed Plots IVa and IVb the content was somewhat lower than in the corresponding unsprayed plots. In 1956 and 1957 no analyses of calcium, magnesium, and phosphorus could be done by the laboratory.

In contrast with the old standard-tree orchard in Eversdijk, in this young spindle orchard there were changes not only in the nitrogen content of the leaves but also in the potassium, calcium, magnesium, and phosphate contents of the leaves as a result of cultivation, fertilization, and pruning. This difference in reaction is in all probability to be attributed to differences in the age and growth-rate of the trees in the two orchards: in the old trees in Eversdijk there may have been less of these elements fixed in the trunk, etc., than in the young, fast-growing trees in Kuenen's Hof.

The more intensive growth of the trees, the better fruit setting, and the higher mean fruit weight in the +sfp plots are in complete agreement with the higher nitrogen content found for these plots (BUTIJN, 1961a).

Moisture content of the leaves:

As in Eversdijk, there were no consistent differences between the moisture content of the leaves from the 4 types of plot. This factor therefore cannot be considered to have contributed to the differences in development of *M. ulmi* in the +sfp and –sfp plots.

Leaf areas:

The differences between the mean leaf areas are on the whole small and can have had only a very slight influence on the differences in the population density of *M. ulmi* in the various plots. As can be seen from Table 23, if the number of mites + eggs per 100 leaves is converted into the number on 100 cm² of leaf area the large differences between the plots remain.

TABLE 23. Mean population density of *M. ulmi* per 100 cm² of leaf area in August.
Gemiddelde populatiedichtheid van M. ulmi *per 100 cm² bladoppervlakte in augustus.*

	unsprayed *onbespoten*				sprayed *bespoten*			
	–sfp		+sfp				–sfp	
	I		II		III		IV	
	a	b	a	b	a	b	a	b
1956	68	23	65	380	0	3	2	8
1957	903	571	1070	374	147	277	126	299
1958	22	9	432	398	213	90	5	16
1959	5	10	431	258	396	190	1	5
1960	38	25	20	1	0	0	0	0

Anatomical structure of the leaf:
In August 1958, sample leaves of comparable length were taken from the 8 plots and preserved in 70% alcohol. In 4 leaves from each plot transverse sections were made at 4 places and from each place two sections were measured (see p. 20). These measurements showed that in the +sfp plots there was a significant increase (at the 5% level) in the total thickness of both the leaf and the palisade mesophyll compared to the –sfp plots (see Eversdijk p. 35). This increase was greatest in the duplicate plots in which chemical control was applied in addition to cultivation, fertilization, and pruning. Chemical control alone caused no significant changes in the measurements in relation to the control Plots Ia and Ib. It also appeared that the greater thickness of the palisade mesophyll was accompanied by a greater, on the average, number of palisade layers. PICKETT & BIRKELAND (1941, 1942a, b) have reported the effect of chemical sprays on leaf structure; according to them, the normal development of the palisade tissue is prevented (the cells remain small) and this difference between the sprayed and unsprayed leaves increases in the course of the season. In contrast with their results, we found no significant differences in the thickness of the palisade mesophyll between the sprayed and unsprayed plots.

Just as in the old standard-tree orchard in Eversdijk, in Kuenen's Hof the highest population density of *M. ulmi* occurred in the +sfp plots, but here this difference occurred in both sprayed and unsprayed plots.

The leaves from the +sfp plots show a higher total nitrogen content and a higher total leaf thickness and thickness of the palisade mesophyll than those from the –sfp plots. A distinct effect of the cultural program on the physiological condition of the trees is also expressed in the better growth of the trees, the higher percentage of fruit setting, and the higher mean fruit weight.

The data concerning the severe damage by *M. ulmi* and the greater thickness of the palisade mesophyll show some agreement with BLAIR's observations

(1951). She reported the correlation between the visible damage to various varieties of apple and the number of layers of palisade mesophyll: in varieties with only one layer, the visible injury occurs earlier than in varieties with several layers, in which connection the size of the leaf also plays a part. According to BLAIR, in varieties with a large leaf area and a thick layer of palisade mesophyll the nutrients in the lower layers are exhausted less rapidly and the leaf therefore shows discolouration later. In our study, therefore, the leaves from the +sfp plots offer a larger food supply to the mites.

BLAIR did not determine the nitrogen content of the leaves in the varieties she studied. There would seem to be a possibility that the nitrogen content of the leaves of the varieties with a thicker palisade layer is higher than that of those with a thin one, because of the correlation between these two variables (BALDINI, 1960, and our observations). An increased nitrogen content of the leaves following nitrogen fertilization may also manifest itself in an increase of the thickness of the palisade mesophyll, and in this way affect the nutritional position of the mite.

The phenomenon of the stronger development of *M. ulmi* on leaves with a high nitrogen content and the resultant low potassium content agrees with the results of FRITZSCHE et al. (1957), who demonstrated by means of experiments with *Phaseolus vulgaris* that the increase in *Tetranychus urticae* on plants grown in nutrient solutions with a potassium, phosphate, or nitrogen deficiency was stronger than on plants in balanced nutrient solutions, the strongest increase occurring with the potassium-deficient plants. Analyses of the leaves, however, showed that even in the plants grown in a nitrogen-deficient solution the total nitrogen content was higher in all cases than that of the leaves of the complete solution. On the basis of further chemical investigation of the leaves, FRITZSCHE found that the following factors promoted the mite increase:

1. An increased total nitrogen content, for which the insoluble nitrogen compounds are important, and the glutamine and glutamic acid content.
2. The increased content of reducing sugars which accompanies this.

In our analyses only the total nitrogen content was determined, so that no distinction was made between the organic and inorganic nitrogen compounds. The severe mite increase is proportional to the increase in this total nitrogen content. Over-fertilization with nitrogen destroys the nitrogen-potassium balance and the plant develops a potassium deficiency.

It is clear from this discussion that leaf analyses are essential to the investigation of the effect of fertilization on the development of the phytophagous mites. It is not sufficient to reckon only with the fertilizers applied.

In conclusion it should be remarked that KUENEN (1946) found severe damage from the fruit tree red spider mite on pear and plum varieties with a thin cuticle. The thickness of the palisade mesophyll was not determined. In the present study the leaf measurements for both Bellefleur and Lombartscalville were done in hand-cut sections of material preserved in alcohol. As a result, differences in the thickness of the cuticle could not be determined.

b. Predators

Predatory mites:

In the experimental field which was regularly sprayed with organophosphorus compounds until 1956, no predatory mites were found in the spring of that year. A few specimens were first seen in August in the unsprayed plots of the species *Typhlodromus tiliae* and *T. tiliarum*. During the investigation, *Phytoseius macropilis* and *Mediolata mali* were also observed.

Unsprayed plots

As Figure 40 shows, the number of predatory mites in the unsprayed plots increased gradually over the years, the increase being strongest in the plots with highest *M. ulmi* population density. The effect of the very favourable

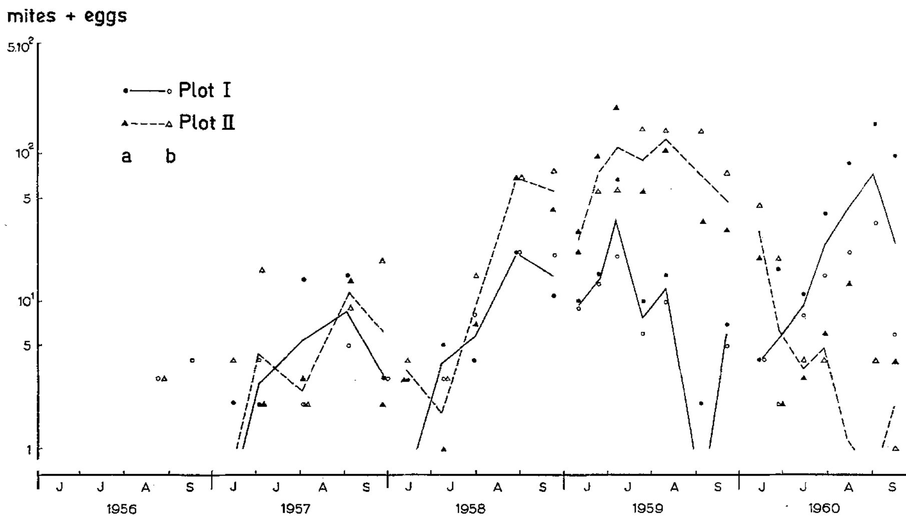


FIG. 40. Population density of predacious mites in the unsprayed plots during 1956–1960. Number of mites + eggs per 100 leaves.
Plot Ia & Ib: −sfp; Plot IIa & IIb: +sfp.
Populatiedichtheid van de roofmijten in de onbespoten percelen gedurende 1956–1960. Aantal mijten + eieren per 100 bladeren.
Perceel Ia & Ib: −sfp; Perceel IIa & IIb: +sfp.

weather conditions in 1959 was also expressed in the development of the predatory mites, especially on the development of *M. mali* which occurred only sporadically in the other years. In the very rainy summer of 1960 the population density of both the phytophagous mites and the predatory mites dropped sharply in the +sfp plots from about the beginning of the rainy period in July. In the –sfp plot, to the contrary, in July and August there was, more or less simultaneously with an increase of the *M. ulmi* population in these plots, a very explosive development of *M. mali* which led to a high mean density of the predatory mites. Table 24 gives the mean densities per 100 leaves of the predatory mites belonging to the Phytoseiidae (*Typhlodromus* spp. and *P. macropilis*) and to the Raphignatidae (*M. mali*).

Predatory Heteroptera:

As early as 1956 we saw the growth of a population of beneficial Heteroptera, primarily *Anthocoris nemorum* and *Blepharidopterus angulatus*. The latter species, which in the English literature (COLLYER, 1952) is considered one of the

TABLE 24. Mean population density of predacious mites of the Phytoseiidae and Raphignatidae per 100 leaves in the unsprayed plots.
Gemiddelde populatiedichtheid der roofmijten der Phytoseiidae en Raphignatidae per 100 bladeren in de onbespoten percelen.

	Phytoseiidae		Raphignatidae		Phytoseiidae		Raphignatidae	
	I -sfp				II +sfp			
	a	b	a	b	a	b	a	b
1959	5	7	10	2	64	52	5	29
1960	3	7	39	3	9	11	0	5

most important predators of the fruit tree red spider mite, is generally seen only rarely in unsprayed orchards in the province of Zeeland. Because the plots were bordered on 3 sides by alders, we assumed that these predators originated in the hedge. STICHEL (1925/38) reports *Alnus* as one of the plants on which *B. angulatus* is found. Inventories of the alder hedge confirmed its presence there.

Over the years, both the number of individuals and the number of Heteroptera species increased. In 1956 and 1957 only *Anthocoris* spp. and *B. angulatus* were found; in 1958, in order of quantity, the species *Heteroptera meriopterum*, *Pilophorus* spp., and *Atractotomus mali*; in 1959: *Orius* spp., *Nabis* spp., *Malacocoris chlorizans*, and *Psallus ambiguus*.

Heteroptera, like the predatory mites (Fig. 41), show the strongest population development in the +sfp plots. In spite of the very favourable weather conditions of 1959, the population density dropped sharply in the -sfp Plots Ia and Ib in relation to that of 1958. This drop is approximately proportional to the

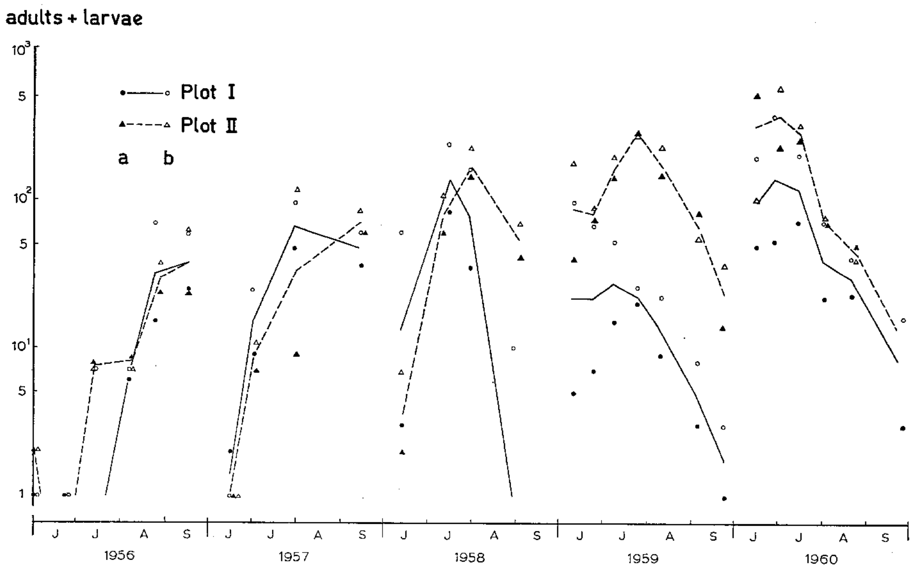


FIG. 41. Population density of predacious Heteroptera in the unsprayed plots during 1956–1960. Number of predacious Heteroptera per sample. Plots as in Fig. 40.
Populatiedichtheid van de roofwantsen in de onbespoten percelen gedurende 1956–1960. Aantal roofwantsen per monster. Percelen als in fig. 40.

reduction in the *M. ulmi* population density in these plots. As a consequence of the very mild winter of 1959/1960, the number of predatory Heteroptera in the beginning of 1960 was rather high, especially in the +sfp plots. After the onset of a very rainy period, however, there was a sharp decrease.

In contrast to the Eversdijk observations, distinct differences in the populations densities of the predatory Heteroptera occurred in relation to the densities of *M. ulmi.* Because of the smaller tree, the inventory method gives a better picture of the actual population in this orchard than in the standard-tree orchard in Eversdijk.

Other predacious insects:

As in Eversdijk, the mean population density of the other predatory insects are given only in a Table.

TABLE 25. Mean population density of the other predacious insects per sample in the unsprayed plots.
Gemiddelde populatiedichtheid der overige roofinsekten per monstername in de onbespoten percelen.

adults + larvae *imago's + larven*	I –sfp		II +sfp	
	a	b	a	b
1956	14	9	9	8
1957	15	29	8	20
1958	4	5	5	11
1959	8	13	27	23
1960	16	18	15	13

When chemical control was concluded at the end of 1955, the number of predatory insects belonging to the Diptera (Syrphidae), Neuroptera (Chrysopidae and Hemerobüdae), and Coleoptera (Coccinellidae) increased. The species observed were the same as those listed for Eversdijk (see p. 22). As mentioned, these species were very polyphagous and also attacked phytophagous mites. They have, however, a preference for aphids such as *A. pomi*, *D. plantaginea*, and *E. lanigerum*. Since the majority of the larvae of the insects occur in aphid colonies, only a small proportion will be collected with our inventory technique, which is probably one of the causes of the rather irregular distribution in the +sfp plots.

Spiders:

The number of spiders also increased over the years in the unsprayed plots, but no detailed observations were done.

Sprayed plots

Predatory mites:

Practically all of the predatory mites in the sprayed plots were destroyed by the chemical control measures, and individuals were observed only sporadically.

Predatory insects:

As shown by Tables 26 and 27, the numbers of insect predators in these plots were also very small. In view of the relatively high density of the *M. ulmi* population from 1956 through 1959, the small numbers cannot be due to a shortage of food.

