CONTROL OF ORCHARD MITES WITH OVERTREE SPRINKLER IRRIGATION SYSTEMS

by

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B. Sc., Washington State University, 1960

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
in the Department
of
Biological Sciences

SIMON FRASER UNIVERSITY

June, 1970

LC

APPROVAL

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Degree: Master of Science

Title of Thesis: Control of Orchard Mites With Overtree Sprinkler Irrigation Systems

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ABSTRACT

Overtree sprinkler irrigation systems were tested as a physical control agent against 3 species of orchard mites on apples. The mite species were the McDaniel spider mite, _Tetranychus mcdanieli_ McGregor, the European red mite, _Panonychus ulmi_ Koch, and the apple rust mite, _Aculus schlechtendali_ (Napela).

The investigation was started in 1968 in a commercial apple orchard near Yakima, Washington and was continued in 1969 at the Canada Department of Agricultural Research Station at Summerland, B.C. Three types of experiments were carried out. They were: (1) detached-leaf experiments, (2) small plot field tests, and (3) commercial orchard trials. The mites were counted before and after each sprinkling in order to estimate the number of mites washed from the foliage. The commercial orchards were sampled for mites throughout the season.

The greatest degree of control was against the McDaniel spider mite. Active stages and eggs of this species were easily washed from upper leaf surfaces but control was much poorer against mites and eggs on lower leaf surfaces. Sprinkling did not control high populations of the McDaniel spider mite but prevented low populations from reaching damaging levels for a 6 week period when sprinkled every 10 days. Overtree sprinkling kept McDaniel spider mites at a low level in the commercial orchard in 1968 while populations reached damaging levels in a non-sprinkled portion of the same orchard.

Sprinkling was less effective against populations of the European red mite. Although active stages of European red mites were reduced, many adults escaped by emigrating from upper to lower leaf surfaces. Eggs of the European red mite were not washed from the leaves. There was no difference in the rate of increase of European red mite populations on sprinkled and non-sprinkled trees over a 6 week period in small test plots. There were fewer, but still damaging numbers of European red mites in overtree sprinkled portions of 2 commercial apple orchards than in non-sprinkled portions in the same orchards. Apple rust mites were suppressed by sprinkling in 3 commercial apple orchards but this mite species was not studied in detail.

Sprinkling did not affect the development of populations of predaceous phytoseiid mites, chiefly *Typhlodromus occidentalis* Nesbitt. Furthermore, sprinkling did not reduce their effectiveness as predators. But the presence or absence of phytoseiid mites was more important in regulating the population density of the McDaniel spider mite than was overtree sprinkling.

In limited tests, high rates of water application controlled European red mites better than standard rates of application and immature stages were more easily controlled than the adult stage. The major factor limiting the effectiveness of overtree sprinkling as a physical control for orchard mites is the seasonal distribution of mites on upper and lower leaf surfaces. Mites on lower leaf surfaces were not greatly affected by sprinkling, even after prolonged irrigations.

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1. INTRODUCTION

Objectives and Scope of Study

The objective of this research project was to investigate to what extent water, when applied with overtree sprinklers, may act as a physical control agent for orchard mites, either causing death by "battering" or by physically displacing the mites from foliage of apple trees. This method of mite control is cheap because orchards are presently irrigated with overtree irrigation systems. I have shown that sprinkling is an effective method of control for the McDaniel spider mite. Sprinkling also suppresses populations of the European red mite and apple rust mite. Consequently, the need for acaricide applications is reduced. This results in direct savings in material and application costs. Fruit finish is improved because the amount of visible pesticide residue on the fruit is reduced. As there is less need to apply phytotoxic acaricides to control the mites the risk of fruit and foliage injury from spray materials or combinations of materials is lessened. Fewer pesticide applications also lessen the selective pressure for resistance in populations of mites and other injurious pests. There is reduced exposure to persons applying chemical pesticides, less contamination of fruit with pesticide residues and less environmental pollution.

Mites infesting fruit trees indirectly affect the color, size, and quality of the fruit and can influence fruit bud set for the following season. The mites cause damage to the foliage by inserting their stylets into the leaf and extracting the cell contents. Symptoms of leaf damage vary according to the species present. Infested leaves become mottled in appearance followed by loss of green color, and finally, bronzing. If infestations are high, the leaves turn yellow and may drop. All varieties of apples are attacked, but some varieties, such as Red Delicious and Golden Delicious, are more susceptible to injury than others.

Economic injury levels have not been firmly established for phytophagous mites on apples. The degree of damage mites cause depends upon the time of year the infestation occurs, duration of the infestation, weather conditions, and vigor of the trees. In chemical control programs threshold levels were often very low. In recent years, with the development of integrated mite control programs, threshold levels for mites have been raised considerably. This is discussed in more detail later in this manuscript.

2. THE MITE PROBLEM IN NORTHWEST ORCHARDS

a. Biology of Orchard Mites

Three species of phytophagous mites and a predaceous phytoseiid mite were studied. The phytophagous species were the McDaniel spider mite, *Tetranychus mcdanieli* McGregor, the European red mite, *Panonychus ulmi* (Koch), and the apple rust mite, *Aculus schlechtendali* (Nalepa). The phytoseiid studied was *Typhlodromus occidentalis* Nesbitt.

The McDaniel spider mite has often been confused with the Pacific mite, *Tetranychus pacificus* McGregor. Since the Pacific mite is not found in apple orchards in Washington and British Columbia, the species referred to in earlier literature was probably *T. mcdanieli*. Several scientific names have been used for the European red mite. From 1912 until 1952 it was known as *Paratetranychus pilosus* (Can. and Franz.). From 1952 to 1956 it was called *Metatetranychus ulmi* (Koch) and since the latter date, *Panonychus ulmi* (Koch).

The apple rust mite is known as either Vasates schlechtendali (Nal.) or Aculus schlechtendali but the latter is more widely accepted.

McDaniel spider mite

The McDaniel spider mite is the most serious mite pest of apples in the South Okanagan of British Columbia and the apple growing areas of Eastern Washington. The mites overwinter as orange-colored females beneath the bark scales of the trunk and scaffold limbs of the tree and in the refuse at the base of the trees. Upward movement of the mites begins in late March and continues through April (Hoyt 1962). As the females begin to feed the typical orange color of the overwintering forms disappear and the mites become light to dark green. Under favorable environmental conditions they begin to lay their eggs within a few days after taking on this green color. Both males and females develop from the eggs of the overwintering females, which indicates that at least some of the overwintering females are fertilized in the fall.

In addition to the egg stage, there are four active stages in the life cycle of the McDaniel spider mite. These are the larva, protonymph, deutonymph, and adult. Between each active stage there is an inactive or quiescent stage.

According to Nielsen (1958) 7.7 days are required to complete development at 90° F. and an average of 119 eggs are deposited per female. Webster (1948) found that the McDaniel spider mite (= T. pacificus McGregor) deposited an average of 150 eggs per female during a 5 to 6 week period and that up to 10 generations were produced in 1940 near Wenatchee, Washington. The mites are gregarious and spin a great deal of webbing in which the eggs are suspended and which offers some protection for the young mites.

In the absence of predators the development of McDaniel spider mite populations proceeds rapidly during late June, July, and early August and maximum density is reached in mid-August or early September. A gradual decline in the population occurs during late August, becoming more rapid during September. Overwintering forms may appear in the first generation but the peak population of overwintering forms occurs from mid-August to October.

European red mite

Unlike the McDaniel spider mite, the European red mite overwinters in the egg stage on spurs and twigs of the trees affected by the mites during the summer months on apples. The eggs start hatching about the middle of April, just before the blossoms open. The hatching of all the winter eggs is usually completed within a week or 10 days. Like the McDaniel spider mite, there are five stages in the life cycle of the European red mite. According to Newcomer and Yothers (1929), about 20 days are required to complete the life cycle and adult females generally deposit from 20-24 eggs over a period of approximately 11 days. An average of six generations are produced in a year.

Populations of European red mites occur in distinct stages during the first generation with practically no overlapping of active stages. After about June 1, generations begin to overlap with various stages present, and during warm seasons mites from three different generations may be present at one time during the remainder of the season (Newcomer and Yothers 1929).

The population density increases slowly during May but a rapid increase occurs during June. In Washington, peak populations occur from late June to mid-July (Hoyt 1969b). A rapid decline in density occurs following the peak. This decline commonly called "the August decline," is also an annual occurrence in sprayed orchards in British Columbia (Anderson and Morgan 1958).

Deposition of winter eggs usually begins about the middle of August and continues until cold weather kills the mites or causes the leaves to drop.

Unlike McDaniel spider mites, European red mites are not gregarious and do not spin copious amounts of webbing. Summer eggs are attached to the leaf surface (Beament 1951), rather than suspended in webbing as are McDaniel spider mite eggs. Some webbing is spun during summer dispersal activity of the mites (Cutright 1963).

Apple Rust Mite

Little is known about the biology of this species. The mites overwinter as adults in colonies behind the buds or in crevices in the bark at the base of buds (Madsen and Arrand 1966). The overwintered forms emerge in late March and early April and congregate on the exposed green tissue of the buds. As the leaves expand the mites are found predominantly on the undersurface of leaves. As populations increase an increasing percentage of the mites are found on the upper surfaces of the leaves. Populations of apple rust mites can develop quite rapidly during the early season. Peak populations in excess of 2000 per leaf have been reported (Hoyt 1969b). They become most numerous in May and June and normally decline in July and August under the influence of high temperatures. In late summer the mites move to the buds to spend the winter.

Typhlodromus occidentalis

There is no common name for this species. The mites overwinter as adult females primarily in the trash at the base of the tree but some are found under bark and in other protected spots on the tree. The females emerge during late March and in April and move to the developing buds. The first generation eggs are deposited on the flower parts or on the underside of the leaves. By early May, and throughout the remainder of the season, the majority of the mites are found on the undersurface of leaves near the midvein. When populations of McDaniel spider mites are high, T. occidentalis can also be found under the webbing on the upper surface of the leaves, on the bark, in the calyx end of fruit or in any area where McDaniel spider mite colonies are found (Hoyt and Retan 1967).

The stages of development of T. occidentalis are the egg, larva, protonymph, deutonymph, and adult. The average developmental time from egg to adult is 6.3 days at 75° F. when fed on Tetranychus urticae Koch and laboratory and field observations suggest that there are at least 10 generations a season (Lee and Davis 1968).

The population density of T. occidentalis tends to follow changes in density of prey populations. Laing (1969) showed that the intrinsic rate of increase of Metaseiulus occidentalis (= T. occidentalis) is larger than that of the prey T. urticae, a factor favoring biological control of the prey species. Although T. occidentalis will feed on the European red mite and apple rust mite, the McDaniel spider mite is the preferred food source. When the density of the McDaniel spider mite population increases in July and August the numerical response of the predator population is rapid and complete destruction of the prey population soon follows.

Hoyt (1969b) showed that European red mite populations are little affected by T. occidentalis in the early season and that T. occidentalis populations are little affected by the presence of European red mite populations. The presence of apple rust mites assures a continuing food supply for T. occidentalis when other sources of food are absent but the predator is incapable of regulating the density of this species at high population levels.

T. occidentalis leave the foliage in September and seek overwintering sites, though many remain on the foliage and are apparently lost when the leaves fall.

b. History

Prior to World War II, orchard mites, although at times troublesome, occupied a minor status as crop pests. The mite problem intensified with the introduction of DDT in 1947 (Webster 1948), and subsequently became more serious due to the development of resistance to acaricides that initially controlled the mites (Downing 1954, Hoyt and Harries 1961, Hoyt and Kinney 1964, and Hoyt 1966). By 1966 in many apple orchards in Washington and British Columbia the McDaniel spider mite had become highly resistant to most registered acaricides (Johnson 1966).

Preliminary investigations into a possible new approach to the mite problem were begun in British Columbia by Anderson and Morgan (1958) and Arrand and Downing (1966 and 1969) and in Washington by Hoyt (1965 and 1969). The results of these investigations led to the development of an integrated mite control program which combines biological control of phytophagous mites, chiefly by the predator mite T. occidentalis, with chemical control of all other pests (Downing and Arrand 1968, Hoyt et al. 1969).

The McDaniel spider mite is the primary target of the integrated control program. When McDaniel spider mite populations begin to develop during the warm weather of July, T. occidentalis responds to this increased food supply, but the length of time required for control of mite populations is determined by the distribution of the predators and the weather conditions. A prolonged period of hot weather will favor the McDaniel spider mites over the predators and extensive foliage damage may occur. Under these conditions it is necessary to apply a corrective spray of a selective miticide to help improve the balance in favor of the predators. Population levels of mites that may cause excessive foliage injury are called "critical population levels." Although critical levels were established rather arbitrarily they serve as guidelines for the practical application of integrated mite control (Johnson 1968, Arrand 1970). An average of 15 to 20 McDaniel spider mites per leaf is considered a critical population level. Once the predators gain control of the situation the McDaniel spider mite population will decline to very low levels. In the absence of an alternate source of food, populations of T. occidentalis will also decline to a low level. This gives rise to a cyclic predator-prey relationship. If apple rust mites are present as an alternate food source this cyclic pattern does not occur. Thus, non-damaging populations of rust mites are desirable to assure survival and to support high populations of predators. Apple rust mites occasionally reach excessive populations. Control measures must be applied when this occurs. An average of 200 to 300 rust mites per leaf during July or August is a critical population level, particularly if populations are increasing.

European red mite populations are little affected by predation by T. occidentalis in the early season but low populations of European red mites are often controlled in the late season by the predator. An average of 5 or more European red mites per leaf during May, June or July is a critical population level.

The extensive reduction of populations of McDaniel spider mites in the integrated control program has so far not allowed the European red mite to become a serious problem as long as effective prebloom controls are applied annually.

About 8000 acres of apples in Yakima County, Washington were under integrated control programs in 1966 and practically all apple growers in the area were using this method of control by 1967 (Hudson 1966 and 1967). A similar pattern of adaptation is taking place in fruit areas of North Central Washington and of Southern British Columbia.

c. Irrigation Practices

The mean annual precipitation is low in the fruit growing district of Southern British Columbia and Eastern Washington, ranging from 6.4 inches in the Lower Yakima Valley to 11.47 inches at Summerland, B.C. Consequently supplemental water must be applied during the growing season (April-September). The amount of irrigation water applied varies according to the latitude and soil texture but normally ranges from thirty to forty acre-inches annually (Wilcox and Brownlee 1961, Jensen et al. 1962).

Most orchards were irrigated by furrows until about 1946 when undertree, portable sprinkler systems began to replace the furrow system of orchard irrigation. By 1953, 50% of the irrigated lands in the Okanagan Valley were sprinkler irrigated (Wilcox 1953). At the present time, practically all orchards in the South Okanagan of British Columbia and a large percentage of Eastern Washington orchards are sprinkler irrigated.

Sprinklers are normally operated for 12 or 24 hour periods, and safe intervals between sprinklings range from 5 to 30 days depending on depth of soil and texture. The amount of water applied in each irrigation period can range from 1.80 to 4.94 inches, depending on soil depth and texture (Wilcox and Brownlee 1961).

Overtree sprinkler systems have been in use for thirty years or more in a limited number of apple orchards in North Central Washington and the southern Okanagan Valley in British Columbia. Overtree irrigation systems differ from conventional undertree sprinkler systems in that the sprinkler heads are placed on tall risers. The water from the sprinklers sprays over the tree tops wetting the entire tree in addition to wetting the orchard floor. They may be of two types; either solid-set, permanent systems or portable tripod systems. But these systems only came into widespread use in the last two or three years. Economics, fear of disease, and other cultural problems (Harley 1930, Overley 1930, Wilcox 1955, Wilcox and Brownlee 1961) prevented the adaptation of these systems to orchards on a large scale.

Increasing scarcity of orchard labor to handle conventional methods of irrigation, plus the development of new, cheaper materials such as polyvinyl chloride pipe, has only recently made it economical for orchardists to install permanent overtree sprinkler systems. The newer orchards, which are using denser plantings of dwarf and semi-dwarf trees, and hedgerow-type plantings, make it very difficult to move conventional, undertree portable sprinkler systems. Distribution of water is poor in dense plantings with undertree sprinklers. Consequently solid-set, overtree sprinkler systems have been installed in many of these orchards.

Although overtree sprinkler systems are being installed primarily for orchard irrigation, additional uses have been investigated. These include frost protection (Cordy 1966, Schultz 1966), summer cooling (Woodbridge 1968), and the application of pesticides (Platter 1962, Liebster 1966).

d. Influence of Rainfall and Water Sprays on Spider Mites

Control of orchard mites with overtree sprinklers has been reported in several popular accounts (Ross 1968, Stark 1969).