TABLE 26. Mean population density of the predacious Heteroptera per sample in the sprayed plots.
Gemiddelde populatiedichtheid der roofwantsen per monstername in de bespoten percelen.

adults + larvae *imago's + larven*	III +sfp		IV −sfp	
	a	b	a	b
1956	3	3	2	3
1957	9	17	7	11
1958	5	5	3	5
1959	4	5	1	1
1960	1	4	0	4

TABLE 27. Mean population density of the other predacious insects in the sprayed plots.
Gemiddelde populatiedichtheid der overige roofinsekten per monstername in de bespoten percelen.

adults + larvae *imago's + larven*	III +sfp		IV −sfp	
	a	b	a	b
1956	1	1	1	1
1957	5	13	5	4
1958	1	1	3	2
1959	7	4	5	8
1960	1	2	3	4

Spiders:
In the sprayed plots only very small numbers of spiders were observed.

c. Competition
Because a normal chemical control program had been applied in the experimental field up to the time it was taken over by us in 1956, competition with *M. ulmi* by other animal or plant organisms was excluded. In the course of the following years, however, the number of species in the unsprayed plots increased.

Bryobia rubrioculus Scheuten
In a well-kept young spindle orchard few or no *B. rubrioculus* occur, as is well known (see p. 42). In Plots I and II where spraying was stopped in 1956 a development of *B. rubrioculus* was observed, starting in the first year of the investigation. However, the numbers are very small compared to those in the standard-tree orchard in Eversdijk. These small numbers may be due to conditions which were less favourable for this mite, but also to the presence of a large *M. ulmi* population which limits the development of *B. rubrioculus*. In specific investigations concerning the competition between the two mite species (POST, 1959b), a reduction in the population density of *B. rubrioculus* was observed, with a ratio between the mite species approximately the same as was found in this experimental plot. With this low density, *B. rubrioculus* does not function as a competitor of *M. ulmi*.

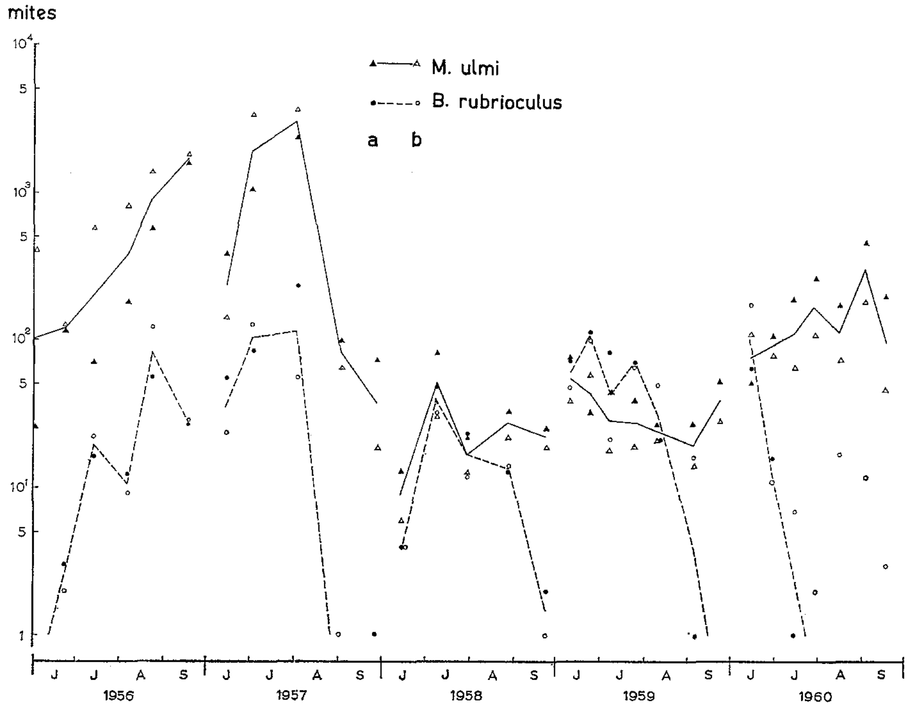


FIG. 42. Development of the *M. ulmi* and *B. rubrioculus* populations in Plot I during 1956–1960. Number of mites per 100 leaves .Plot Ia & Ib: unsprayed –sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *in Perceel I gedurende 1956–1960. Aantal mijten per 100 bladeren. Perceel Ia & Ib: onbespoten –sfp.*

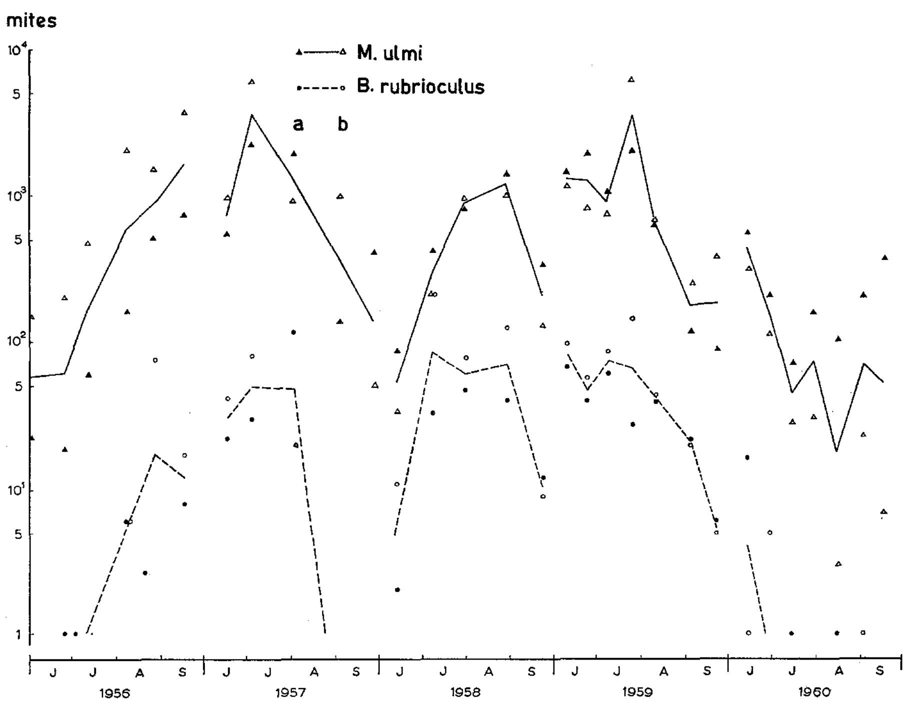


FIG. 43. Development of the *M. ulmi* and *B. rubrioculus* populations in Plot II during 1956–1960. Number of mites per 100 leaves. Plot IIa & IIb: unsprayed +sfp.
Populatie ontwikkeling van M. ulmi *en* B. rubrioculus *in Perceel II gedurende 1956–1960. Aantal mijten per 100 bladeren. Perceel IIa & IIb: onbespoten +sfp.*

Figures 42 and 43 indicate that, as in Eversdijk, there was only a small difference in *B. rubrioculus* development in the +sfp and the –sfp plots.

In 1960 the population density of the mite was determined in the unsprayed plots on leaves and branches. Because in this young plot there was an average of about 3 leaves per centimetre of branch, the mean densities were converted into the densities per 10 cm of branch + 30 leaves. This method also failed to bring out any difference in the development of the mite in the +sfp and –sfp plots. Because of the high densities of the *M. ulmi* population in the +sfp plots from 1956 to 1960, the possibility remains that the inhibitory effect of this population on the development of *B. rubrioculus* eliminated the effect of the higher nitrogen content of the leaves in these plots on the development of the mite.

TABLE 28. Mean population density of *B. rubrioculus* per 10 cm of branch + 30 leaves in the unsprayed plots.
Gemiddelde populatiedichtheid van B. rubrioculus *per 10 cm tak + 30 bladeren in de onbespoten percelen.*

1960	I –sfp		II +sfp	
	a	b	a	b
mites/*mijten*	7	10	18	14
eggs/*eieren*	12	25	13	3
total/*totaal*	19	35	31	17

Other species of mites (*Eotetranychus pomi*, *Tydeus* spp., *Eriophyidae*, and *Tarsonemidae*) were found in such very small numbers that they may be neglected. As to the other competing organisms, it may be said that the damage to the leaves by scab was very small even in the unsprayed plots; Lombartscalville is not very susceptible to scab.

Especially in the +sfp plots, there was severe damage to the terminal leaves of the twigs by apple mildew which eliminated them as a source of food for the mites. In general *M. ulmi* is not found on the very young leaves before middle or late summer, so that this would not seriously limit the population development. Infection of the trees by *M. ulmi* takes place during the course of the summer from the lower part to the top of the shoots (ANDERSEN, 1948; CHANT, 1959b). With a high population density of *M. ulmi* the mites deposit eggs later in the year on the younger terminal leaves as well. In this case the mildew will exert a limiting effect on the *M. ulmi* population because these leaves are made inedible by the mildew. As the summer advances, a severe mildew infestation produces a secondary infection of the older leaves; however, generally the entire leaf is not eliminated as a food source for the mite.

A severe aphid infestation also prevents an *M. ulmi* population from developing on the affected leaves.

In the unsprayed plots the possibility of competition with *M. ulmi* by other phytophagous mites may therefore be neglected because of the very low density of these mites. A severe mildew or aphid infestation will be able to inhibit development to some extent only in the +sfp plots. In the sprayed plots competition does not play a role because of the almost complete absence of any organism which might act as a competitor.

d. Chemical control

The spray program in Plots III and IV has already been discussed on page 50. As a result of this control the population densities of *M. ulmi* in the sprayed Plots III and IV were appreciably lower than in the unsprayed Plots I and II (Figs. 28 and 29).

In the sprayed, unfertilized Plots IVa and IVb, after an initial increase of the population density in 1957 a gradual decrease was observed. Even in the unusually warm, dry summer of 1959 there was no great increase of the kind seen in the fertilized Plots IIIa and IIIb. In these fertilized plots *M. ulmi*, in spite of the chemical control, reached a very injurious level in various years, so that by the end of those seasons the mite infestation had caused some bronzing of the leaves. After each spraying the population recovered rapidly. However, chlorbenside control in 1960 applied before and after blossoming gave very good results, after which the wet summer of that year helped to keep the population density at a low level. In 1961 the densities also remained rather low and no pronounced differences were observed between the sprayed +sfp and –sfp plots.

5. INVESTIGATION OF SPECIFIC PROBLEMS

5.1. EFFECT OF THE NITROGEN CONTENT OF THE LEAVES ON THE DEVELOPMENT OF PHYTOPHAGOUS MITES

5.1.1. *Metatetranychus ulmi* Koch

Since some of the laboratory and other detailed experiments have already been published (BREUKEL & POST, 1959), only a summary of the results will be given here together with a few additional data. In Chapter 5.1 significance at the 5% level was determined with Wilcoxon's test (see WABEKE & VAN EEDEN, 1955).

5.1.1.1. Laboratory experiments

M. ulmi mites from an unsprayed tree were cultured in the laboratory on leaf punches in petri dishes containing wet sand. The leaves were taken from two unsprayed Bellefleur trees, one in a fertilized and one in an unfertilized plot. The mean total nitrogen contents of the leaves during the months June through September was 2.44% for the leaves from the fertilized tree and 1.78% for those from the unfertilized tree. The potassium, calcium, magnesium, and phosphate contents of the leaves showed no consistent differences between the trees from the fertilized and unfertilized plots.

The mean egg production per female per 24 hours of the mites cultured on leaves with a high nitrogen content (+N leaves) was significantly higher in 6 of the 7 series of observations than it was on leaves with a low nitrogen content (–N leaves). Although this factor of 1.6 does not seem large, it can be very important since under our climatic conditions 5 generations of *M. ulmi* occur per season.

TABLE 29. Relation of the total nitrogen content of the leaves and the development and mortality of *M. ulmi*.
Invloed van het totale stikstofgehalte der bladeren op ontwikkeling en sterfte van M. ulmi.

M. ulmi	fertilized trees (+N) *bemeste bomen (+N)*		unfertilized trees (–N) *onbemeste bomen (–N)*	
	initial number *aantal* [1])		initial number *aantal*	
egg production per ♀ per 24 hours *eiproductie per ♀ per 24 uur*	91 ♀♀	1.5 ± 0.5[2])	76 ♀♀	1.0 ± 0.4
total egg production per ♀ *totale eiproductie per ♀*	91 ♀♀	16.2 ± 11.5	76 ♀♀	10.7 ± 7.2
oviposition period in days *eilegperiode in dagen*	91 ♀♀	10.6 ± 6.2	76 ♀♀	10.7 ± 6.1
mortality in eggs *sterfte eieren*	1965	10.1%	1020	12.9%
mortality in immature stages *sterfte niet-volwassen stadia*	1275	23.3%	846	31.4%
immature period in days [3]) *ontwikkelingsduur niet-volw. stadia in dagen*				
♀ 1st–4th generation	406	7.9 ± 1.1	263	8.8 ± 1.4
♂ 1st–4th generation	347	7.1 ± 1.6	177	8.0 ± 1.3
♀ 5th generation	136	11.2 ± 1.4	84	12.0 ± 2.3
♂ 5th generation	98	10.0 ± 1.0	58	11.3 ± 1.3

[1]) This column gives the initial number of specimens, i.e. the number of mites, eggs, and larvae resp.
[2]) Standard deviation.
[3]) The immature period of the 5th generation in the second half of August appeared to be longer than in the first 4 generations both on the +N and on the –N leaves. Therefore the results are given separately for the first 4 generations and for the 5th generation.
[1]) *In deze kolom staat het aantal exemplaren, waarvan is uitgegaan, dus aantal mijten, resp. eieren en larven.*
[2]) *Standaard deviatie.*
[3]) *Uit de waarnemingen bleek, dat de ontwikkelingsduur van de niet-volwassen stadia van de 5e generatie in de 2e helft van augustus zowel op de +N als op de –N bladeren langer was dan van de eerste 4 generaties. Met het oog hierop zijn de resultaten van de eerste 4 generaties en van de 5e generatie afzonderlijk vermeld.*

The total egg production per female shows the same picture. The mean oviposition period per female, calculated from the depositing of the first egg to the death of the females, shows no differences between the +N and –N leaves. The mortality during the egg stage and the development from larva to adult is on the average higher on the –N leaves. In contrast to what was reported in the above-mentioned publication, the differences in mortality on the +N and –N leaves are not significant. The distribution of the mortality over the various stages is the same for the specimens of both kinds of leaves. The immature period of both sexes is about one day shorter on the +N leaves than on the –N leaves. Although the differences are significant, this difference in development is less important for the building up of the mite population in the course of a season than the difference in egg production. HAMSTEAD & GOULD (1957) found that an increased nitrogen content of the leaves had no effect on the rate of development of *M. ulmi* mites but affected only the egg production.

5.1.1.2. Experiments with rootstocks

Apple rootstocks M XI were planted in pots containing subsoil with a low organic-matter content. The isolated shoots of the rootstocks were infected with *M. ulmi* mites in order to study the effect of the nitrogen fertilization of the rootstocks on the population development of the mite. The mean nitrogen content of the leaves in June, August, and September was 1,96% for the +N and 1.62% for the –N leaves. *M. ulmi* showed a much greater increase on the +N leaves than on the –N leaves. One of the causes of this difference lies in the higher egg production per female on the +N rootstocks, where it was, as in the laboratory experiments, 1.6 to 1.7 times that on the –N rootstocks.