Spuler (1930), investigating the effect of overtree sprinkling on the codling moth, *Carpocapsa pomonella* L., compared other insects and mite populations in sprinkled and non-sprinkled orchards. The only pests that were affected to any extent were the European red mite, clover or brown mite, and two-spotted spider mite. Very few mites were found in any of the sprinkled orchards while mite infestations in non-sprinkled orchards varied from light to severe and in most cases necessitated the use of oil sprays to control them.

A drenching spray of water has been suggested for control of several species of tetranychid mites on trees and ornamental plants (Hamilton 1926, Brock 1929, Roberti 1946).

Various workers, while conducting acaricide tests, noted substantial reductions in mite populations due to the mechanical effect of the spray (Newcomer 1927, Moore *et al.*, 1939, Chaboussou 1961). Frost (1924) stated, "In conducting spraying experiments it seems that high pressure is a valuable factor in the control of the red spider" (P. pilosus C. and F.).

Of the various weather factors that influence the seasonal abundance of spider mites, rainfall has been reported to be a chief limiting factor (Garman 1923, Britton 1925, Dean 1950). But serious mite outbreaks have occurred in spite of heavy rainfall (Massee 1937, Kearns and Martin 1940, Dean 1941).

Heavy rainfall or a series of showers have reportedly washed mites from the leaves of fruit trees and other crops (McGregor 1914, Ross and Robinson 1922, Garman 1923, Frost 1924, Hamilton 1924, Garman and Townsend 1938, Kuenen 1943, Linke 1953). Newcomer and Yothers (1929) stated that the European red mite, P. pilosus, is not easily washed off by rains, as is the common red spider (probably T. pacificus). Blair and Groves (1952) showed that neither active stages or eggs of the fruit tree red spider, Metatetranychus ulmi Koch were swept off the foliage during a heavy rainstorm.

Little work has been done to evaluate overtree sprinkling for mite control on fruit trees. Hoyt (personal communication) tested overtree sprinkling for mite control in 1968. He found that sprinkling did not control high populations of the McDaniel spider mite on apples. The mite population was in excess of 60 mites per leaf before the sprinklers were in operation and the population continued to increase following the use of overtree sprinklers.

Overtree sprinkling, if found to be an effective method of reducing population densities of phytophagous mites without destroying or reducing the efficiency of mite predators, could help assure a more stable integrated mite control program. It could eliminate the need for corrective sprays in orchards where cyclic predator-prey patterns develop and prevent populations of apple rust mites from reaching damaging levels. Sprinkling could also prevent the European red mite from filling the void created by the extensive reductions of the McDaniel spider mite in integrated programs.

e. The Mite Problem in 1969

Climatic conditions were favorable for the development of mite populations in 1969. The severe winter of 1968 and 1969 did not affect the survival of orchard mites in the Summerland area.

Monthly mean temperatures did not vary from the 30-year average except for the month of June which was 6 degrees above normal. Rainfall during April totaled about 3 times the normal amount for this period. May was normal but June received only 1/3 the normal amount of rainfall. Rainfall in August was far below normal. During September rainfall was twice the normal amount for this period.

The wet weather in April had little effect on hatching and development of the European red mite. High populations developed in the early season in experimental plots and in commercial orchards in the area.

McDaniel spider mites were not generally a serious problem in commercial orchards. Most growers practiced integrated mite control and predaceous phytoseiid mites prevented the McDaniel spider mite population from reaching high levels in these orchards. But very high populations of McDaniel spider mites developed in experimental plots at the research station that were intentionally sprayed with pesticides toxic to the phytoseiid mites.

3. MATERIALS AND METHODS

The investigations were carried out in 1968 in a commercial apple orchard near Yakima, Washington and during the 1969 season at the Canada Department of Agriculture Research Station at Summerland, B.C. During 1969, experiments were conducted in the station orchards and in commercial orchards in the Summerland and Naramata fruit districts.

Three types of experiments were carried out. They were (1) detached-leaf experiments, (2) small plot field tests, and (3) commercial orchard trials.

In early-season detached-leaf experiments, mite infested leaves were collected from Delicious apple trees. The petiole of each leaf was inserted into a snap-cap vial which had a small hole drilled in the top (Fig. 1). The vials were kept full of water to keep the leaves turgid for the duration of the tests. In late-season tests, short sections of shoot growth were removed from the tree. All leaves except one were removed and the shoot with leaf attached inserted into a vial through a bored cork stopper (Fig. 2). The latter method prevented the leaves from dessicating for a much longer period of time. The mites and eggs on the prepared leaves were then hand-counted under a dissecting microscope. Five of the leaf vials were then fastened to a rack eight feet off the ground and 20 feet from a single, 14 foot high sprinkler tripod. A Rainbird 20-A sprinkler head was used with an 11/64-inch nozzle operating at 30 psi. The sprinkler head rotated completely every 30 seconds. Check leaves were treated the same as sprinkled leaves except they were placed outside the throw of the sprinkler during the sprinkling periods.

A portable overtree sprinkling system was used in all field tests except those conducted in growers' orchards. The specifications of the latter systems are described in the section entitled "commercial orchard trials." The portable system consisted of 10 foot-high sprinkler tripods with a 7 foot, ½-inch pipe extension placed between the tripod and the sprinkler head (Fig. 3).

When placed in position, the sprinklers were approximately 14 feet above the orchard floor. The spray of water from the sprinklers arced 3 feet above the sprinklers or about 17 feet above the orchard floor. This was a sufficient height to spray over the tops of the experimental trees. One-half inch plastic hose connected the tripods to 2-inch portable aluminum irrigation pipe which was connected to the supply source. Thus, the system was entirely portable and could be set up in a short time in any one of several test plots. Four tripods were used in single-tree plots, and six tripods for two-tree plots. The tripods were spaced 20X20 feet or 20X40 feet depending on the amount of water to be applied. This arrangement simulated conditions in an overtree sprinkled orchard.

Rainbird 20-A sprinkler heads were used in all tests. Nozzle sizes were varied from 3/32-inch to 7/32-inch and pressure was regulated by a standard 2-inch gate valve. All pressure measurements were made at the nozzle with a 0 to 100 pounds per square inch (psi) gauge and pitot tube.

The system was tested for evenness of water distribution prior to setting up any experiments. Distribution was satisfactory in calm air using 1/8-inch nozzles but was poor in light winds or when operated with the large, 7/32-inch nozzles. Water distribution could have been improved considerably by substituting larger sprinkler heads when testing the 7/32-inch nozzles. Larger sprinklers would have necessitated the use of much larger plot sizes which would have proven too cumbersome to handle. In order to minimize drift, experiments were conducted only in relatively calm weather.

Twenty-leaf samples were taken to estimate mite populations in field tests except in the commercial orchard tests where fifty-leaf samples were taken. The leaves were brushed by the method of Henderson and McBurnie (1943) as modified by Morgan _et al_. (1955). The mites were counted under a dissecting microscope and the numbers of each species recorded. In some preliminary tests, mites on individual leaves were hand-counted under a dissecting microscope. The student t-test was used to determine significant differences in each of the detached-leaf experiments. The degree of significance is denoted by an asterisk in the appropriate column in each table.

The station orchards in which the experiments were conducted are normally irrigated with an undertree, portable sprinkler system every two weeks. Ground cover is grass that is mowed regularly.

Experiments were limited to the Red Delicious variety of apple although the Spartan variety was included in the sampling of one commercial orchard.

Fig. 1 Apparatus for early-season detached leaf experiments

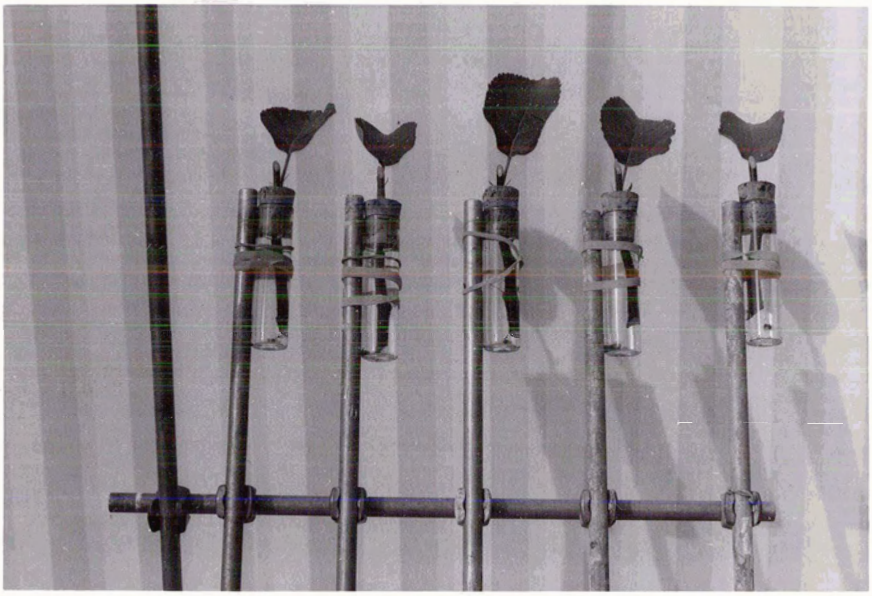


Fig. 2 Apparatus for late-season detached leaf experiments

Fi 3 Portable sprinkling tripods used in overtree sprinkling experiments

4. RESULTS

a. Detached Leaf Experiments

European Red Mites

This series of tests was conducted to determine how overtree sprinkling might affect the behavior of European red mites and to what extent sprinkling washed the different stages of mites and mite eggs from upper and lower leaf surfaces. Mite populations on the same leaves were counted before and after each treatment. Absolute numbers of mites and eggs are recorded for each leaf surface in tables 1 to 5.

First Test - June 11, 1969

After 4 hours of sprinkling, the sprinkled leaves and check leaves were brought into the laboratory and the mites on them recounted. Only an occasional active stage was found on the upper leaf surface. Those that were present were mostly quiescent forms. Sprinkling removed 97% of the active stages from the upper leaf surface but caused a reduction of only 19% on the lower surface, for a total reduction of 59% (Table 1).

There was a marked reduction of active stages on 3 of the 5 check leaves at the end of 4 hours. The total reduction for the 5 leaves amounted to 21% (Table 2). Some difficulty was experienced during handling and counting in keeping the mites on the foliage as active stages would tend to disperse and run down the petioles and over the surface of the vial. Cooling the leaves to 43° F. helped to some extent. However, a number of leaves were discarded prior to counting because of this dispersal activity. This occurred both on the sprinkled and the check leaves. In later tests of this type, the mites were counted in an air-conditioned room which lessened the dispersal problem.

The active stages were present on both upper and lower leaf surfaces of the check leaves at the end of the test, whereas the remaining mites on the sprinkled leaves were all on the lower leaf surface.

There was no reduction in the number of eggs on any of the sprinkled leaves. The pre-treatment egg count totalled 418 and the post-treatment count was 431. The number of eggs increased from 319 to 342 during the 4 hour period on the check leaves.

Second Test - June 14, 1969

In the second test of this series, 4 leaves were sprinkled for a period of 12 hours. The fifth leaf fell to the ground and was discarded. Leaves 2 and 3 turned over in their vials during the test, subjecting the lower surface of the leaves to the sprinkler water. Sixty-nine percent of the active stages were removed from the sprinkled leaves while mites on the check leaves varied only 2% during the period of the test (Table 3).

The egg count on the sprinkled leaves increased 26% during the 12 hour period while a 6% increase was noted on the check leaves.

Third Test - June 16, 1969

In the third test of this series, 5 leaves were sprinkled for a period of 12 hours. Because of the large number of eggs present, egg counts were made on only three of the five sprinkled leaves. Cotton gauze was packed around the leaf petioles to prevent the leaves from rotating in the vials. Thus, only the upper leaf surfaces were subjected to the sprinkler droplets. The sprinkling resulted in a reduction of 56% of the active stages. This was consistent for each of the 5 leaves (Table 4).

The increase in numbers of adult females on lower leaf surfaces following sprinkling confirmed what had been suspected in previous experiments; that is, many of the adult females migrate from the upper leaf surface to the lower surface of the leaf when the sprinklers are turned on.

This phenomena has been observed to occur just prior to thunderstorms by Morgan (personal communication). I observed that in the early morning, following a heavy dew, all active stages of European red mites were on the dry, lower surface of the leaf or beneath a curl in the upper leaf surface where no moisture occurred.

Within 2 hours after re-examining the leaves, the adult females had migrated back onto the upper leaf surfaces.

The egg count remained almost unchanged during the sprinkling period (+14%). The population of active mites on the check leaves remained unchanged over the 12 hour period (+6%), however, eggs were not counted on any of the check leaves (Table 5).

The following conclusions are based on the results of the detached-leaf tests:

1. Twelve hours of sprinkling washed 50% to 70% of the active stages of the European red mites from the leaves.
2. Many of the adult European red mites escaped the water droplets by emigration from the upper leaf surface to the lower leaf surface.
3. In a limited number of observations, a greater proportion of immature mites were washed from the leaves than adult mites.
4. Eggs were not washed from either the upper or the lower surface of the leaves.

5. The tests suggest that oviposition is not inhibited during periods of sprinkling. Furthermore, there was some evidence that the rate of oviposition may even be greated during periods of sprinkling.

Table 1. Comparison of European red mite populations on detached leaves before and after 4 hours of sprinkling. Sprinkled leaves. June 11, 1969.

Leaf No.		Before Sprinkling			After Sprinkling	
	Adults	Immature	Eggs	Adults	Immature	Eggs
1. Upper Surface	10	49	95	0	1	58
Lower Surface	16	26	25	17	36	48
2. Upper Surface	11	27	34	1	1	28
Lower Surface	11	15	33	4	13	39
3. Upper Surface	6	20	37	0	1	40
Lower Surface	31	18	43	20	16	57
4. Upper Surface	11	19	18	0	0	25
Lower Surface	20	11	52	11	8	44
5. Upper Surface	15	24	49	0	0	52
Lower Surface	13	23	32	12	12	40
Total Upper Surface	53	119	233	1***	4*	203
Total Lower Surface	91	93	185	64	85	228
Leaf Total	144	212	418	65*	89**	431

Percent change: Adults -54.9%, Immature -58.0%, All Active Stages -56.7%, Eggs +3.1%.

* Differences are significant at the 5% level.
** Differences are significant at the 1% level.
*** Differences are significant at the 0.1% level.

Table 2. Comparison of European red mite populations on detached leaves before and after 4 hours of sprinkling. Check leaves. June 11, 1969.

Leaf No.		Before			After		
		Adults	Immature	Eggs	Adults	Immature	Eggs
1.	Upper Surface	12	12	21	13	16	37
	Lower Surface	16	9	43	12	13	45
2.	Upper Surface	13	23	41	22	10	36
	Lower Surface	14	15	36	11	15	43
3.	Upper Surface	7	12	3	18	2	5
	Lower Surface	40	20	53	15	12	57
4.	Upper Surface	17	14	58	17	15	44
	Lower Surface	21	9	34	4	6	45
5.	Upper Surface	13	58	14	11	31	8
	Lower Surface	10	15	16	7	26	22
Total Upper Surface		62	119	137	81	74	130
Total Lower Surface		101	68	182	49	72	212
Leaf Total		163	187	319	130	146	342

Percent Change: Adults -20.3%, Immature -21.9%, All Active Stages -21.1%, Eggs +7.2%.

Table 3. Comparison of European red mite populations on detached leaves before and after 12 hours of sprinkling. June 14, 1969.

Sprinkled Leaves

Leaf No.	Before Sprinkling				After Sprinkling			
	♀	♂	Immature	Eggs	♀	♂	Immature	Eggs
1.	6	11	33	26	7	3	8	35
2.[1]	14	7	15	43	0	0	0	62
3.[1]	21	3	26	111	1	0	2	129
4.	42	14	13	109	36	5	1	137
Total	83	35	87	289	44	8*	11**	363

Percent Change: Active Stages -69%, Eggs +26%

*Differences are significant at the 5% level.
**Differences are significant at the 1% level.

1) Leaves turned over.