Differences in the period of egg laying, mortality, and the rate of development could not be determined in this type of experiment (see BREUKEL & POST, 1959).

5.1.2. *Bryobia rubrioculus* SCHEUTEN

5.1.2.1. Methods

In contrast with *M. ulmi, B. rubrioculus* spends its summer cycle on the leaves and branches of the trees and is thus much more active, which makes it impossible to culture this mite on leaf punches: the mites wander off the leaves and drown. SNETSINGER (personal communication) cultured *Bryobia* mites on twigs with a single terminal leaf, at a temperature of 60°–70°F (= ± 16–21°C) and a constant humidity of 90%. We were unable to fulfil the two latter con-

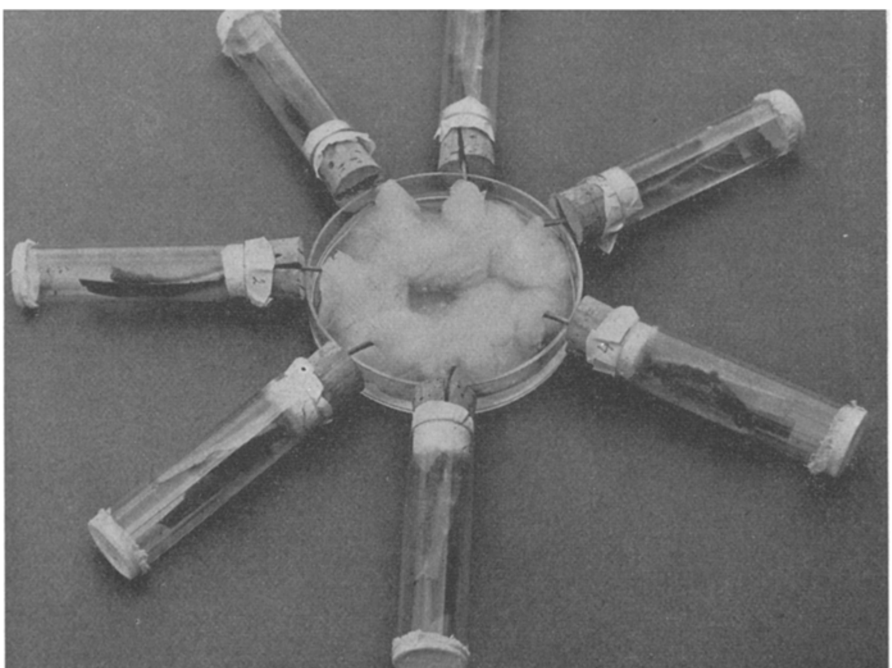


FIG. 44. Technique used for breeding *B. rubrioculus*.
Kweektechniek van B. rubrioculus.

ditions in our laboratory and consequently chose another method (Fig. 44) in which the mites were raised on leaves in a glass tube. The leaves were cut to size and placed together with a small piece of twig in the tube, which was closed with cheesecloth at one end and at the other by a paper-covered cork. Via the cork the leaf stem, wrapped in cotton wool, was kept in contact with water supplied in a petri dish. The eggs were deposited on the leaf, the cheesecloth and the paper. New leaves had to be substituted, depending on the temperature, every 4 to 10 days, when a check was also made on the number of eggs present and the stage of the mites. When necessary, checks were made more frequently.

Mites taken from Boskoop trees in a neglected standard-tree orchard in the deutochrysalid stage were used at the start of the experiments. Series A, with mites deriving from the 1st field generation, was set up on May 12th; two generations (A1 and A2) were followed from adult to adult; from the 3rd generation (A3) only the egg production was determined. Series B, with mites from the 2nd field generation, was set up on June 23rd, only one generation (B2) being completely followed; from the 3rd generation (B3) only the number of eggs produced was counted.

The leaves for the experiments were taken from one Boskoop tree in the unfertilized plot and one in the fertilized plot of the Eversdijk orchard in which no chemical control had been applied. The condition of the leaves, especially those from the unfertilized tree, was so poor in the latter half of August that the experiment had to be stopped: as a result of the warm, dry summer and a severe infestation of the trees by *Leucotricha scitella* and the mite *Eotetranychus pomi*, no fresh leaf material was available.

TABLE 30. Total nitrogen content of the leaves of Boskoop in mmol per 100 gram dry matter.
Totaal stikstofgehalte van de bladeren van Schone van Boskoop in mgmol per 100 gram droge stof.

Date *Datum*	fertilized plot *bemest perceel*	unfertilized plot *onbemest perceel*
29 May	153	111
26 June	158	104
28 July	140	127
28 August	140	98
mean/*gemiddelde*	148	110

The temperature of the temporary wooden building which housed the experimental set-up varied greatly with outside weather conditions.

5.1.2.2. Results

In Table 31 the reproduction rate of the mites is compared for the leaves from fertilized and unfertilized trees.

If differences between the generations are excluded from consideration, and the number of individuals and eggs produced are totalled, the mean number of eggs for the 64 specimens on the +N trees is 0.83 ± 0.60 and for the 55 specimens on the –N trees 0.71 ± 0.47 eggs per female per 24 hours. The mean reproduction rate per mite per 24 hours on the +N leaves is hardly any higher than that on the –N leaves. Only in the 2nd generation of series A is the difference in egg production on the +N and –N leaves nearly significant, which

TABLE 31. Mean egg production per ♀ per 24 hours on leaves of fertilized and unfertilized trees.
Gemiddelde eiproductie per ♀ per 24 uur op bladeren van bemeste en onbemeste bomen.

Fertilized trees (+N) / *Bemeste bomen (+N)*

Generation	Series A ♀♀	Series A eggs *eieren*	Series B ♀♀	Series B eggs *eieren*	Total ♀♀	Total eggs *eieren*
1	15	0.88 ± 0.64 [1])			15	0.80 ± 0.64
2	15	1.12 ± 0.81	14	0.91 ± 0.41	29	1.03 ± 0.64
3	11	0.41 ± 0.23	9	0.54 ± 0.32	20	0.47 ± 0.27
Total	41	0.86 ± 0.69	23	0.89 ± 0.42	64	0.83 ± 0.60

Unfertilized trees (–N) / *Onbemeste bomen (–N)*

Generation	Series A ♀♀	Series A eggs *eieren*	Series B ♀♀	Series B eggs *eieren*	Total ♀♀	Total eggs *eieren*
1	15	0.85 ± 0.58			15	0.85 ± 0.58
2	15	0.82 ± 0.72	13	0.82 ± 0.64	28	0.82 ± 0.67
3	7	0.32 ± 0.31	5	0.29 ± 0.25	12	0.31 ± 0.27
Total	37	0.74 ± 0.62	18	0.66 ± 0.60	55	0.71 ± 0.47

[1]) standard deviation [1]) *standaard deviatie*

TABLE 32. Mean oviposition period per ♀ in days on leaves of fertilized and unfertilized trees.
Gemiddelde eilegperiode per ♀ in dagen op bladeren van bemeste en onbemeste bomen.

Fertilized trees (+N) / *Bemeste bomen (+N)*

Generation	Series A	Series B	Total
1	19.4 ± 5.7		19.4 ± 5.7
2	16.4 ± 6.1	17.9 ± 5.3+	17.2 ± 5.6+
3	14.3 ± 6.0	17.6 ± 7.6	15.8 ± 7.2
Total	16.7 ± 6.1	17.8 ± 6.1	17.1 ± 6.1
Unfertilized trees (–N) / *Onbemeste bomen (–N)*			
1	16.6 ± 5.0		16.6 ± 5.0
2	13.1 ± 4.3	13.8 ± 3.4+	13.5 ± 3.9+
3	14.8 ± 5.4	16.3 ± 1.0	15.4 ± 4.2
Total	14.6 ± 4.8	14.4 ± 9.6	14.6 ± 4.3

+) Differences are significant +) *Significante verschillen*

also holds for the comparison of the mean egg production per mite of all individuals of the 3rd generation (series A3 + B3).

Although the mean oviposition period of the mites on the +N leaves was on the average higher than on the –N leaves, this difference is significant in only a few cases (+). The total egg production per mite on the +N leaves is again higher than on the –N leaves, but the difference is significant only for series A2 + B2.

TABEL 33. Total egg production per ♀ on leaves of fertilized and unfertilized trees.
Totale eiproductie per ♀ op bladeren van bemeste en onbemeste bomen.

Fertilized trees (+N) / *Bemeste bomen (+N)*

Generation	Series A ♀♀	Series A eggs *eieren*	Series B ♀♀	Series B eggs *eieren*	Total ♀♀	Total eggs *eieren*
1	15	13.1 ± 12.8			15	13.1 ± 12.8
2	15	17.1 ± 13.3	14	17.1 ± 11.4	29	17.1 ± 12.2+
3	11	5.7 ± 4.0	9	8.8 ± 6.2	20	7.1 ± 5.2
Total	41	12.6 ± 12.0	23	13.8 ± 10.4	64	13.0 ± 11.3

Unfertilized trees (–N) / *Onbemeste bomen (–N)*

Generation	Series A ♀♀	Series A eggs *eieren*	Series B ♀♀	Series B eggs *eieren*	Total ♀♀	Total eggs *eieren*
1	15	11.3 ± 10.5			15	11.3 ± 10.5
2	15	10.5 ± 9.4	13	11.0 ± 9.3	28	10.8 ± 9.2+
3	7	4.3 ± 3.7	5	4.2 ± 4.3	12	4.3 ± 3.6
Total	37	9.7 ± 8.4	18	9.1 ± 8.6	55	9.5 ± 8.4

+) as in Table 32
+) *als in tabel 32*

TABLE 34. Egg mortality on leaves of fertilized and unfertilized trees.
Sterfte van eieren op bladeren van bemeste en onbemeste bomen.

Fertilized trees (+N) / *Bemeste bomen (+N)*

Generation	Series A number of eggs *aantal eieren*	Series A % mortality *sterfte*	Series B number of eggs *aantal eieren*	Series B % mortality *sterfte*	Total number of eggs *aantal eieren*	Total % mortality *sterfte*
1	144	10			144	10
2	206	3+	160	11	366	7+
Total	350	6	160	11	510	8

Unfertilized trees (–N) / *Onbemeste bomen (–N)*

Generation	Series A number of eggs *aantal eieren*	Series A % mortality *sterfte*	Series B number of eggs *aantal eieren*	Series B % mortality *sterfte*	Total number of eggs *aantal eieren*	Total % mortality *sterfte*
1	126	7			126	7
2	135	27+	120	18	255	23+
Total	261	17	120	18	381	18

+) as in Table 32
+) *als in tabel 32*

Most of the eggs were deposited on the leaf or on the cheesecloth. The eggs which had not hatched after about 10 days and showed no sign of embryonic development were considered dead. With the exception of the 1ste generation of the A series, the mortality of the eggs on the leaves of the unfertilized tree was higher. This difference is significant only for the 2nd generation of series A. For the total of the observations of the 2nd generation of series A + B the differences in the mortality of the eggs were also significant.

TABLE 35. Percentages of winter eggs deposited by the second generation on leaves of fertilized and unfertilized trees.
Percentages door de tweede generatie afgezette wintereieren op de bladeren van bemeste en onbemeste bomen.

2nd generation	Series A		Series B		Total	
	number of eggs *aantal eieren*	% not hatched *% niet uitgekomen*	number of eggs *aantal eieren*	% not hatched *% niet uitgekomen*	number of eggs *aantal eieren*	% not hatched *% niet uitgekomen*
Fertilized trees *Bemeste bomen*	206	2	160	6	366	4
Unfertilized trees *Onbemeste bomen*	135	22	120	15	255	19

As already mentioned, the eggs which failed to hatch after a given period were considered dead. However, mites of the 2nd generation deposit winter eggs (KREMER, 1956) which do not hatch in the current year. Very probably the high percentage of unhatched eggs on the leaves of the unfertilized tree was caused by the fact that the mites on these trees deposited winter eggs earlier than those on the fertilized tree. This may also have been the cause of the difference, however limited, in egg production on the fertilized and unfertilized trees (Table 31). With the increase in the number of generations, the total number of eggs produced decreases (KREMER, 1956). This might conceivably be due to the fact that per mite on the average less winter eggs are deposited than summer eggs. On the unfertilized trees the mites will deposit winter eggs earlier, and in smaller numbers. Table 35 gives the number of eggs of the 2nd generation which did not hatch but remained in good condition and were therefore probably winter eggs. The percentages of the probable 'winter' eggs are very much higher for the second generation on the unfertilized trees than the percentages on the fertilized trees.

Especially during the young immature stages some specimens succeeded in escaping (Table 36, difference per series between the 2 columns). In determining the mortality percentage these were of course not included. As a result, the numbers for which the mortality percentage was determined were small.

Summarizing, it may be said that in these laboratory experiments there was no distinct effect from the level of the nitrogen content of the leaves on the development and reproduction of *B. rubrioculus*. The egg production per female per 24 hours and the total egg production per female were, as for *M. ulmi*, higher, and the mortality of the eggs, was lower on the fertilized trees than on the unfertilized, but only in exceptional cases were these differences significant.

TABLE 36. Mortality in immature stages on leaves of fertilized and unfertilized trees.
Sterfte van niet-volwassen stadia op bladeren van bemeste en onbemeste bomen.

Fertilized trees (+N) / *Bemeste bomen (+N)*

Generation	Series A number of specimens / *aantal exemplaren* initial / *begin*	final[1] / *einde*[1]	% mortality / *% sterfte*	Series B number of specimens / *aantal exemplaren* initial / *begin*	final / *einde*	% mortality / *% sterfte*	Total number of specimens / *aantal exemplaren* initial / *begin*	final / *einde*	% mortality / *% sterfte*
1	60	34	35				60	34	35
2	42	30	60	38	27	55	80	57	58
Total	102	64	47	38	27	55	140	91	50

Unfertilized trees (-N) / *Onbemeste bomen (-N)*

Generation	Series A number of specimens / *aantal exemplaren* initial / *begin*	final / *einde*[1]	% mortality / *% sterfte*	Series B number of specimens / *aantal exemplaren* initial / *begin*	final / *einde*	% mortality / *% sterfte*	Total number of specimens / *aantal exemplaren* initial / *begin*	final / *einde*	% mortality / *% sterfte*
1	43	33	52				43	33	52
2	23	14	36	16	10	40	39	24	38
Total	66	47	47	16	10	40	82	57	46

[1]) number of immature stages minus the escapes
[1]) *aantal niet-volw. stadia zonder de ontsnapten*

5.2. EFFECT OF PREDATORS ON THE POPULATION DEVELOPMENT OF PHYTOPHAGOUS MITES

5.2.1. *Differences in predation on* Metatetranychus ulmi *Koch and* Bryobia rubrioculus *Scheuten by predatory mites and predatory insects*

In neglected orchards the density of the *M. ulmi* population is very low in relation to the *B. rubrioculus* population. In Chapters 4.2 and 4.3 it was brought out that one of the factors which causes the limited development of *M. ulmi* in neglected orchards is the poor condition of the tree, i.e. the low total nitrogen content of the leaves. However, predation on both phytophagous species by predatory mites and insects may also be of great importance. If certain predators prefer *M. ulmi*, this might partially explain the relative abundance of *B. rubrioculus* on the neglected trees. A laboratory study was made to determine the extent to which the predators have any preference for one of the two mite species.

5.2.1.1. Methods

Mites were placed on leaf punches (18 mm in diameter) lying on wet sand in glass containers, and either predatory mites or predatory insects were also placed on the leaves. Because of the wetness of the sand, few mites left the leaves and the drowned specimens were easily found. The predatory insects also sometimes left the leaf, but without drowning. The containers were closed off with cheesecloth. In Chapter 5.2.1 significance at $P \leqslant 5\%$ was determined with χ^2 test (see BROWNLEE, 1957).

5.2.1.2. Results

To determine the preference of the Heteroptera *Orius minutus*, *Anthocoris nemorum*, *Blepharidopterus angulatus* and the coccinellid *Stethorus punctillum* Weise, for either *M. ulmi* or *B. rubrioculus*, an approximately equal number of mites of both species were placed on the leaf punches with several specimens of the predatory insects. After 24 hours the numbers of killed mites were recorded. As Table 37 shows, these predators showed no preference for either mature *M. ulmi* or *B. rubrioculus* mites. In a second series of observations with *S. punctillum*, both the larval and mature stages of the beetle were used.

TABLE 37. Preference of some predacious insects for *M. ulmi* and *B. rubrioculus*.
Voorkeur van enkele roofinsekten ten opzichte van M. ulmi *en* B. rubrioculus.

	number of predators *aantal predatoren*	number of mites *aantal mijten*		killed *gedood*		P: [3]
		M. [1]	B. [2]	M.	B.	
O. minutus	37	52	52	37	35	50–90%
A. nemorum	32	109	107	57	54	> 99%
B. angulatus	32	76	77	25	21	> 99%
S. punctillum	21	78	76	35	28	50–90%

[1]) *Metatetranychus ulmi*
[2]) *Bryobia rubrioculus*
[3]) *Probability*

TABLE 38. Preference of *S. punctillum* for *M. ulmi* and *B. rubrioculus*.
Voorkeur van S. punctillum *ten opzichte van* M. ulmi *en* B. rubrioculus.

S. punctillum	number of predators *aantal predatoren*	number of mites *aantal mijten*		killed *gedood*		P: [3]
		M. [1]	B. [2]	M.	B.	
adults / *imago's*	12	75	75	42	12	>10%
larvae / *larven*	5	34	34	25	13	2–5%
total	17	109	109	67	25	5–10%

[1]), [2]) and [3]) as in Table 37
[1]), [2]) *en* [3]) *als in tabel 37*

It can be seen from Tables 37 and 38 that the adults show a slight preference for *M. ulmi* over *B. rubrioculus*, but the difference is not significant in either case. The larvae of the beetle, however, significantly prefer *M. ulmi* over *B. rubrioculus*. In the first series of observations (Table 37) the difference in predation on the phytophagous mites by the adult beetles is less strong than in the second series (Table 38). A change in food may have had an effect here: the beetles of the first series originated from neglected orchards, and those of the second series from greenhouses where they had previously fed exclusively on *Tetranychus telarius*.

For the determination of preference in predatory mites, 11 adult *M. ulmi* and 10 adult *B. rubrioculus* mites were offered on separate leaves to 15 predatory mites (*Typhlodromus* sp.) for 11 days. Every 24 hours the number of killed mites was counted and fresh specimens were added to make up the original number. The total numbers of supplied and killed mites are given in Table 39: 1.

TABLE 39. Preference of predacious mites for *M. ulmi* and *B. rubrioculus*.
Voorkeur van roofmijten ten opzichte van M. ulmi *en* B. rubrioculus.

	Number of mites *aantal mijten* M. [1]	B. [2]	killed *gedood* M.	B.	P: [3]
1. *Typhlodromus* sp.	132	110	31	2	<0.1%
2. *P. macropilis* [4]	66	66	26	6	<0.1%
3. *Typhlodromus* sp.	61	61	30	2	<0.1%
4. *Typhlodromus* sp.	48	48	19	3	<0.1%
5. *Typhlodromus* sp.	86	86	26	2	<0.1%
6. *Typhlodromus* sp.	132	132	65	16	<0.1%

[1], [2] and [3] as in Table 37
[1], [2] *en* [3] *als in tabel* 37
[4] *Phytoseius macropilis*

HERBERT (1959) studied the predation of 6 species of predatory mites (Phytoseiidae) on various stages of the phytophagous mites *Panonychus ulmi* Koch, *Bryobia arborea* M. & A. (= *B. rubrioculus* Scheuten), *Tetranychus telarius*, and *Vasates schlechtendali* Nal. For this purpose she placed each species of predatory mite with the various stages of the prey species in a separate capsule for 24 hours, and found that the species *Typhlodromus tiliae* fed on winter and summer eggs, larvae, green nymphs, and adults of *P. ulmi* and *B. arborea*. *Phytoseius macropilis* did not take the winter eggs of *P. ulmi* and *B. arborea* or adult *T. telarius*. In these experiments done by HERBERT, as in those shown in Table 39: 1, only one kind of food was offered to the predators. Under natural conditions in the neglected orchard the predators can generally make a choice among the various mite species or various stages of the phytophagous mites. Experiments were therefore done in which the predators could choose between various species and stages present on the leaves in equal numbers. Here again, 24 hour counts were made and mites added to maintain the initial number. The totals per series of observations are given in Table 39: 2–6.

With the Typhlodromidae it is not possible to identify living individuals as to species. However, the predatory mites were taken from neglected orchards in Nisse (series 1, 3 and 4) where *T. tiliarum* is the most numerous species and from Eversdijk (series 5 and 6) where *T. aberrans* is the most abundant one. The species *P. macropilis*, taken from a neglected orchard in Goes, can be identified with a magnifying glass (10 ×). After the experimental period the 57 predatory mites used for the preference experiments done in 1960 were identified as 46 *T. aberrans*, 10 *T. tiliarum*, and 1 *T. tiliae*.

As Table 39 shows clearly, the predatory mites belonging to the Phytoseiidae exhibit a distinct preference for the adult females of *M. ulmi* over those of *B. rubrioculus*. To investigate this phenomenon further, a study was made to find out whether the younger stages of *B. rubrioculus* were subject to heavier predation by the above-mentioned mites, by offering them the larvae, protonymphs (N I), and deutonymphs (N II) in the same numbers as the adults.

TABLE 40. Preference of *Typhlodromus* sp. for adult and immature stages of *B. rubrioculus*. *Voorkeur van* Typhlodromus *sp. ten opzichte van volwassen en onvolwassen stadia van* B. rubrioculus.

B. rubrioculus	initial number *ingezet* ad. [1]	im. [2]	killed *gedood* ad.	im.	P.: [3]
adult: N II [4]	20	20	0	6	2–5 %
adult: N I	38	38	0	6	2–5 %
adult: larva	120	102	0	50	<0.1 %
adult: immature	160	160	0	62	<0.1 %

[1]) ad. = adult / *volwassen*
[2]) im. = immature / *niet volwassen*
[3]) as in Table 37 / *als in tabel 37*
[4]) N = nymph / *nymphe*

As can be seen in Table 40, the immature stages of *B. rubrioculus* are very distinctly preferred to the adults. In experiments with *Typhlodromus cucumeris* Oudms., DOSSE (1955 b) found that this predatory miteaccepted larvae, nymphs,

TABLE 41. Preference of *Typhlodromus sp.* for adult *M. ulmi* and immature stages of *B. rubrioculus.*
Voorkeur van Typhlodromus *sp. ten opzichte van volwassen* M. ulmi *en niet volwassen stadia van* B. rubrioculus.

M. ulmi and *B. rubrioculus*	initial number *ingezet* M. ad. [1]	B. im. [2]	killed *gedood* M. ad.	B. im.	P: [3]
Series 1					
M. ad.: B. N II [4]	51	51	5	9	10–50%
M. ad.: B. N I	88	88	16	23	10–50%
M. ad.: B. larva	82	82	11	21	5–10%
Series 2					
M. ad.: B. N II	87	87	29	19	10–50%
M. ad.: B. N I	116	116	47	47	99%
M. ad.: B. larva	97	97	43	51	10–50%
Series 1					
M. ad.: B. R III [5]	36	36	11	1	0.1– 1%
M. ad.: B. R II	40	40	11	3	2– 5%
M. ad.: B. R I	29	29	6	13	5–10%
Series 2					
M. ad.: B. R III	76	76	28	9	<0.1%
M. ad.: B. R II	82	82	34	17	0.1–1%
M. ad.: B. R I	57	57	19	20	99%

[1]) *M. ulmi*, adult / M. ulmi, *volwassen*
[2]) *B. rubrioculus*, immature / B. rubrioculus, *niet volwassen*
[3]) as in Table 37 / *als in tabel 37*
[4]) N = nymph / *nymphe*
[5]) R = rest (quiescent) stage / *ruststadium*

and quiescent stages of *B. praetiosa* Koch but ignored the adult mites; *T. tiliae* ignored the adult mites as well (DOSSE, 1960).

In addition, the preference of the predatory mites in relation to adult *M. ulmi* and active or quiescent stages of *B. rubrioculus* (= B. R I–III) was studied (Table 41). The number of specimens of the quiescent stages was small. As far as the active mite stages are concerned, there seems to be no significant preference for *M. ulmi* adults over the immature stages of *B. rubrioculus*. In the choice between *M. ulmi* and the quiescent stages of *B. rubrioculus*, however, there is a distinctly significant preference for *M. ulmi* over the older quiescent stages II and III of *B. rubrioculus*. In quiescent stage I there is no preference for either phytophagous mite species.

A preference of the predatory mites in relation to the eggs of the two species was not determined. According to LORD (1949), NESBITT observed that the predatory mite *T. tiliae* fed on *Bryobia* eggs only when it was starving. HERBERT (1959) found to the contrary that *T. tiliae* consumed both winter and summer eggs of *P. ulmi* and *B. arborea*.

It can be seen from Table 42 that the young stages of *M. ulmi* are more frequently consumed by the predatory mites than the adult stages. In the adult

TABLE 42. Predation by *Typhlodromus* sp. on various *M. ulmi* stages.
Predatie van verschillende M. ulmi *stadia door* Typhlodromus *sp.*

M. ulmi	initial number *ingezet*		killed *gedood*		P: ¹)
adults: larvae	88	88	9	40	<0.1%
♀♀: ♂♂	70	70	3	25	<0.1%

¹) as in Table 37 ¹) *als in tabel 37*

stages the males are most severely reduced. This is in agreement with COLLYER's observation (1958) that adult females (and the eggs) of *M. ulmi* are the stages which are least attacked by *T. tiliae*.

Summarizing, it may thus be said that the predatory mites *O. minutes*, *A. nemorum*, *B. angulatus*, and the adult stages of the beetle *S. punctillum* show no preference in predation for either adult *M. ulmi* or *B. rubrioculus*. The larvae of the beetle show a slight preference for *M. ulmi* over *B. rubrioculus*. A few predatory mite species belonging to the Phytoseiidae, however, prefer *M. ulmi* over *B. rubrioculus*. In a test of the preference for either immature active stages or adult *B. rubrioculus*, the immature stages are preferred, as is also the case for *M. ulmi*. Further, no preference was observed in the predatory mites for either adult *M. ulmi* or active immature stages of *B. rubrioculus*, or for *M. ulmi* or the youngest quiescent stages of *B. rubrioculus*. The adult *M. ulmi* mites were, however, preferred to the older quiescent stages II and III of *B. rubrioculus*.

Besides this preference of the predatory mites for *M. ulmi* over the older quiescent stages and adults of *B. rubrioculus*, the distribution of the predatory and phytophagous mites may be important to the degree of predation. CHANT (1959a, b) greatly doubts the effectiveness of *Typhlodromus pyri* Scheuten (= *T. tiliae* Oudms.) as predator for *Panonychus ulmi* in the orchards of south-eastern England because of the difference in localization of predators and prey. *T. pyri* occurs frequently on the lower surfaces of the leaves along the midvein and lateral veins, while *P. ulmi* is found on both the upper and lower surfaces of the leaf. In addition, *T. pyri* is found most often on young leaves and *P. ulmi* clearly prefers the older leaves. This failure of prey and predator to occur in the same places will be even more pronounced for *B. rubrioculus* because this species occurs on branches for the greater part of its life.

In the summer of 1960 observations were made in a neglected orchard at Goes to determine where the predatory mites of the Phytoseiidae occur on the leaves. With only short intermissions, for two days from morning until about midnight leaves were picked, one by one from the trees and immediately examined under a binocular microscope, a method which avoided any shifting of the mites during collecting and transportation to the laboratory. The results are given in Table 43.

TABLE 43. Distribution of Phytoseiidae on the surface of apple leaves.
Plaats van voorkomen der Phytoseiidae op de bladeren.

1960			number of predacious mites *aantal roofmijten*					
			lower surface of leaf *onderkant blad*			upper surface of leaf *bovenkant blad*		
date *datum*	time *tijd*	number of leaves *aantal bladeren*	along veins *langs nerf*	over the leaf *op bladschijf*	total *totaal*	along veins *langs nerf*	over the leaf *op bladschijf*	total *totaal*
Aug. 9th	10:10 – 23:05 h.	450	485	258	743	13	8	21
Sept. 23rd	11:30 – 23:15 h.	519	237	150	387	7	7	14

This table shows that the predatory mites occurred mainly on the under surface of the leaves, the majority remaining near the veins and only a small proportion distributed over the leaf. The localization appears to be independent of changes in temperature and cloudiness. During full sunshine and just after a thunderstorm the mites are present almost exclusively on the under surface of the leaves, and no change was observed after it became dark (± 20:00 h.). After 23:15 h. no further observations were made because of dew on the leaves.

Identification of the predatory mites which were collected showed that a large proportion belonged to the species *P. macropilis*; also represented were *T. tiliarum*, *Amblyseius potentillae* Garm. and a few specimens of *T. aberrans*. Thus in the neglected orchard the predation on *B. rubrioculus* by the Phytoseiidae will have been less than on *M. ulmi* because of their preference for *M. ulmi* over the older stages and adults of *B. rubrioculus*. In addition, fewer of the *Bryobia* mites will fall prey to the predators than *M. ulmi* because the former spend a large part of their cycle on the branches, while the predators, like *M. ulmi*, are present mainly on the under surfaces of the leaves. Only in sunny, warm weather are the phytophagous mites distributed over the whole leaf.

5.2.2. *Effect of predators on the development of a population of* Metatetranychus ulmi *Koch*

In investigations into the effect of predators on the population development of phytophagous mites, this aspect of the development of a mite population has often been studied on trees where the predators have been eliminated by chemical control and compared with the development on untreated trees where the predators are still present (e.g. BERKER, 1958; CLANCY & POLLARD, 1952; GILLIATT, 1935). With this approach, however, it is impossible to investigate the isolated effect of the elimination of the predators because the chemicals also directly or indirectly affect to some extent the population density of the phytophagous mite. The resulting picture is therefore not accurate concerning the effect of the absence of the predators on the development of the phytophagous mite.

With the method used in the present study, insecticides were not used to remove the predators. Small apple trees infected with *M. ulmi* were set out in pots in a neglected orchard where many predators were present and in a well-kept orchard where as a result of chemical control there were almost no predators. This technique makes it possible to compare the development of the *M. ulmi* population with and without the presence of predators. Moreover, the use of potted trees allowed us to keep nutritional factors constant for all trees. During spraying in the well-kept orchards the potted trees were covered by large plastic bags to prevent affecting the *M. ulmi* populations.