Check Leaves

Leaf No.	Before				After			
	♀	♂	Immature	Eggs	♀	♂	Immature	Eggs
1.	13	8	38	143	23	10	20	146
2.	16	13	93	86	22	23	78	85
3.	16	13	59	98	20	6	48	114
4.	35	2	9	126	37	1	6	147
5.	13	4	63	121	15	8	70	115
Total	93	40	262	574	117	48	222	607

Percent Change: Active Stages -2%, Eggs +6%

Table 4. Comparison of European red mite populations on detached leaves before and after 12 hours of sprinkling. Sprinkled leaves. June 16, 1969.

Leaf No.		Before Sprinkling				After Sprinkling			
		♀	♂	Immature	Eggs	♀	♂	Immature	Eggs
1.	Upper Surface	25	6	2	-	0	0	0	-
	Lower Surface	5	4	3	-	14	2	8	-
2.	Upper Surface	31	0	0	210	0	0	0	315
	Lower Surface	16	1	0		26	0	1	
3.	Upper Surface	64	24	2	-	0	0	1	-
	Lower Surface	18	16	1		26	1	11	
4.	Upper Surface	30	0	0	223	0	0	0	236
	Lower Surface	24	0	1		24	0	1	
5.	Upper Surface	53	3	5	587	1	0	1	612
	Lower Surface	19	0	2		38	0	0	
Total Upper Surface		203	33	9		1***	0	2	
Total Lower Surface		82	21	7		128	3	21	
Leaf Total		285	54	16	1020	129*	3	23	1163

Percent Change: Active Stages -56%, Eggs +14%.

*Differences are significant at the 5% level.
***Differences are significant at the 0.1% level.

Table 5. Comparison of European red mite populations on detached leaves before and after 12 hours of sprinkling. Check leaves. June 16, 1969.

Leaf No.		Before			After		
		♀	♂	Immature	♀	♂	Immature
1.	Upper Surface	57	1	0	40	1	1
	Lower Surface	50	2	2	61	1	0
2.	Upper Surface	17	0	0	26	0	0
	Lower Surface	22	0	0	17	0	0
3.	Upper Surface	57	2	0	43	13	1
	Lower Surface	13	5	1	26	0	1
4.	Upper Surface	38	3	6	47	3	4
	Lower Surface	14	2	7	22	4	6
5.	Upper Surface	36	1	9	18	2	6
	Lower Surface	13	2	7	38	3	6
Total Upper Surface		205	7	15	174	19	11
Total Lower Surface		112	11	17	164	8	13
Leaf Total		317	18	32	338	27	24

Percent Change: Active Stages +6%.

b. Field Trials

European Red Mites

Five tests were conducted during late May to early August on trees heavily infested with European red mites. The experiments were designed to test whether overtree sprinkling could control high populations of European red mites and to determine if varying droplet size and duration of sprinklings would affect the degree of control obtained with each sprinkling.

The first 3 tests were conducted during a period when only the adult and egg stages of first generation mites were present on the trees. Test 4 was directed against the second generation larval stage. All stages of European red mites were present on the trees in test 5.

Acaricides were not applied to any of the test trees but a schedule of sprays was applied to control the codling moth except test 4 trees which were left unsprayed.

First Test - May 18, 1969

A single tree was sprinkled for a 4 hour period. Sprinklers were fitted with 7/32-inch nozzles and operated at 30 psi. Twenty-leaf samples were picked from short sections of 2 limbs prior to sprinkling and again immediately after sprinkling. The leaves were taken into the laboratory and the mites on them were hand-counted under a dissecting microscope. No checks were maintained because of the short duration of the experiment.

At the end of 4 hours of sprinkling, active stages of the European red mite had declined by 64% on the upper limb and 25% on the lower limb (Table 6). The total number of eggs remained the same on the upper limb but a 46% increase was noted on the lower limb.

Table 6. Numbers of European red mites per 20 leaves before and after 4 hours of overtree sprinkling. May 18, 1969.

	Upper Limb	
	Before Sprinkling	After Sprinkling
♀ upper leaf surface	64	10
♀ lower leaf surface	174	69
♂ upper leaf surface	2	0
♂ lower leaf surface	26	15
Q3 upper leaf surface	0	1
Q3 lower leaf surface	3	1
	269	96
Eggs upper leaf surface	56	14
Eggs lower leaf surface	985	977
	1041	991

	Lower Limb	
	Before Sprinkling	After Sprinkling
♀ upper leaf surface	41	36
♀ lower leaf surface	129	77
♂ upper leaf surface	2	2
♂ lower leaf surface	19	27
Q3 upper leaf surface	0	0
Q3 lower leaf surface	1	1
	192	143
Eggs upper leaf surface	131	162
Eggs lower leaf surface	612	923
	743	1085

Q3 = Quiescent deutonymphs

Second Test - May 20, 1969

A single apple tree was sprinkled for a 2½ hour period. In order to reduce variability due to sampling, 20 non-fruiting spurs on a single limb were marked with numbered thumbtacks. A single leaf was picked from each spur and taken into the laboratory where the mites and eggs were hand-counted under a dissecting microscope.

After sprinkling, when the foliage had dried, another 20 leaves were selected from the same spurs and taken into the laboratory for counting. Because of the short duration of the experiment, no checks were maintained.

There was a 33% reduction in numbers of active stages of the European red mite after 2½ hours of sprinkling (Table 7). There were much higher numbers of mites and eggs on the lower leaf surfaces than on upper leaf surfaces prior to sprinkling. Consequently 2½ hours of sprinkling did not provide very effective control. Although there were 35% fewer eggs on the leaves after sprinkling, this difference was probably due to variability between the leaves sampled before and after sprinkling. Sampling leaves from the same spurs did not solve the problem of sampling error due to variability in the distribution of mites.

Table 7 - Numbers of European red mites per 20 leaves before and after 2½ hours of overtree sprinkling. May 20, 1969

	Before Sprinkling	After Sprinkling
♀ upper leaf surface	25	6
♀ lower leaf surface	161	114
o upper leaf surface	1	2
o lower leaf surface	22	19
Total active stages	209	141
Eggs upper leaf surface	292	180
Eggs lower leaf surface	2228	1466
	2520	1646

Third Test - May 21, 1969

In order to further reduce the variability due to sampling error a third test was conducted using 2 test trees. Two limbs, one upper and one lower were sampled on each tree. Twenty non-fruiting spurs were marked on each limb with numbered thumbtacks with small ribbons attached for easier detection. In addition, a single leaf on each spur was marked by wrapping a thin piece of white marking tape around the petiole.

A visual count of adult female mites was made on each marked leaf prior to sprinkling. These leaves were left attached and mites on the same leaves were again visually counted after the trees were sprinkled. A comparable leaf was removed from the same spur to obtain counts of eggs and males as these stages are too small to observe without the aid of a hand-lens. The mite population consisted entirely of adult males and females from the overwintered generation, and first summer generation eggs.

Sprinklers were turned on at 6 p.m. and were to be left on until 6 a.m. A pump failure occurred during the night and it is not known exactly how much water was applied. The sprinkled trees were nearly dry at 6 a.m., indicating the sprinkler had been off at least an hour.

The results of this test were very similar to the results obtained in test #1. The control was better on the upper, more exposed limbs than on the lower, sheltered ones. The reduction of adult female mites on the upper limbs was 49% and 54% while reductions of 23% and 29% occurred on the lower limbs (Table 8). Male mites were not present in sufficient numbers to be meaningful. Numbers of eggs increased markedly during the 12 hour period averaging +23% for the four limbs.

Two check trees were sampled at the same time the sprinkled trees were sampled but leaves were selected randomly from small sections of marked limbs rather than from marked spurs. The number of female mites remained unchanged on two of the check limbs but a 17% reduction occurred on the third limb (Table 9). Too few mites were present on the fourth limb to give an accurate measure. Time did not permit the detailed marking of leaf spurs on the check trees.

The population of adult female mites declined rapidly as the start of the first summer generation approached so the experiment was not repeated.

Table 8. Number of European red mites before and after 12 hours of overtree sprinkling. Sprinkled trees. May 21, 1969.