In 1956 one-year old Boskoop trees with a rather high initial *M. ulmi* population density were used. In Figure 45 the course of the *M. ulmi* population

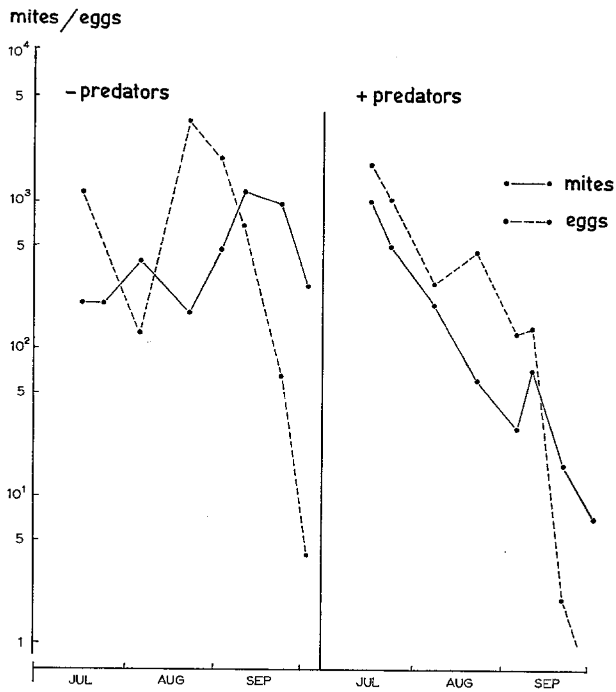


FIG. 45. Development of an *M. ulmi* population on potted apple trees set out in a well-kept orchard (– predators) and a neglected orchard (+ predators), 1956.
Number of mites and eggs per tree.
Populatie ontwikkeling van M. ulmi *op appelboompjes in potten geplaatst in een verzorgde boomgaard (– predatoren) en een verwaarloosde boomgaard (+ predatoren), 1956.*
Aantal mijten en eieren per boom.

can be seen for the well-kept orchard (without predators) and the neglected orchard (with predators). The mites and eggs were counted on the trees by means of a binocular microscope.

As is shown in Figure 45, the initial population on the potted trees placed in the neglected orchard was higher than on those in the well-kept orchard. However, this density showed a very sharp decrease. (In September an *Eotetranychus pomi* infection developed which may have been partially responsible for the further severe decrease in this month). By contrast, in the well-kept orchard the population increased heavily in relation to the neglected orchard.

It might be thought that the sharp drop in the population density in the plot with predators was caused by a more unfavourable nutritional position of the mites due to the higher initial population in the plot without predators (± 5 mites and 1 mite per leaf resp.), but in that case a second peak could have been expected with the hatching of the eggs of the initial population, after which the density would drop further. However, in Figure 45 we see a simultaneous drop in the number of mites and in the number of eggs, suggesting that destruction of eggs and/or young larvae prevented the development of a second peak.

In 1959 potted trees nos. 1 and 2 (one-year old Boskoop Verheul on M IX) were placed in the well-kept orchard and trees nos. 3 and 4 in the neglected orchard. They were then infected with 50 *M. ulmi* females per tree, the mites deriving from the unsprayed, fertilized plot in Kuenen's Hof. After 6 weeks trees nos. 1 and 2 were shifted to the neglected plot so that the development of

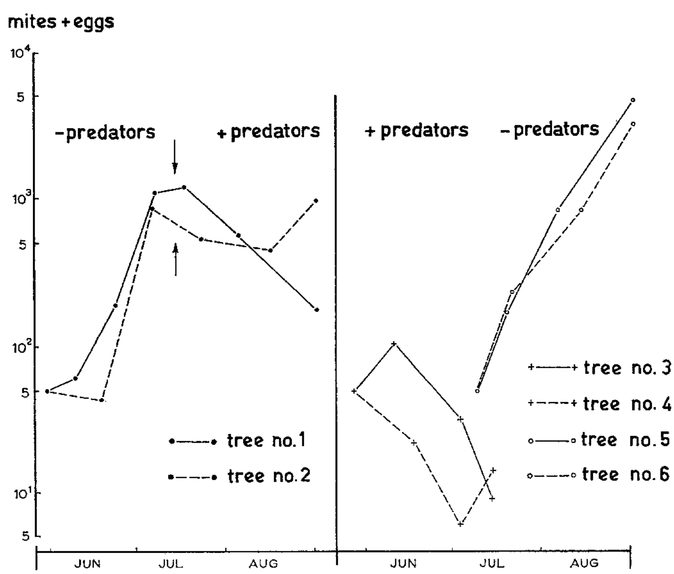


FIG. 46. Development of an *M. ulmi* population on potted apple trees set out in a well-kept orchard (– predators) and a neglected orchard (+ predators), 1959. → = exchange. Number of mites + eggs per tree.
Populatie ontwikkeling van M. ulmi *op appelboompjes in potten geplaatst in een verzorgde boomgaard (– predatoren) en een verwaarloosde boomgaard (+ predatoren), 1959. → = overplaatsing.*
Aantal mijten + eieren per boom.

their populations could be observed in the presence of numerous predators (Fig. 46). Trees nos. 3 and 4 were not shifted to the well-kept orchard because all the predators on them could not be removed by means of a field magnifier; they were also in rather poor condition. For these reasons the leaves of trees nos. 3 and 4 were cut off and the mites and eggs counted in the laboratory. Two new trees, nos. 5 and 6, were placed in the well-kept orchard one week after having been infected with 50 *M. ulmi* females per tree.

As can be seen from Figure 46, the *M. ulmi* population showed a greater increase on trees nos. 1 and 2 in the well-kept plot without predators than on trees nos. 3 and 4 in the neglected plot with predators over the same period from the end of May to the beginning of July. Trees nos. 1 and 2 were shifted to the neglected plot on July 15th, after which a sharp drop in the population density can be seen. The population density on tree no. 2 shows a small increase towards the end of the period.

The number of predatory mites is very low, which may have been caused by predation of the Heteroptera. The number of predatory mites on the surrounding trees is also relatively small. This is in agreement with COLLYER (1956) who found that the population density of the Phytoseiidae is low in a completely neglected orchard. According to her, this is caused by the predatory Miridae and Anthocoridae, which are active throughout the summer.

TABLE 44. Number of predacious Heteroptera inventoried from 5 surrounding trees, 1959.
Aantal roofwantsen geïnventariseerd op 5 omringende bomen, 1959.

15/5	1/6	15/6	1/7	15/7	1/8	19/8	11/9
61	174	130	441	331	110	116	34

It is also not excluded that the limited number of predatory mites on the small experimental trees was due to a greater difficulty in immigration for them than for the winged predatory insects.

In the same period between July 10th and September 2nd the *M. ulmi* population in the well-kept plot increased heavily. Between July 22nd and August 15th a large number of leaves were accidently knocked off tree no. 6, reducing them from 79 to 22. Because this took place suddenly, the mites and eggs on these leaves were lost. It can be seen from Figure 46 that the intensive multiplication of *M. ulmi* on tree no. 6 continued in spite of the sparse leaves.

In June 1960 trees in pots (Boskoop Lambrechts M IX) were once again placed in the well-kept and the neglected plots, and infected on June 7th with 40 *M. ulmi* females per tree. In August the trees were exchanged. Four trees were placed in each plot, 2 of which weekly received supplementary nitrogen (+N trees). Although at the end of the observation period in September there was a distinct difference in the total nitrogen content of the leaves, no effect of this higher content on the mite development on these trees was observed. It is, however, very possible that this difference in nitrogen content developed so late in the season that it could not be expressed in the mite population level. Intermediate leaf analyses could not be carried out.

As can be seen from Figure 47, the development of the *M. ulmi* population on trees nos. 1 and 2 (+N and –N) in the neglected plot with predators was

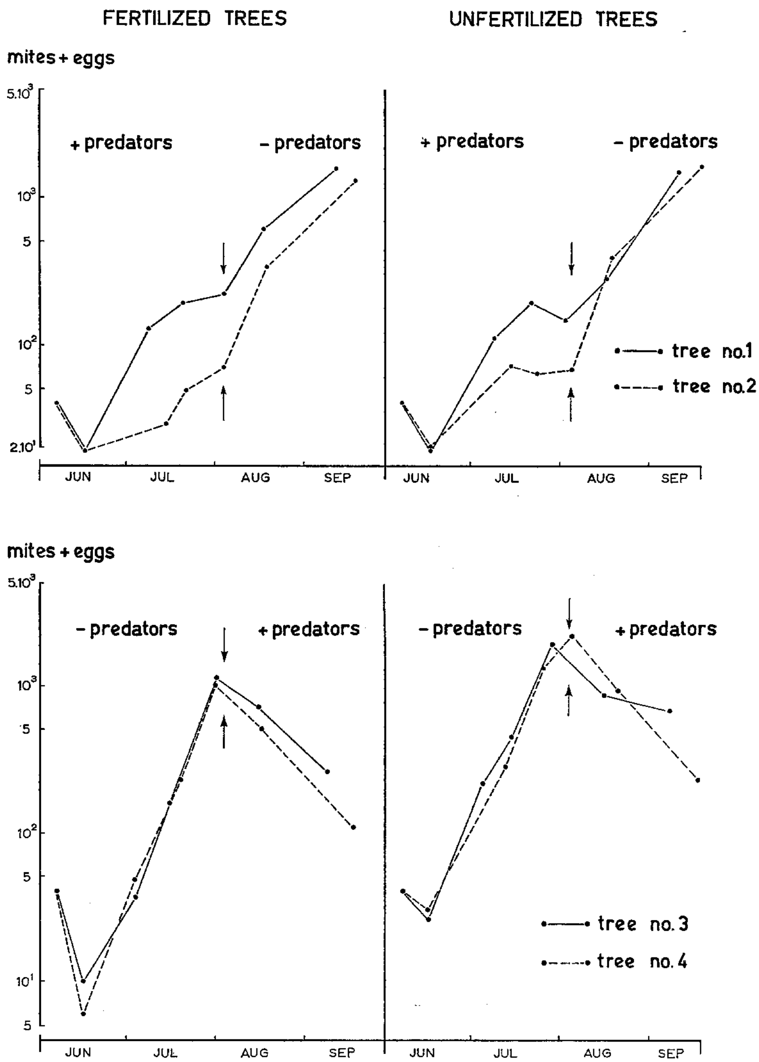


FIG. 47. Development of an *M. ulmi* population on potted apple trees set out in a well-kept orchard (– predators) and a neglected orchard (+ predators), 1960. → = exchange. Number of mites + eggs per tree.
Populatie ontwikkeling van M. ulmi *op appelboompjes in potten geplaatst in een verzorgde boomgaard (– predatoren) en een verwaarloosde boomgaard (+ predatoren), 1960. → = overplaatsing.*
Aantal mijten + eieren per boom.

much lower than on trees nos. 3 and 4 (+N and –N) in the well-kept plot without predators. After the trees were exchanged the population dropped on nos. 3 and 4 and rose on nos. 1 and 2.

In shifting trees nos. 1 and 2 from the neglected to the well-kept orchard an attempt was made to remove all the predators from them, but later counts showed that for the predatory mites this succeeded only partially. The sharp increase of the *M. ulmi* population was accompanied by an increase in the predatory mite population.

The effect of shifting the trees from the neglected to the well-kept plot was far less spectacular than the reverse. The rather high predatory mite population may have prevented an increase to some extent, especially on the +N trees, for on the +N trees the predatory mite population is approximately three times as high as on the -N trees (Table 45). The large number of predatory mites may

TABLE 45. Final number of predacious mites per potted tree.
Aantal roofmijten per proefboom bij het einde der waarnemingen.

Tree no.: *Boom no.*:	+N	-N
1	168	60
2	156	51
3	4	8
4	8	5

have obliterated the favourable effect of the fertilization on the development of *M. ulmi*. At the end of the observations, the trees transferred from the well-kept to the neglected orchard (trees nos. 3 and 4) showed only a few predatory mites.

Table 46 gives the number of predatory Heteroptera on surrounding trees in the neglected plot. The number in the well-kept plot was zero.

TABLE 46. Number of predacious Heteroptera inventoried from 5 surrounding trees, 1960.
Aantal roofwantsen geinventariseerd van 5 omringende bomen, 1960.

31/5	19/6	4/7	20/7	6/8	8/9
251	146	280	98	74	44

The importance of the complex of predators for the development of *M. ulmi* is clearly brought out by the observations shown in Figures 45, 46, and 47. It is unquestionably a weak point in these observations that there was a possibility of infection of the experimental trees by *M. ulmi* from the surrounding fruit trees, which could exaggerate to some extent the increase in the well-kept plots. On the whole, however, the population density on the surrounding trees could be kept low by spraying. Only in 1960 were there a few population peaks later in the season. Had such an infection occurred, it would have been visible as a sharp increase in the number of mites followed by an increase in the number of eggs. Instead, there was an increase in the number of eggs directly after the trees were shifted to the plots without predators, which demonstrates that the increase was not primarily one of infection by older stages.

Placement of the high *M. ulmi* population trees in the neglected plot was consistently followed by a sharp drop in density which could not have been caused by emigration of the mites. There are sufficient observations which indicate that *M. ulmi* migration is very limited within the trees, and certainly from tree to tree. Predation by insects will have played a large role in the reduction of *M. ulmi*, in view of the small numbers of predatory mites present in the neglected orchards. In addition, the large numbers of predatory mites on trees nos. 1 and 2 with high *M. ulmi* population densities produced no distinct reduction in the *M. ulmi* population in the absence of predatory insects.

The species of predatory Heteroptera found in the neglected plot include: *Anthocoris nemorum, A. nemoralis, Orius minutus, O. majusculus, Phytocoris tiliae, P. reuteri, Atractotomus mali, Heteroptera meriopterum, Blepharidopterus angulatus, Psallus ambiguus,* and *Nabis apterus.* The species of predatory mites included *Phytoseius macropilis* and *Typhlodromus tiliae.*

5.2.3. *Effect of predatory mites on the development of a population of* Metatetranychus ulmi *Koch*

In the experiments reported in Chapter 5.2.2, a study was made of the effect of the entire predator complex on the population development of *M. ulmi.* In order to study the sole effect of the predatory mites, observations were done on trees placed in an enclosure constructed of fine gauze screening with a transparant plastic roof. This method prevented infection of the trees by predatory insects and, in addition, the enclosure was placed near a well-kept orchard with practically no predatory insects.

The two trees (Cox's Orange Pippin M XVI) were of about equal size and

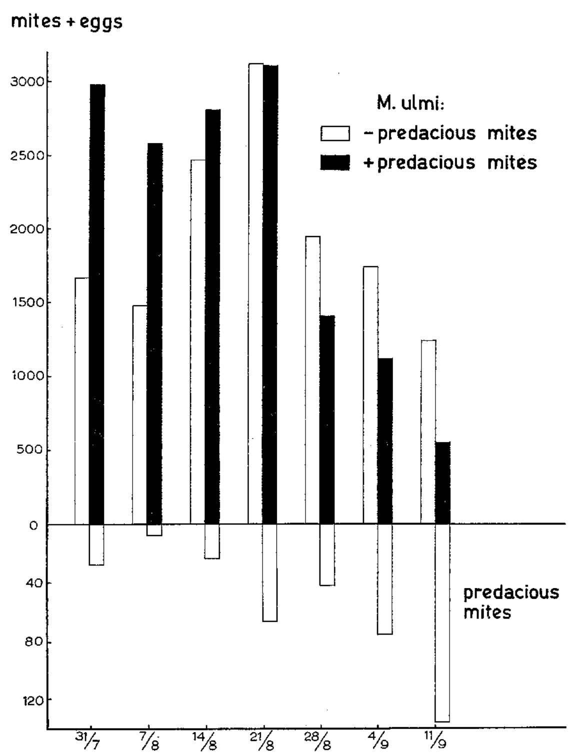


FIG. 48. Effect of predacious mites on the development of an *M. ulmi* population. Number of mites + eggs per tree.
Invloed van roofmijten op de ontwikkeling van een M. ulmi *populatie. Aantal mijten + eieren per boom.*

both were severely infested with *M. ulmi.* In the middle of July one tree was infected with 80 young and adult predatory mites taken from Eversdijk. Starting on the 14th day after this infection a sample of 20 leaves was taken from both trees each week until the middle of September, and the phytophagous and predatory mites counted. Figure 48 shows the total population of mites and of eggs of both *M. ulmi* and the predatory mites.

Figure 48 indicates that during the first 3 weeks of the observations the *M. ulmi* population on the tree without predatory mites (–P tree) was lower than on that with predatory mites (+P tree). On August 21st the population densities were about the same on both trees, after which there was a much sharper drop on the +P tree than on the –P tree.

TABLE 47. Relation between population densities of *M. ulmi* on trees with predators (+P) and without predators (–P).
Verhouding populatiedichtheid van M. ulmi *op bomen met predatoren (+P) en zonder predatoren (–P).*

mites + eggs *mijten + eieren*	31/7	7/8	14/8	21/8	28/8	4/9	11/9
+P : –P	1.8	1.7	1.1	1.0	0.7	0.6	0.4

From Figure 48 and Table 47 it can be seen that in the course of the observations a change occurred in the ratio of the *M. ulmi* population densities on the +P and –P trees.

6. DISCUSSION

The results of the investigation show that the question of whether cultural measures used in fruit growing promote the intense increase of *M. ulmi* can be answered in the positive.

The orientational observations concerning the presence of *M. ulmi* in orchards indicate that there is a correlation between the density of *M. ulmi* and the management of the orchard. A more detailed investigation into the effect of a cultural program on the development of *M. ulmi* demonstrated that in a neglected standard-tree orchard (Eversdijk) in which *M. ulmi* occurred only sporadically, even without chemical control, there was a heavy increase of the mite after soil cultivation, fertilization, and pruning. This increase corresponded with the improvement in the physiological condition of the fruit trees in these orchards. The improved condition was primarily expressed in a higher nitrogen content of the leaves and a higher growth rate of the trees.

After discontinuation of soil cultivation, fertilization, and pruning in a well-kept orchard (Kuenen's Hof) the damage from *M. ulmi* decreased. To this, the very rainy summer of 1960 and wet spring of 1961 formed somewhat of an exception. The decrease in damage from *M. ulmi* corresponds almost directly with the deterioration in the condition of the fruit trees, as estimated from the drop in the total nitrogen content of the leaves, reduced growth, a lower percentage of fruit setting, and smaller fruit.

In Eversdijk in spite of changes in the total nitrogen content of the leaves there were no changes in the potassium, calcium, magnesium, and phosphate contents. In Kuenen's Hof, however, the drop in the total nitrogen content in the –sfp plots was accompanied by a gradual rise in the potassium and phosphate contents and a drop in the calcium and magnesium contents.

This difference in reaction was due among other things to the difference in age, which affected the growth rate and metabolism of the trees in the two orchards.

Field experiments in Eversdijk and laboratory studies with material from this orchard showed that a change in the total nitrogen content of the leaves is sufficient to bring about a difference in the development of *M. ulmi.* The effect of the changes in the levels of the other elements can thus be ignored for the time being, the more so since these changes can be brought about by over- or under-fertilization with nitrogen. In the old orchard in Eversdijk in the plots with chemical control the effect of the increased nitrogen content on *M. ulmi* development could not be observed because of a very large difference in the height and foliage density of the trees which causes a wide divergence in both the natural development of the mite and the effect of chemical control on it. In the rather uniform spindle orchard Kuenen's Hof in the plots with chemical control the difference in the development of the fruit tree red spider mite in the fertilized and unfertilized plots is very spectacular, at any rate in the first four years.

The observations in the two orchards also show that with the intensive cultivation of the fruit tree in the well-kept plots the predators were unable to check the sharp increase of *M. ulmi,* even including those plots in which no chemical control was applied. Laboratory and field experiments were made to determine the importance of predatory mites and Heteroptera for the reduction of *M. ulmi.* Under orchard conditions, the combined mite and insect predators are unable to reduce the increased *M. ulmi* population produced by fertilization, etc. to a non-injurious level. Since the predator population can reach very high densities, especially with favourable weather conditions such as prevailed in 1959, these results are disappointing.

Only under weather conditions which are extremely unfavourable for the phytophagous mite (1960) do the predators get a chance to account for a sharp decrease in the *M. ulmi* population (cf. MATHYS, 1959). Under normal weather conditions the reproductive potential of *M. ulmi* is high, especially in the +sfp plots, and the increase begins early in the spring. The potential of the predators is much smaller and, in addition, the densities of both mite and insect predators only begin to show an appreciable increase in July and August. Thus in the first months of their development the phytophagous mites have the advantages of the high nitrogen content of the leaves in May and June and the low number of predators.

Even if we ignore the effect of fertilization, etc. on the development of *M. ulmi,* the heavy multiplication of the mite following chemical control measures still cannot be ascribed solely to the elimination of predatory enemies. After the application of pesticides in the neglected orchard in Eversdijk, for example, *M. ulmi* increased severely. Observations showed that in addition to the majority of the predators, all plant (scab and mildew) and animal (other phytophagous mites, leafminers, etc.) organisms were also destroyed by the chemicals. This meant that, besides the reduction in predation, *M. ulmi* benefitted nutritionally from the removal of competitors, to which can also be ascribed the sharp increase of the mite population in Kuenen's Hof after spraying with acaricides, especially in the fertilized plots. It is in these plots that we see an excellent demonstration of the dominating effect of *M. ulmi*'s nutritional position on its development. In the absence of predators and plant or animal competitors brought about by chemical control, *M. ulmi* developed into a severe infestation in the +sfp plots (until 1960), while in the –sfp plots it did not occur in injurious numbers. Only extremely intensive chemical control can keep the population within bounds in the +sfp plots. Thus, under the prevailing conditions the physiological condition of the fruit tree effected by soil cultivation, fertilization, and pruning is of decisive significance for the excessive multiplication of the mite.

The heavy increase of an injurious organism in connection with the application of cultural measures is not restricted to *M. ulmi*, but can also be established for other fruit pests and diseases. For example, the apple blossom weevil (*A. pomorum*) hibernates as an adult and deposits its eggs in the flower buds. The larvae develop in these buds, which they consume from the core outwards. The blossoms become brown and fail to expand. In choosing the apple varieties for a modern orchard, preference is given to those which bear annually rather than biennially. Fertilization and pruning also tend to suppress the biennial pattern. As a result, the beetle is annually provided with a superfluity of blossoms in which to deposit its eggs. This also applies to the apple sawfly (*Hoplocampa testudinea* Klug), which deposits its eggs just below the calyx of the flower. When there are many flowers and fruitlets per cluster, the larvae can migrate easily from one fruit to another during their development. Both insects can effectively be controlled with DDT and BHC or an organophosphorus compound, so that they cause but little damage in well-kept orchards.

The relation of the host plant to fruit pests can be clearly seen in the case of the woolly aphid (*E. lanigerum*) and the green apple aphid (*A. pomi*), which establish themselves preferably on the young shoots or twigs, the woolly aphid also choosing places on the branches where the bark has been cracked (frost splits, pruning cuts, etc.). In the fertilized plots in both Eversdijk and Kuenen's Hof there was a severe aphid infection on the young shoots. In the unfertilized plots the young shoots showed infection only in the spring, after which it disappeared rapidly. Figures 9 and 33 show the shoot formation in both experimental fields. In the fertilized plots the total shoot length is distinctly greater than in the unfertilized plots. In the neglected orchard in Eversdijk a severe aphid infection appeared after the trees had been fertilized and pruned only once. In Kuenen's Hof there was a heavy aphid infestation during the first years in all the unsprayed plots because the trees were still in excellent condition as a result of the treatment applied before 1956.

It has been demonstrated for various species of aphids that their rate of development and reproduction is strongly dependent on the chemical composition of the host plant (BARKER & TAUBER, 1951; BONNEMAISON, 1951; EVANS, 1938; KENNEDY, 1958; KENNEDY & BOOTH, 1959; LINDEMANN, 1948). According to BONNEMAISON (1951), EVANS (1938), and MITTLER (1958b) under certain conditions nitrogen deficiency produces a winged generation which may in turn produce migration to other host plants, and it seems likely that this occurred in the unfertilized experimental plots in the present investigation.

It has been demonstrated for the pea aphid (*Acyrtosiphon pisum* Harr.) that in resistant pea varieties (*Pisum sativum* L.) the total nitrogen content and the content of amino acids is lower than in the non-resistant varieties; the ratio of the sugar content to the nitrogen content is, however, higher (AUCLAIR, 1953; AUCLAIR & MALTAIS, 1950; AUCLAIR, MALTAIS & CARTIER, 1957; MALTAIS, 1951; MALTAIS & AUCLAIR, 1957).

According to these authors, the aphids on the resistant varieties cannot get enough of the amino acids they require to show optimal growth and reproduction, which restricts their number. An increased nitrogen content caused by fertilization would thus reduce the natural immunity of the plants.

Little is known concerning the effect of the chemical composition of the plant juices on the development of the woolly aphid. JANCKE (1933) observed no effect from potassium on woolly aphid infection. In the fertilized plots in Kuenen's Hof, which had a high nitrogen and a low potassium content, there was a severe woolly aphid infestation. In the unsprayed plots the colonies had to be removed by brushing the branches.

Observations in both Eversdijk and Kuenen's Hof showed that a severe infestation of the green apple aphid and the woolly aphid also occurred in the unsprayed, fertilized plots in spite of the relatively numerous parasites and predators present. According to EVENHUIS (1958) under the prevailing orchard conditions the population density of *E. lanigerum* cannot be held below an economically acceptable level by the parasite *Aphelinus mali* Hald. The reproduction rate of the woolly aphid is so much higher than that of the parasite that the former has an increasingly greater start on the parasite in the spring and early summer. According to this author, in most cases a massive increase of the woolly aphid will be limited only slightly by the predators in the orchard. This will hold for the green apple aphid as well. In spite of the numerous aphid parasites and predators in the unsprayed plots, the aphids show a heavy increase.

Reference should also be made to the relation between the host plant and the harmful plant organisms scab and mildew. According to MOORE & BENNETT (1952) application of a balanced fertilization program with nitrogen and potassium showed no observable effect on the susceptibility of the trees to scab infection, but a markedly unbalanced influencing of the nutritional equilibrium of the trees produced a distinct effect under given conditions (MOORE, 1936). For example, excessive grassing-down could reduce the incidence of scab, but only at the expense of nitrogen deficiency in the trees. Since Lombartscalville shows very little susceptibility to scab, the effect of fertilization on scab infection could not be observed in our experiment. However, in Kuenen's Hof a severe mildew infestation occurred in the fertilized plots, while in the unfertilized plots the infestation was of minor importance. We were unable to determine whether this effect of fertilization on the mildew development was directly due to the higher nitrogen content of the leaves or to the higher rate of leaf development, although the latter factor is also induced by the higher nitrogen content of the tree (see also SCHAFFNIT & VOLK, 1930).

7. CONCLUSIONS

The strong positive effect of the physiological condition of the fruit tree on the development of harmful organisms is thus quite clear. Modern fruit growing methods have resulted in such heavy increases of the fruit pests that it has become impossible to keep them below an injurious level even in the presence of relatively numerous parasites and/or predators in orchards in which no chemical control is applied. Thus a purely biological control of the animal organisms is not, under the given circumstances, economically feasible or, as DOWNING et al. (1958) put it: 'Strong reliance on biological control may encourage a mental withdrawal from the hard realities of making a living from the soil'. Even if we could ignore biological control of the animal organisms, the plant organisms scab and mildew would, under our climatic conditions and with the varieties used, still greatly reduce the quality of the fruit.

Decreasing the fertilization, which will inhibit the heavy increase of these organisms, is impracticable because it also reduces the yield per hectare, and in actual practice the tendency in fruit growing is still to use increasingly larger quantities of nitrogen fertilization to increase the yield. Since a change in the cultural methods applied at present would involve taking the risk of lower yield or poorer quality of the fruit, the fruit grower will continue to prefer a curative method for as long as chemical control, however intensive and noxious, gives good results and normally (for the conditions in the province of Zeeland) constitutes on the average only 9.5% of the total costs (*Tuinbouwgids*, 1961). Nevertheless, the development of resistance has to some extent destroyed the certainty of obtaining satisfactory results. Since 1953 the resistance of the injurious organisms, in this case the fruit tree red spider mite, to the usual chemicals has become most troublesome in just these well-kept orchards (VAN DE VRIE 1954, 1959). At first this resistance was seen only for the organophosphorous compounds, but it later became evident for the ovolarvicides as well. At present, according to VAN DE VRIE (personal communication), in about 95% of the well-kept orchards in Zeeland strains of *M. ulmi* occur which are more or less resistant to the organophosphorus compounds. This factor represents a threat to the fruit-growing industry which has made it imperative to investigate the possibilities of other forms of control.

The first attempts in this direction were made in Canada and the United States, where the difficulties created by intensive chemical control were first felt. Observations showed, that each region required its own special control program, adjusted to climate and to the diseases and infestations dependent on climate.

In 1959, with a particular eye to the emergence of resistance, an attempt was made with the cooperation of the Committee for '*Harmonische Bestrijding van Plagen*' (Integrated Control of Pests) to evolve a spray program, appropriate to local conditions, for a combined chemico-biological control of pests and diseases in the orchard. According to DE FLUITER (1960), integrated control should be based on satisfactory co-ordination of a minimal curative (chemical) control keyed to the action of the natural enemies to keep the residual population in check. In this sense chemical control would be carried out only when imperative, and then preferably with a selective pesticide in low concentration in order to preserve the beneficial organisms as much as possible (see also VOÛTE and DE FLUITER, 1961).

With a modified spray program, a '*schonender Behandlung*', or an '*Harmonische Bestrijding*', the parasites and predators are spared as much as possible for their importance to the control of pests in the orchard. Under certain circumstances this appears to be possible (BERKER, 1958; CHANT & FLESCHNER, 1960; COLLYER, 1958; DEBACH, 1958; DOSSE, 1960; LORD, 1956; PICKETT, 1948; our observations). The present study re-emphasizes the fact that a fundamental investigation, for our local conditions, into the significance of the predators for the development of the most important fruit pests, including *M. ulmi*, is urgently needed. Such a study, however, must also include the effect of the host plant on the relationship of predator to prey.

According to RODRIGUEZ (1951, 1960), his experiments with *Tetranychus bimaculatus* on tomatoes show that the optimal nitrogen level for this mite lies at a nitrogen content of the leaf of about 3 % of dry weight; and he also assumes an optimal nutritional level to exist for *Panonychus ulmi*. On these grounds it may be asked whether under our conditions an optimum occurs for the development of *M. ulmi*. Such an optimum has clearly not yet been reached in our orchards. The height of this level would determine whether it would have practical consequences: too high a nitrogen level would have an unfavourable effect on fruit storage (BUTIJN, 1961a). It is also known that increasing the nitrogen nutrition of the tree has an antagonistic effect on potassium uptake, which under certain conditions may lead to potassium deficiency. In Zeeland the risk of this effect is not great, but in the Betuwe it would be.