Tree #1				Tree #2			
♀ Upper Limb		♀ Lower Limb		♀ Upper Limb		♀ Lower Limb	
Before	After	Before	After	Before	After	Before	After
2	0	10	9	2	0	13	13
9	4	2	2	9	2	9	6
3	1	6	4	2	1	5	8
5	3	7	6	0	0	1	0
5	0	2	3	0	0	19	17
26	10	8	5	1	0	2	0
4	1	7	7	1	0	8	6
3	4	5	2	4	2	11	0
9	6	5	4	0	0	5	7
2	0	2	1	4	3	7	7
5	6	7	3	6	5	11	8
2	0	6	5	5	4	28	30
1	1	7	3	12	6	28	22
0	0	5	5	1	0	15	9
16	10	8	8	2	0	22	18
7	2	7	2	1	0	40	22
2	4	8	2	0	0	3	1
6	3	6	5	3	2	15	11
1	0	6	5	0	0	12	11
120	61	117	83	54	25	274	212
Total Males		Total Males		Total Males		Total Males	
6	2	11	3	6	5	33	13
Total Eggs		Total Eggs		Total Eggs		Total Eggs	
994	1460	2170	2304	1410	1840	3804	5228

Table 9. Number of European red mites (1) before and after 12 hours of overtree sprinkling. Check trees. May 21, 1969.

Tree #1				Tree #2			
Upper Limb		Lower Limb		Upper Limb		Lower Limb	
Before	After	Before	After	Before	After	Before	After
9	6	90	88	55	60	125	104
Eggs		Eggs		Eggs		Eggs	
67	24	1096	1144	558	590	1512	1728

(1) Counts are totals from 20 leaves.

Fourth Test - June 6, 1969.

The purpose of this experiment was to determine if overtree sprinkling would control a high population of European red mites if applied when only immature stages of mites were present. The experiment was conducted in the dwarf apple orchard so that a large number of trees could be sampled and in order to test the effectiveness of overtree sprinkling on apple varieties other than Red Delicious. The test was also designed to test whether or not trees receiving greater amounts of water would have better mite control than trees receiving lesser amounts of water. Sample trees were chosen according to their proximity to the sprinklers. Some trees were wetted with water from four sprinklers, some from only two sprinklers, and others were wetted by only one sprinkler (Fig. 4). These trees are denoted as 4-X, 2-X, and 1-X respectively in (Table 10).

Beginning June 1, daily leaf samples were taken to determine the proportion of eggs hatched and the number of first generation adults still remaining on the foliage. These pre-treatment counts per 20-leaf samples are listed below.

Stage of Development	6/1	6/3	6/4	6/5
Adults	51	23	28	2
Larvae and Nymphs	20	136	372	272
Eggs	1752	2215	1023	760

Prior to sprinkling, 20 spurs on each sample tree were marked with thumbtacks as in the previous experiments. Leaves from the same spurs were then sampled before sprinkling and again immediately after. The trees were sprinkled from 6 a.m. until 6 p.m. on June 6. Check trees were also sampled the same time the sprinkled trees were sampled. Check trees were located in the same rows as sprinkled trees but were outside of the sprinkled area.

The results of this test were difficult to interpret because of the influence of predaceous phytoseiid mites on the population of European red mites. The population of European red mites declined rapidly in all the test trees whether sprinkled or non-sprinkled. There was no consistent correlation of percent control between sprinkled and check trees nor was there any correlation between percent control and numbers of phytoseiid mites in each treatment (Table 10).

A second sampling of check trees on June 9 showed a further decline in numbers of European red mites on 4 of the 6 check trees.

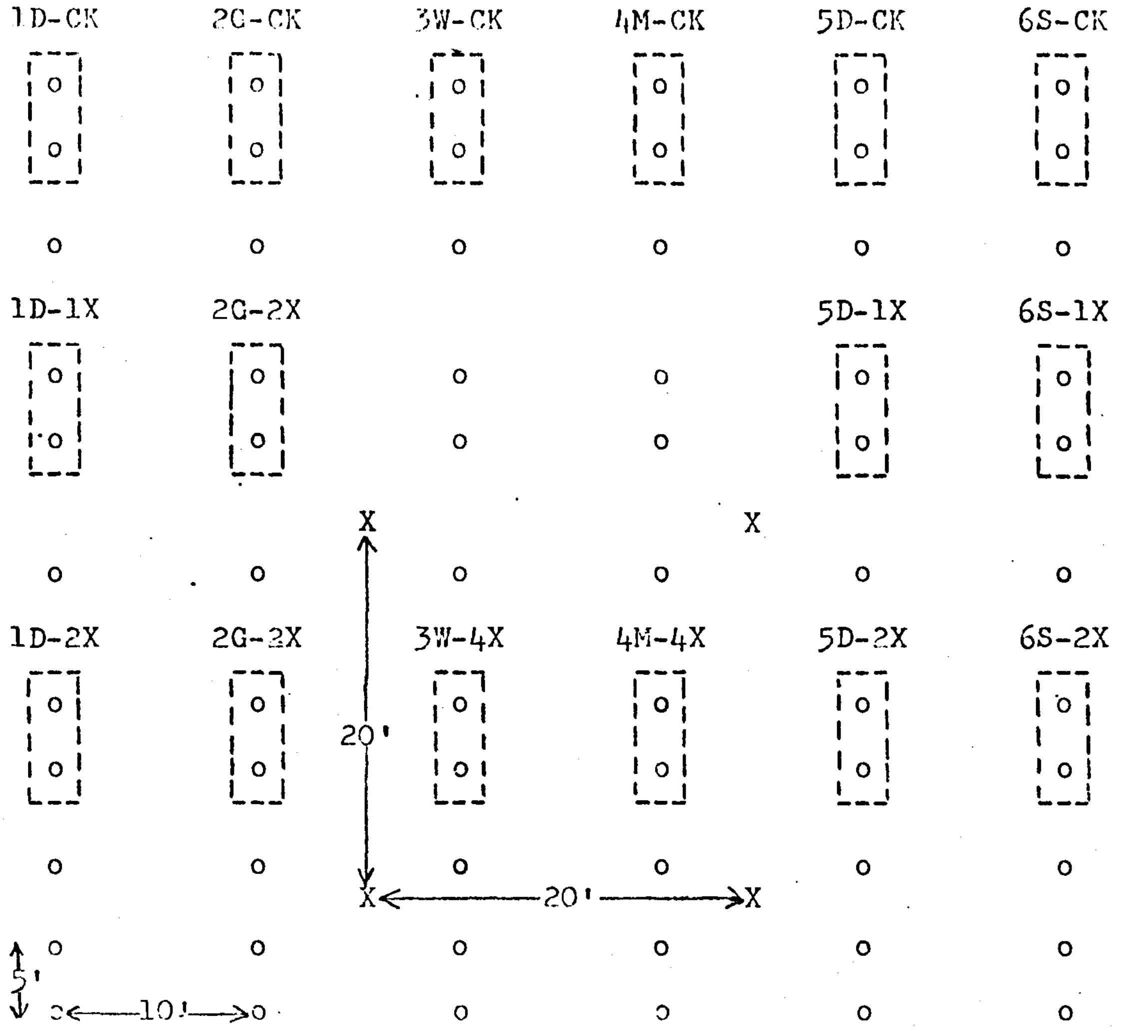
	1D-Ck	2G-Ck	3W-Ck	4M-Ck	5D-Ck	6S-Ck
Larvae and Nymphs per 20 leaves	96	274	124	166	122	78

The phytoseiid mites were identified by R.S. Downing and T.K. Moilliet, Summerland Research Station, as <u>Neoseiulus caudiglans</u> (Schuster) and <u>Typhlodromus pyri</u> Scheut. Both species are very efficient predators of the European red mite. The population of European red mites was nearly destroyed by them within 5 days.

The trees in the dwarf orchard also presented a problem in sampling. As they were grown primarily for entomological purposes they were not trained according to modern horticultural practice, the result being a very dense orchard with trees shaped like inverted pyramids with interlocking bases. Drops of water falling onto the trees were intercepted by the dense shoot growth in the tops. Spurs growing lower in the trees received only that water which filtered down through the trees and little, if any, direct spray from the sprinklers. The dwarf orchard was excluded from further experiments because of these problems.

Fig 4. Plot design for test #4. Dwarf apple orchard.

June 6, 1969



o=apple tree
X=sprinkler tripod

1D-1X Row 1, Delicious, tree wetted by one sprinkler.

Other varieties are: G = Golden Delicious
W = Winesap
M = McIntosh
S = Spartan

Table 10. Number of European red mites and phytoseiid mites on dwarf apple trees before and after 12 hours of overtree sprinkling. June 6, 1969.