It may also be asked whether balanced fertilization does not have a favourable, i.e. inhibitory, effect on the mite population (cf. LEROUX 1954). FRITZSCHE et al. (1957) found for *Tetranychus urticae* on *Phaseolus vulgaris* a heavier increase in population density on plants grown in potassium, phosphate, and nitrogen deficient solutions than on plants with balanced nutrient solutions. According to BUTIJN (personal communication) the application of more potassium would, at least for Zeeland soils, give no improvement in the potassium nutrition of the tree because the soil already contains a sufficient quantity of this element. Thus, under these conditions the substitution of balanced fertilization for the use of only nitrogen would not solve this problem.

8. SUMMARY

Orientational observations on the development of the fruit tree red spider mite (*Metatetranychus ulmi* Koch) in orchards in the province of Zeeland indicated that there is a distinct correlation between the population density of *M. ulmi* and the management of the orchard.

Starting in 1954 a study was made of the effect of cultural measures (i.e. soil cultivation, fertilization, pruning, and chemical control) on the development of *M. ulmi* in an old, standard-tree orchard in Eversdijk containing two varieties of apple tree, Boskoop and Bellefleur, with the addition in 1956 of the young spindle orchard Kuenen's Hof with Lombartscalville M I. The effect of such factors as nutrition, predators, competitors, and chemical control on the population development of *M. ulmi* was investigated.

In both experimental orchards the effect of the physiological condition of the tree was pronounced. In the neglected orchard (Eversdijk), in wich *M. ulmi*

occurred only sporadically, an increase in population density corresponded to an increase in the total nitrogen content of the leaves in the unsprayed plot which received soil cultivation, fertilization, and pruning. In the control plot a small increase was observed due to the effect of the border trees which were partially exposed to the fertilization applied in the adjacent plot. In the plots with chemical control an effect of cultivation, fertilization, and pruning on the development of *M. ulmi* was not observed: the great variation in the height and the foliage density of the trees brought about a wide divergence in both the natural development of *M. ulmi* and the effect of the chemical control used against it. In the well-kept orchard (Kuenen's Hof), with a high initial *M. ulmi* population, both the sprayed and unsprayed plots which received no cultivation, fertilization, or pruning showed a decrease in the density of *M. ulmi* following the reduction in the nitrogen content of the leaves induced by suspension of these cultural measures. In the summer of 1960 this correlation is less pronounced because of the weather conditions.

In spite of the changes in the total nitrogen content of the leaves, no consistent changes in the potassium, calcium, magnesium, and phosphate contents of the leaves occurred in Eversdijk. In Kuenen's Hof, to the contrary, the drop in nitrogen content corresponded with a drop in the calcium and magnesium content and a rise in the potassium and phosphate content. Field experiments in Eversdijk and laboratory experiments on leaves from this orchard demonstrated that even a difference in only the total nitrogen content of the leaves is sufficient to produce a change in the development of *M. ulmi*. Thus, any effect of the other elements on the population density of *M. ulmi* can be ignored for the time being. In the plots where cultivation, fertilization, and pruning were carried out, the leaves showed an increase in the total thickness of the leaf and of the palisade mesophyll compared to the leaves in the untreated plots. The increased thickness of the palisade mesophyll is generally accompanied by a greater number of palisade layers.

Observations in both orchards also indicate that in the unsprayed plots in which soil cultivation, fertilization, and pruning were applied, the combined activity of predatory mites and predatory insects is not sufficient to reduce the increased development of *M. ulmi* (brought about bij these cultural practices) to below an injurious level.

An increase in *M. ulmi* was also observed after application of only chemical control in the neglected orchard. This cannot be entirely ascribed to destruction of the predators: the chemicals also destroyed all the other plant and animal organisms (e.g. scab, mildew, other phytophagous mites, leafminers, etc.) and therefore, by reducing competition, improved *M. ulmi*'s nutritional situation. In the sprayed part of Kuenen's Hof it could be clearly seen that the effect of the chemical control on the excessive increase of *M. ulmi* was less important than that of cultivation, fertilization, and pruning. Given the absence of predators and competitors brought about by chemical control, *M. ulmi* developed into serious infestation in the plots with soil cultivation, fertilization, and pruning, while in the plots without such measures *M. ulmi* did not appear in injurious numbers.

In order to obtain a general impression of the relation between the condition of the tree and the nutrition of *M. ulmi*, in addition to the chemical composition and anatomical structure of the leaves a study was made of the growth, fertility, and yield of the trees. The improved physiological condition of the trees in the fertilized plots was expressed in Eversdijk only in the increased rate of growth in these plots. In Kuenen's Hof the effect of soil cultivation, fertilization, and pruning could be seen not only in an increased growth rate but also in a higher percentage of fruit setting and a higher weight per fruit.

All of this evidence indicates that the heavy increase of *M. ulmi* occurs in the plots which from the point of view of the fruit grower offer the most favourable conditions for the production of fruit of good quality.

Specific investigations showed that the relatively low density of *M. ulmi* in the neglected orchards in comparison with that of *Bryobia rubrioculus* Scheuten is probably due to the low nitrogen content of the leaves and the preference shown by the predatory mites for *M. ulmi* mites over the mature and older quiescent stages of *B. rubrioculus*, with an additional limitation of predation on the latter caused by the difference in localization of predatory and phytophagous mites.

9. SAMENVATTING

1. INLEIDING EN PROBLEEMSTELLING

Ondanks de vele middelen die ter bestrijding van de fruitspintmijt (*Metatetranychus ulmi* Koch) steeds weer ter beschikking komen, is *M. ulmi* tot een van de belangrijkste plagen in de fruitteelt blijven behoren. In het onderzoek betreffende de schadelijke vermeerdering van de mijt is in het bijzonder aandacht geschonken aan de invloed van de eliminatie van de natuurlijke vijanden van de mijt tengevolge van de giftige werking van vele chemische bestrijdingsmiddelen. De relatie tussen fytofage mijt en de fysiologische conditie van de voedselplant is alleen in meer recente onderzoekingen bestudeerd.

Het is van grote betekenis de vraag te stellen of beide factoren, zowel de natuurlijke vijanden als de fysiologische conditie der voedselplant, een belangrijke rol spelen bij de massale vermeerdering van het fruitspint of dat één van de twee een zodanig overwicht heeft, dat met de andere slechts in zeer beperkte mate rekening behoeft te worden gehouden.

2. LITERATUUROVERZICHT

Bij een bestudering van het vóórkomen en het ontstaan van ziekten en plagen in de fruitteelt blijkt, dat in het begin van de twintigste eeuw ongeveer voor het eerst sprake is van een schadelijke aantasting van de vruchtbomen door fytofage mijten. Op verschillende manieren is getracht het probleem van de zeer sterke vermeerdering van deze mijten te benaderen. De vernietiging van de natuurlijke vijanden tengevolge van de chemische ziektebestrijding wordt door vele onderzoekers als de belangrijkste factor voor deze vermeerdering beschouwd. Over het verband tussen de populatieontwikkeling van de mijt en de fysiologische toestand van de voedselplant i.c. de vruchtboom, als gevolg van bemesting en snoei is naar verhouding betrekkelijk weinig gepubliceerd. Deze experimenten zijn bovendien voor een groot deel onder laboratorium- of kasomstandigheden uitgevoerd, waarbij slechts in enkele gevallen *M. ulmi* als proefobject is gebruikt. Alhoewel de weersomstandigheden de ontwikkeling van de mijt tijdelijk zeer kunnen begunstigen, wordt deze factor niet van grote betekenis geacht voor de massale ontwikkeling van *M. ulmi.*

3. BIOLOGIE VAN ENKELE FYTOFAGE MIJTEN

3.1. *M. ulmi* overwintert als ei. De eieren worden in het najaar door de wijfjes afgezet aan de onderzijde van takken en twijgen. Vóór de bloei (ongeveer eind april) komen de eieren uit, waarna de pas uitgekomen larven naar de bladeren gaan. De ontwikkeling van ei tot imago verloopt via 3 actieve (1 larve en 2 nymphe) en 3 rust (chrysalis) stadia. De zomereieren worden op de bladeren afgezet. De ontwikkeling van larve tot volwassen mannetje verloopt ongeveer 1 dag sneller dan van larve tot volwassen wijfje. In Nederland komen 4 à 5 generaties per jaar voor.

3.2. *Bryobia rubrioculus* Scheuten, de harlekijnmijt, is vooral in de minder goed verzorgde boomgaarden naast *M. ulmi* van betekenis. *B. rubrioculus* overwintert eveneens als ei. De eieren komen ongeveer 2 weken eerder uit dan die van *M. ulmi.* Ook bij deze mijt komen 3 actieve stadia voor afgewisseld door 3 ruststadia. De zomereieren worden zowel op het hout als op de bladeren afgezet. In Nederland worden 3 generaties mijten waargenomen; mannetjes komen niet voor.

4. VELDONDERZOEK

4.1. Uit oriënterende waarnemingen betreffende de ontwikkeling van *M. ulmi* in boomgaarden in Zeeland, blijkt een duidelijk verband te bestaan tussen de verzorging van de boomgaard en de populatiedichtheid van de mijt. In de verwaarloosde boomgaarden komt *M. ulmi* slechts in zeer geringe aantallen voor. Bij een betere verzorging van de boomgaard neemt de populatiedichtheid van de mijt toe. In de goed verzorgde bedrijven kan *M. ulmi* alleen door middel van een zeer intensieve bestrijding beneden het schadelijke niveau worden gehouden.

4.2. Van 1954 tot 1959 werd het onderzoek uitgevoerd in een verwaarloosde hoogstamboomgaard te Eversdijk met de variëteiten Schone van Boskoop en Bellefleur (fig. 1 en 2). Het doel van het onderzoek was om na te gaan of de zeer sterke ontwikkeling van het fruitspint te wijten is aan de chemische ziektebestrijding door de vernietiging van een regulatie door predatoren of aan de overige cultuurmaatregelen: grondbewerking, bemesting en snoei, als gevolg van een verbetering van de voedselpositie van de fytofage mijt of mogelijk aan de combinatie van deze twee factoren. In verband hiermee was de indeling van het proefveld als volgt:

Perceel I – onbehandeld
Perceel II – grondbewerking, bemesting, snoei
Perceel III – grondbewerking, bemesting, snoei en chemische ziektebestrijding
Perceel IV – chemische ziektebestrijding.

De volgende afkortingen zullen verder worden gebruikt:
–sfp: zonder grondbewerking, bemesting en snoei
+sfp: met grondbewerking, bemesting en snoei.

In de percelen II en III werd de grond tot ongeveer juli zwart gehouden, terwijl deze percelen ieder jaar een stikstofgift ontvingen overeenkomende met 100 kg zuivere stikstof per ha; bovendien werden in deze percelen de bomen in het voorjaar gesnoeid. De percelen I en IV waren in gras gelegen. In tabel 1 wordt een overzicht gegeven van de bestrijdingsschema's in de percelen III en IV; in tabel 2 wordt de chemische samenstelling der bestrijdingsmiddelen vermeld.

Voor het bepalen van de populatiedichtheid van de fytofage mijten en de roofmijten werd om de 2 tot 3 weken in de vroege ochtenduren een monster van 100 bladeren per perceel en per variëteit genomen en het aantal daarop voorkomende mijten en eieren onder een binoculaire loupe geteld. *B. rubrioculus* werd geïnventariseerd op bladeren en takken. Hiertoe werd een monster genomen van 12 kortloten binnenuit de boomkruin en 12 van de buitenkant der bomen. Het aantal mijten en eieren werd omgerekend per eenheid van taklengte en bladeren. Voor het verzamelen van roofinsekten werd met een stok tegen de onderste takken der bomen geslagen en de insekten in een vangnet opgevangen (fig. 3).

Om een indruk te krijgen van de fysiologische conditie van de vruchtbomen werd van de bomen in de 4 percelen bepaald: de lengte van de éénjarige scheuten (fig. 4) en het aantal gemengde knoppen en bladknoppen per 10 meter taklengte, het percentage vruchtzetting, de totale opbrengst aan vruchten en het gemiddelde gewicht per vrucht, het gehalte aan stikstof, kalium, calcium, magnesium en fosfaat der bladeren, het vochtgehalte der bladeren, de gemiddelde bladoppervlakte en de anatomische structuur der bladeren (fig. 5).

Op pagina 21 en 22 wordt een overzicht gegeven van de waargenomen mijtensoorten en de insekten, die volgens de literatuur en eigen waarnemingen als predatoren kunnen optreden.

In de verwaarloosde boomgaard, waarin *M. ulmi* slechts sporadisch voorkomt is in het onbespoten +sfp perceel vooral op Bellefleur een sterke toename van de dichtheid van de mijt te constateren (fig. 6 en 7), parallel aan de toename van het totale stikstofgehalte der bladeren (fig. 15 en 16). Tengevolge van de beïnvloeding van de randbomen in het –sfp perceel door de bemesting in het aangrenzende perceel, is ook in het onbehandelde perceel een geringe vermeerdering van de mijt opgetreden (tabel 7 en 8). Verplaatsing van de mijten door de wind is niet van betekenis (fig. 17, tabel 9). In de percelen met chemische ziektebestrijding is de invloed van grondbewerking, bemesting en snoei op de ontwikkeling van *M. ulmi* niet waar te nemen (fig. 8 en 9), als gevolg van een zeer groot verschil in hoogte en dichtheid der bomen, waardoor zowel de natuurlijke ontwikkeling van *M. ulmi* als het effect van de bestrijding op de mijt sterk uiteenloopt (tabel 17).

Ondanks de veranderingen in het totale stikstofgehalte der bladeren (fig. 15 en 16) zijn in Eversdijk geen regelmatige wijzigingen opgetreden in het kalium-, calcium-, magnesium- en fosfaatgehalte der bladeren (tabel 3–6).

Teneinde een indruk te krijgen van de toestand van de gehele vruchtboom in verband met de voedselpositie van *M. ulmi* is tevens de groei (fig. 10), vruchtbaarheid (fig. 11 en 12) en de opbrengst der bomen (fig. 13 en 14) bestudeerd. De betere conditie van de bomen in de +sfp percelen komt alleen duidelijk tot uiting in de sterkere groei. In de +sfp percelen vertonen de bladeren (var. Bellefleur) een grotere totale dikte van het blad en van het palissadenparenchym ten opzichte van de bladeren uit de –sfp percelen. Tussen de vochtgehaltes van de bladeren uit de +sfp percelen konden geen regelmatige verschillen worden vastgesteld, evenmin als tussen de gemiddelde oppervlaktes van de bladeren uit deze percelen. Uit tabel 10 blijkt, dat bij het bepalen van de populatiedichtheid van *M. ulmi* per eenheid van bladoppervlakte, de verschillen tussen de onbespoten +sfp en -sfp percelen blijven bestaan.

In de onbespoten +sfp percelen is het complex van roofmijten (fig. 18 en 19) en roofinsekten (fig. 20 en 21, tabel 11) niet in staat de sterkere ontwikkeling van *M. ulmi* als gevolg van deze cultuurmaatregelen, tot beneden het schadelijk niveau te reduceren.

Na toepassing van de chemische ziektebestrijding is een toename van *M. ulmi* opgetreden (fig. 8 en 9). Deze kan niet zonder meer toegeschreven worden aan het doden der roofvijanden (tabel 12 en 13). Door de bestrijdingsmiddelen zijn eveneens alle concurrenten vernietigd, waardoor de voedseltoestand van *M. ulmi* verbeterd is. Tot deze concurrenten behoren zowel de plantaardige organismen (schurft en meeldauw) als de dierlijke organismen (andere fytofage mijten: *Bryobia rubrioculus* Scheuten (fig. 22–25, tabel 14), *Eotetranychus pomi* Sep. (fig. 26, tabel 15), *Brevipalpus oudemansi* Geyskes (tabel 16) en de bladmineerder *Leucotricha scitella* Zell.).

4.3. Van 1956 tot 1961 is de invloed van de cultuurmaatregelen op de ontwikkeling van *M. ulmi* eveneens bestudeerd in een jonge spillenaanplant met Lombartscalville M I. Vanaf het planten in 1953 zijn deze bomen tot 1956 normaal verzorgd. Terwijl in het proefveld Eversdijk werd uitgegaan van de toestand in een verwaarloosd bedrijf, is daarentegen in dit proefveld, Kuenen's Hof, uitgegaan van de toestand in een verzorgde jonge boomgaard (fig. 32 en 33). De indeling van beide proefvelden is gelijk; de percelen liggen hier echter in duplo (fig. 27). Ieder perceeltje wordt aan drie zijden begrensd door een elzenhaag, aan de vierde zijde door een populierenhaag.

In verband met het andere type boomgaard, vertonen de cultuurmaatregelen in dit perceel enige verschillen met die uitgevoerd in Eversdijk. De percelen II en III werden van 1956 tot 1960 ieder jaar bemest met 100 kg zwavelzure ammoniak, hetgeen overeenkomt met een gift van 80 kg zuivere stikstof per ha; in 1961 werd dit verhoogd tot 120 kg per ha. In tabel 18 wordt een overzicht gegeven van de bestrijdingsschema's in de percelen III en IV. Zeer veel aandacht moest in deze percelen worden geschonken aan de bestrijding van meeldauw *Podosphaera leucotricha* (Ell. et Everh.) Salm. Tengevolge van het kleinere boomtype konden de insekten in dit geval verzameld worden door de takken op ongeveer 1 meter van de grond met de hand boven het klopnet te schudden.

In deze oorspronkelijk verzorgde boomgaard met een tamelijk hoge beginpopulatie van *M. ulmi* is zowel in het bespoten als in het onbespoten gedeelte een daling van de populatiedichtheid te constateren in de -sfp percelen (fig. 28 en 29), evenredig met de vermindering van het stikstofgehalte der bladeren (fig. 39). De regenrijke zomer van 1960 maakt hierop een uitzondering.

In tegenstelling tot in Eversdijk is de daling van het stikstofgehalte gepaard gegaan met een daling van het calcium- en magnesiumgehalte (tabel 20 en 21) en een stijging van het kalium- en fosfaatgehalte (tabel 19 en 22) in deze percelen. De invloed van grondbewerking, bemesting en snoei komt eveneens tot uiting in een sterkere groei (fig. 30), een grotere vruchtbaarheid (fig. 31 en 34) en een groter gemiddeld gewicht per vrucht (fig. 38). Het verschijnsel van beurtjaren, dat de variëteit Lombartscalville enigszins vertoont, komt in de -sfp-percelen zeer duidelijk naar voren (fig. 31, 34 en 37). In 1956 en 1960 treedt vooral in de onbespoten -sfp perceeltjes een hoog percentage vruchtzetting op ten opzichte van de bespoten -sfp perceeltjes. Deze hoge vruchtzetting komt voor in de jaren, dat er een zeer sterke aantasting aanwezig is van de rose appelluis (*Dysaphis plantaginea* Pass.) (fig. 35 en 36). Zowel in de bespoten als in de onbespoten +sfp percelen vertonen de bladeren een grotere totale bladdikte en dikte van het palissadenparenchym dan in de –sfp percelen. De grotere dikte van het parenchym gaat over het algemeen samen met een groter aantal lagen parenchym. Evenmin als in Eversdijk is er een effect waar te nemen van de cultuurmaatregelen op het vochtgehalte der bladeren. De verschillen tussen de gemiddelde bladoppervlaktes tengevolge van de cultuurmaatregelen zijn zeer gering. Bij het bepalen van de populatiedichtheid van *M. ulmi* per eenheid van bladoppervlakte blijven de dichtheidsverschillen tussen de percelen dan ook zeer duidelijk bestaan (tabel 23).

In de onbespoten percelen treedt vanaf 1956 een geleidelijke ontwikkeling op van een populatie van roofmijten (fig. 40, tabel 24) en andere predatoren (fig. 41, tabel 25), terwijl de toename in het +sfp perceel over het algemeen het grootste is. Tengevolge van de sterke ontwikkeling van de fytofage mijt in het +sfp perceel zijn de predatoren ook hier niet in staat de populatie van *M. ulmi* tot beneden het schadelijke niveau te reduceren. De regenrijke zomer van 1960 maakt hierop een uitzondering. In het bespoten gedeelte van Kuenen's Hof blijkt zeer duidelijk, dat de invloed van de chemische ziektebestrijding op de massale vermeerdering van *M. ulmi* van geringere betekenis is dan de invloed van grondbewerking, bemesting en snoei. Bij de afwezigheid van predatoren (tabel 26 en 27) en concurrenten tengevolge van de ziektebestrijding kan *M. ulmi* zich in de percelen met grondbewerking, bemesting en snoei tot een plaag ontwikkelen, terwijl in de percelen waarin deze drie cultuurmaatregelen niet worden toegepast, *M. ulmi* niet in schadelijke aantallen voorkomt (fig. 29). Alleen een zeer intensieve bestrijding kan in de +sfp percelen de *M. ulmi* populatie in toom houden.

In het onbespoten gedeelte zal de mogelijkheid tot concurrentie van *M. ulmi* door andere fytofage mijten te verwaarlozen zijn tengevolge van de zeer geringe dichtheden van deze mijten (fig. 42 en 43, tabel 28). In de +sfp percelen kan de ontwikkeling van *M. ulmi* mogelijk worden afgeremd door een sterke meeldauw- of luisaantasting.

5. DETAIL ONDERZOEK

5.1. *Invloed van het stikstofgehalte der bladeren op de ontwikkeling van fytofage mijten*

5.1.1. Uit proeven in het laboratorium waarbij *M. ulmi* mijten gekweekt werden op geponste blaadjes gelegen op vochtig zand, blijkt dat de sterkere ontwikkeling van *M. ulmi* op bladeren van bemeste bomen in hoofdzaak te wijten is aan de significant hogere eiproductie van de mijt op deze bladeren ten opzichte van die uit onbemeste percelen (tabel 29). Ook bij proeven op onderstammen blijkt een sterkere populatie ontwikkeling van *M. ulmi* op de bemeste onderstammen ten gevolge van een hogere eiproductie op te treden.

5.1.2. In laboratoriumproeven met *B. rubrioculus* (fig. 44) komt geen duidelijke invloed van het stikstofgehalte van de bladeren naar voren op de ontwikkeling van deze mijt (tabel 30–34, 36). Wel blijkt uit de waarnemingen, dat de mijten op de bladeren van de onbemeste bomen eerder overgaan tot het leggen van wintereieren dan die op de bladeren van de bemeste bomen. Het percentage door de tweede generatie mijten afgezette wintereieren (= % niet uitgekomen eieren in tabel 35) is op de onbemeste bomen veel hoger dan op de bemeste bomen.

5.2. *Invloed van predatoren op de populatie ontwikkeling van fytofage mijten*

5.2.1. Uit laboratoriumproeven met enkele volwassen roofinsekten, n.l. *Orius minutus* L., *Anthocoris nemorum* L., *Blepharidopterus angulatus* Fall. en *Stethorus punctillum* Weise blijkt, dat deze geen significante voorkeur vertonen ten opzichte van de imago's van *M. ulmi* en *B. rubrioculus* (tabel 37). De larven van *S. punctillum* daarentegen prefereren *M. ulmi* mijten boven *B. rubrioculus* mijten (tabel 38). Roofmijten (Phytoseiidae) prefereren volwassen *M. ulmi* wijfjes boven de volwassen mijten en de oudere ruststadia van *B. rubrioculus* (tabel 39, resp. 41). Zowel bij *B. rubrioculus* als bij *M. ulmi* worden verder de niet-volwassen stadia verkozen boven de volwassen stadia (tabel 40, resp. 42). Uit waarnemingen blijkt tenslotte dat de roofmijten voor het grootste deel aan de onderzijde der bladeren tegen de nerven voorkomen (tabel 43). Hierdoor zal *B. rubrioculus* in geringere mate aan deze roofmijten ten prooi vallen dan *M. ulmi*, doordat de eerstgenoemde soort een belangrijk deel van zijn leven op de takken doorbrengt.

5.2.2. Met *M. ulmi* geïnfecteerde boompjes, variëteit Schone van Boskoop, zijn in potten geplaatst in een verwaarloosde boomgaard (+ predatoren) en in een verzorgd bedrijf (– predatoren). De populatie ontwikkeling van *M. ulmi* op deze boompjes is gevolgd (fig. 45). In 1959 en 1960 zijn de boompjes na enkele weken omgewisseld (fig. 46 en 47), terwijl in 1960 tevens de helft van de boompjes is bemest.

Uit de waarnemingen blijkt, dat de ontwikkeling van *M. ulmi* in het verwaarloosde perceel veel geringer is dan in het verzorgde perceel. Bij een omwisseling van de potboompjes uit het verwaarloosde naar het verzorgde perceel neemt de dichtheid van de *M. ulmi* populatie toe; bij het verplaatsen van het verzorgde naar het verwaarloosde perceel daalt zowel het aantal mijten als eieren.

Bij de potproeven in 1960 is geen invloed van de stikstofbemesting op de fruitspint ontwikkeling waar te nemen. Mogelijk is het verschil in het stikstofgehalte der bladeren van de bemeste en onbemeste bomen zo laat in het seizoen ontstaan, dat een invloed hiervan op de populatie ontwikkeling van de mijt niet meer tot uiting is gekomen.

Het aantal roofwantsen op de omliggende bomen wordt vermeld (tabel 44 en 46), evenals het aantal roofmijten op de potboompjes in 1959 (tabel 45).

5.2.3. Tenslotte wordt in figuur 48 de invloed weergegeven van roofmijten (Phytoseiidae) op de ontwikkeling van een *M. ulmi* populatie op Cox's Orange Pippin. De boompjes staan in een gazen kooi met plastic dak. Eenmaal per week is het aantal fytofage mijten en roofmijten op een monster van 20 bladeren per boom geteld. Op de boom met roofmijten (+P boom) daalt de populatiedichtheid van *M. ulmi* in veel sterkere mate dan op de boom zonder roofmijten (– P boom) (fig. 48 en tabel 47).

7. CONCLUSIE

Uit de resultaten van het onderzoek blijkt de grote invloed van de fysiologische conditie van de vruchtbomen op de ontwikkeling van *M. ulmi*. De invloed van de toestand van de bomen is eveneens waar te nemen op de ontwikkeling van andere dierlijke fruitbeschadigers, zoals groene appeltakluis (*Aphis pomi* DeG.) en bloedluis (*Eriosoma lanigerum* Hausm.) en in zekere mate op die van plantaardige organismen, zoals appelmeeldauw. Door de sterke ontwikkeling van de dierlijke organismen tengevolge van de moderne teeltmethode van de vruchtbomen kunnen deze fruitbeschadigers, ook bij de aanwezigheid van een relatief groot aantal parasieten en/of predatoren in bedrijven waarin geen chemische ziektebestrijding wordt toegepast, niet beneden het schadelijke niveau worden gehandhaafd.

Een zuiver biologische bestrijding van de dierlijke organismen is onder de gegeven omstandigheden economisch niet mogelijk. Afgezien van een eventuele biologische bestrijding van de dierlijke organismen zullen de plantaardige organismen schurft en meeldauw onder onze klimaatomstandigheden de kwaliteit van de vruchten bovendien nog sterk doen dalen. Een vermindering van de bemesting waardoor de sterke ontwikkeling van de organismen wordt afgeremd is in de praktijk moeilijk uitvoerbaar, daar dan eveneens de opbrengst per ha zal dalen. Zolang men met een chemische ziektebestrijding goede resultaten kan bereiken en deze ziektebestrijding in ieder geval voor de Zeeuwse omstandigheden gemiddeld slechts ongeveer 9.5 % uitmaakt van de totale teeltkosten, zal de fruitteler deze curatieve methode verkiezen boven de preventieve bestrijding (geringere bemesting en snoei), waarbij hij een verminderde opbrengst in kilogram of in kwaliteit der vruchten zal riskeren.

Door de ontwikkeling van resistentie is echter de zekerheid van het verkrijgen van goede resultaten wel sterk verminderd. Momenteel komen volgens VAN DE VRIE (mondelinge mededeling) in ongeveer 95 % van de goed verzorgde Zeeuwse bedrijven stammen van *M. ulmi* voor, die ten opzichte van de organische fosforverbindingen min of meer resistent zijn. Deze ontwikkeling vormt een bedreiging voor de fruitteelt, waardoor het noodzakelijk is geworden de mogelijkheden te onderzoeken de ziektebestrijding in andere banen te leiden.

In Canada en de Verenigde Staten zijn hiertoe het eerst pogingen in het werk gesteld, daar de fruittelers in deze gebieden het eerst met resistentie problemen te kampen kregen. Uit onderzoekingen bleek, dat voor iedere streek een apart ziektebestrijdingsschema moet worden opgesteld, aangepast aan de bodem, het klimaat en de daarmee samenhangende ziekten en plagen, terwijl tevens rekening gehouden moet worden met de economische omstandigheden.

In 1959 werd vooral met het oog op de resistentie ontwikkeling in het kader van de Werkgroep 'Harmonische Bestrijding van Plagen' getracht voor onze omstandigheden een spuitschema samen te stellen voor gecombineerde chemisch-biologische bestrijding van plagen en ziekten in de boomgaarden. Volgens DE FLUITER (1960) moet deze harmonische bestrijding gebaseerd zijn op een goede coördinatie van een tot een minimum gereduceerde curatieve (chemische) bestrijding met een aansluitende actie van het natuurlijke weerstandscomplex, waardoor de restpopulatie in toom wordt gehouden. Slechts indien noodzakelijk wordt dus een chemische bestrijding uitgevoerd en dan liefst met een specifiek middel in een lage concentratie om zoveel mogelijk nuttige organismen te sparen (DE FLUITER, 1960; VOÛTE & DE FLUITER, 1961).

Bij het uitvoeren van een dergelijk harmonisch bestrijdingsschema worden zoveel mogelijk parasieten en predatoren gespaard. Uit dit onderzoek blijkt echter, dat de predatoren van *M. ulmi* op geïsoleerde en relatief kleine percelen niet in staat zijn de plaag te onderdrukken. Nader zal moeten worden bestudeerd of dit wel mogelijk is als de oppervlaktes van de percelen groter zijn. Eveneens zal onderzocht moeten worden in hoeverre veranderingen in de fysiologische toestand van de boom zijn aan te brengen, die de populatie ontwikkeling van *M. ulmi* ongunstig beïnvloeden.

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