	European Red Mites						Phytoseiid Mites			
	Adults		Larvae & Nymphs		Eggs		Active		Eggs	
Tree Number[1]	Before	After	Before	After	Before	After	Before	After	Before	After
1D-1X	4	0	354	246	872	550	30	26	26	18
1D-2X	2	4	404	234	1036	682	10	20	16	16
1D-CK	0	0	200	220	640	468	24	32	10	18
2G-1X	0	4	224	188	988	800	12	32	16	22
2G-2X	12	0	312	314	1364	1010	0	20	12	12
2G-CK	2	6	430	242	900	488	8	24	6	8
3W-4X	8	18	944	618	1994	1238	4	6	4	2
3W-CK	0	8	220	174	450	232	0	12	2	20
4M-4X	10	10	884	754	1406	1404	6	16	12	20
4M-CK	2	2	316	208	454	366	18	30	20	40
5D-1X	0	2	288	110	390	220	26	16	38	32
5D-2X	0	2	352	162	386	424	6	6	14	6
5D-CK	12	2	288	134	700	336	8	6	4	8
6S-1X	0	0	136	44	272	132	22	28	4	30
6S-2X	14	6	326	280	1302	856	16	18	4	12
6S-CK	6	0	152	62	474	146	30	40	18	32

[1] 1D-1X = Row 1, Delicious, tree wetted by one sprinkler.
Other varieties are: G = Golden Delicious
W = Winesap
M = McIntosh
S - Spartan

Fifth Test - July 7, 1969

This series of tests was conducted on a single, large apple tree to determine if varying the size of water droplets would effect the degree of control of European red mites by overtree sprinkling and whether intermittent sprinkling might provide better control than constant sprinkling. The test was designed not only to measure reductions in numbers of mites resulting from each sprinkling but also to compare population trends of the sprinkled and a non-sprinkled tree over a several week period.

Two, exposed upper limbs and two, sheltered lower limbs were marked and 20-leaf samples were taken prior to and after each sprinkling. A check tree, several rows away from the sprinkled tree, was also sampled during the experiments.

First Sprinkling - July 7, 1969

The tree was sprinkled overnight for a 12-hour period. Sprinklers were equipped with 1/8-inch jets and operated at 30 psi.

Second Sprinkling - July 8, 1969

The tree was sprinkled intermittently, one hour on and one hour off, over a ten-hour period. Jets were 1/8-inch operating at 30 psi.

Third Sprinkling - July 9, 1969

Inserted large, 7/32-inch jets and sprinkled for a 12-hour period.

Fourth and Fifth Sprinklings - July 21 and August 4, 1969

These were two, 24-hour sprinklings using 1/8-inch jets at 30 psi. Only two limbs, one upper and one lower, were sampled during these sprinklings.

Although there was a natural decline in the European red mite population during the latter part of the test period it was possible to measure reductions in mite numbers resulting from each sprinkling (Tables 11 to 14). Only in one case was there a decline in the mite population on the check tree during a sprinkling period (Tables 15 and 16). This, plus the fact that when sprinkling was discontinued for 12 days on July 9 the number of active mites on the sprinkled tree quickly climbed to a level higher than when the tests were begun, is further evidence that the decline was, in fact, caused by the sprinkling.

During the latter part of July, McDaniel spider mites became well established on the check tree and had reached 46 and 134 mites per leaf respectively on August 5. McDaniel spider mites numbered 1.2 and 6.4 respectively on the sprinkled tree on August 4. The last 24-hour sprinkling, reduced McDaniel spider mites to 0.5 and 1.1 mites per leaf. Sprinkling also reduced the number of eggs of the McDaniel spider mite.

In a single test, twelve hours of sprinkling with large 7/32-inch nozzles provided a greater degree of control than twelve hours of sprinkling with 1/8-inch nozzles or 10 hours of intermittent sprinkling with 1/8-inch nozzles.

The August 4 test was conducted during a windstorm which was accompanied by some rain. The greatest degree of control occurred during this sprinkling period. The wind undoubtedly blew many of the mites from the tree but the combination of wind plus sprinkling probably accounted for better control than either of these factors alone. The sprinkler water was carried nearly horizontally by high gusts of wind and both upper and lower surfaces of leaves were wetted.

The sprinkled tree retained fairly good foliage up to harvest time whereas the check tree and practically all other trees in the block suffered severe foliage injury from the feeding of mites. The block of trees received numerous sprays for codling moth control but were not sprayed for mites. No phytoseiids were observed in any of the leaf samples. The numerous codling moth sprays probably accounted for the complete absence of phytoseiids from the test trees. The absence of phytoseiids was good for experimental purposes because it eliminated at least one variable encountered in earlier tests. In a practical situation, however, the presence of phytoseiids would probably have enhanced mite control considerably.

About 60 inches of water was applied during the 30-day test period or twice the annual water requirement of the trees. The soil was very well drained, however, and no adverse effects were noted in the sprinkled area.

Summary of Field Trials for Control of European Red Mites

1. Large numbers of European red mites were washed from the foliage each sprinkling but repeated sprinkling gave only temporary control of a high mite population.
2. Control of adult stages of the European red mite was greater on upper leaf surfaces than lower leaf surfaces.
3. Adult European red mites emigrated to the lower leaf surface when the sprinklers were turned on and returned to the upper leaf surface as soon as sprinklers were turned off.
4. Control was better on upper, exposed limbs than on lower, sheltered ones.
5. European red mite eggs were not washed from the leaves.
6. Adult female mites continued to oviposit during sprinkling periods.
7. Overtree sprinkling could not be evaluated as a control for European red mites where predaceous phytoseiid mites were also a controlling factor.
8. Both active and egg stages of the McDaniel spider mite were washed from leaves during sprinkling.
9. Populations of the McDaniel spider mite remained below injurious levels when large amounts of water was applied before populations developed.

Table 11. Effect of droplet size and duration of overtree sprinkling on populations of European red mites and McDaniel spider mites. Sprinkled tree. Upper limb-north. Number of mites per 20 leaves.

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	3360	2675	0	0
*	12 hour sprinkling - 1/8" nozzle at 30 psi.			
7/8/69	3030	1688	0	0
*	10 hours of intermittent sprinkling 1 hour on - 1 hour off 1/8" nozzles.			
7/8/69	3160	1080	0	0
*	12 hour sprinkling 7/32" nozzle at 30 psi.			
7/9/69	2360	384	0	0
7/21/69	3390	2695	0	0
*	24 hours sprinkling 1/8" nozzle at 30 psi.			
7/22/69	3110	1710	0	5
8/4/69	398	433	127	80
*	24 hour sprinkling 1/8" nozzle at 30 psi.			
8/5/69	333	171	20	22

* = sprinkling period

Table 12 - Effect of droplet size and duration of overtree sprinkling on populations of European red mites and McDaniel spider mites. Sprinkled tree. Upper limb-south. Number of mites per 20 leaves.

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	3220	2370	0	0
*	12 hour sprinkling 1/8" nozzle at 30 psi.			
7/8/69	2940	1556	0	0
*	10 hours intermittent sprinkling, 1 hour on--1 hour off 1/8" nozzles.			
7/8/69	3290	982	0	0
*	12 hour sprinkling with 7/32" nozzle.			
7/9/69	4050	532	0	0
7/21/69 *	- -	- -	- -	- -
7/22/69	- -	- -	- -	- -
8/4/69 *	- -	- -	- -	- -
8/5/69	- -	- -	- -	- -

* = sprinkling period.

Table 13 - Effect of droplet size and duration of overtree sprinkling on populations of European red mites and McDaniel spider mites. Sprinkled tree. Lower limb-south. Number of mites per 20 leaves.

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	5640	3320	- -	- -
*	12 hour sprinkling 1/8" nozzle at 30 psi.			
7/8/69	4930	2290	- -	- -
*	10 hours of intermittent sprinkling 1/8" nozzle.			
7/8/69	8720	1537	- -	- -
*	12 hours sprinkling 7/32" nozzle.			
7/9/69	3140	886	- -	- -
7/21/69	4100	3595	0	0
*	24 hour sprinkling 1/8" nozzle.			
7/22/69	3960	3180	0	0
8/4/69	377	329	33	24
*	24 hours sprinkling 1/8" nozzle.			
8/5/69	271	124	16	10

* = sprinkling period.

Table 14 - Effect of droplets size and duration of overtree sprinkling on populations of European red mites and McDaniel spider mites. Sprinkled tree. Lower limb-north. Number of mites per 20 leaves.

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	3520	2120	--	--
*	12 hour sprinkling 1/8" nozzle at 30 psi.			
7/8/69	4190	1852	--	--
*	10 hours of intermittent sprinkling 1/8" nozzle.			
7/8/69	6210	1234	--	--
*	12 hour sprinkling 7/32" nozzle.			
7/9/69	Plates deteriorated before counts could be completed.			
7/21/69 *	--	--	--	--
7/22/69	--	--	--	--
9/4/69 *	--	--	--	--
8/5/69	--	--	--	--

* = sprinkling period.

Table 15 - Effect of droplet size and duration of overtree sprinkling on populations of European red mites and McDaniel spider mites. Check tree. Number of mites per 20 leaves.

Upper Limb - North

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	2950	2815	0	0
7/8/69	3380	3515	0	0
7/9/69	1885	2055	0	0
7/21/69	1115	1590	345	665
7/22/69	880	1550	370	425
8/5/69	265	140	3850	2690

Upper Limb - South

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	2910	3065	- -	- -
7/8/69	2400	2595	- -	- -
7/9/69	1985	3545	- -	- -
7/21/69	- -	- -	- -	- -
7/22/69	- -	- -	- -	- -
8/5/69	- -	- -	- -	- -

Table 16 - Effect of droplet size and duration of overtree sprinkling on population of European red mites and McDaniel spider mites. Check tree. Number of mites per 20 leaves.

Lower Limb - South

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	5140	2585	--	--
7/8/69	5480	2710	--	--
7/9/69	4120	2020	--	--
7/21/69	4100	3595	--	--
7/22/69	2665	2705	145	155
8/5/69	615	454	1960	923

Lower Limb- North

	European Red Mite		McDaniel Spider Mite	
Date	Eggs	Active	Eggs	Active
7/7/69	3760	1856	--	--
7/8/69	3530	2075	--	--
7/9/69	Plate deteriorated before counting could be completed.			
7/22/69	--	--	--	--
8/4/69	--	--	--	--
8/5/69	--	--	--	--

c. Detached Leaf Experiments - McDaniel Spider Mites

These tests were conducted to determine how effective overtree sprinkling is in controlling McDaniel spider mites on upper and lower leaf surfaces. The leaves were collected and prepared using the same methods outlined for detached leaf experiments with the European red mite.

First Test - June 23, 1969

Five leaves were sprinkled for a period of 12 hours beginning at 9:30 p.m. until 9:30 a.m. the next day. Only active stages of mites were counted as the egg population was too high to obtain an accurate count.

Although 12 hours of sprinkling removed virtually 100% of the active mites from the upper leaf surfaces, active mites increased 20% on the more densely populated lower leaf surfaces, leaving a net reduction of 16% for the 5 leaves (Table 17).

The number of mites increased 27% on the 5 check leaves during the 12 hour period. Many more larvae were present on the second count, probably enough to explain the marked increase in numbers of mites. Since the number of mites on the lower surfaces of check leaves increased 37%, the 20% increase on the lower surface of sprinkled leaves was probably due to egg hatch rather than to emigration of mites from the upper to the lower leaf surface.

Table 17 - Comparison of McDaniel spider mite populations on detached leaves before and after 12 hours of sprinkling. June 23, 1969.

Sprinkled Leaves

Leaf No.	Before Sprinkling	After Sprinkling	
1. Upper surface	16	0	
Lower surface	100	123	
2. Upper surface	168	6	
Lower surface	181	205	
3. Upper surface	32	0	
Lower surface	59	80	
4. Upper surface	35	0	
Lower surface	81	111	
5. Upper surface	48	0	
Lower surface	243	280	
Total upper leaf surface	299	6	(-98%)
Total lower leaf surface	664	799	(+20%)
Leaf Total	963	805	(-16%)

Check Leaves

Leaf No.	Before Sprinkling	After Sprinkling	
1. Upper surface	72	84	
Lower surface	119	149	
2. Upper surface	17	23	
Lower surface	79	124	
3. Upper surface	135	134	
Lower surface	147	245	
4. Upper surface	99	127	
Lower surface	130	178	
5. Upper surface	77	73	
Lower surface	160	176	
Total upper surface	400	441	(+10%)
Total lower surface	635	872	(+37%)
Leaf total	1035	1313	(+27%)

Second Test - August 21, 1969

Five shoots were removed from a Delicious apple tree 4 days prior to the test and prepared as illustrated in figure 2. The 5 leaves were artifically infested with McDaniel spider mites by pinning sections of infested leaves to them and leaving them in this manner for 4 days.

As mite counts were completed on each leaf, it was subjected to sprinkling as described in the previous experiments. At the end of 2 hours, each leaf vial was removed from the rack, taken into the laboratory and counted, then placed back on the rack for the remainder of the 24 hour sprinkling. No check leaves were maintained because of the short duration of the test and the time required to count the mites.

Two hours of sprinkling removed 95% of the active stages and 90% of the eggs from the upper surfaces of the leaves (Table 18). At the end of 24 hours, 100% of the active stages and 99% of the eggs were removed from the upper leaf surfaces.

Active stages increased 3% at the end of 2 hours on lower leaf surfaces but at the end of the 24 hour sprinkling had decreased 28%.

Eggs on the lower leaf surfaces were not removed to any degree. Eggs increased markedly on one leaf, remained the same on one leaf, and dropped on the other 3 for a total average reduction of 13%.

Check leaves would have been of value to establish the trend in egg-laying on non-sprinkled leaves. Although sprinkling resulted in an average reduction of 52%, leaves not subjected to sprinkling may well have increased in numbers of eggs by 50% during the 24 hour period. The average reduction of active stages plus eggs during the 24 sprinkling was 54%.

Table 18 - Comparison of McDaniel spider mite populations on detached leaves before and after 2 hours and 24 hours of sprinkling. August 21, 1969.

Leaf No.	Start		2 Hours		24 Hours	
	Eggs	Active	Eggs	Active	Eggs	Active
1. Upper surface	52	15	5	1	0	0
Lower surface	64	25	67	24	84	16
2. Upper surface	17	13	0	1	0	0
Lower surface	17	19	14	16	16	15
3. Upper surface	11	4	1	0	1	0
Lower surface	54	33	60	35	37	27
4. Upper surface	46	21	5	0	0	0
Lower surface	54	26	53	28	30	16
5. Upper surface	75	14	1	1	0	0
Lower surface	32	12	34	16	25	9
Total upper leaf surface	201**	67*	12	3	1**	0*
Total lower leaf surface	221	115	228	119	192	83
Leaf total	422*	182*	240	122	193*	83*

* = Differences are significant at 5% level.

** = Differences are significant at 1% level.

d. Field Trials - McDaniel Spider Mites

The first series of field trials was started July 9, 1969. A mite population was stimulated in a block of 13-year-old Delicious apple trees by a spray of DDT 50-W, 6 lbs/acre applied on May 20, and two applications of Guthion 50-W, 1.25 lbs/acre on June 1 and 0.675 lbs/acre on July 7.

The test was designed to measure any difference in mite control that may occur from light, medium, and heavy rates of water application. Reductions in numbers of mites resulting from each sprinkling was measured by sampling the trees just prior to sprinkling and again immediately after each sprinkling. I had intended to observe the effects of repeated sprinklings on the population development of McDaniel spider mites over a period of a month or more. But the test was terminated after 12 days because of predator interference and rapidly declining mite populations.

The test consisted of three single-tree treatments and three check trees. Four sprinkling tripods were placed around each treated tree. The spacing of the sprinklers was 20 x 20 feet, the same as the tree spacing. Twenty leaf samples were taken from two marked limbs on each tree.

Treatment #1 Medium rate - 1/8-inch nozzles 30 psi - 24 hr. sprinkling
Treatment #2 Light rate - 3/32-inch nozzles - 50 psi - 31 hr. sprinkling
Treatment #3 Heavy rate - 7/32-inch nozzles - 20 psi - 10 hr. sprinkling

By varying pressure and nozzle size the average size of water droplets changes appreciably. The 3/32-inch nozzle at 50 psi produces a very fine mist, while a 7/32-inch nozzle at 20 psi produces very large droplets. The 1/8-inch nozzle falls between these two extremes. The total amount of water applied (14 inches each application) was kept constant by varying the duration of sprinkling for each treatment.

The population density of McDaniel spider mites ranged from 50 to 250 mites per leaf on July 9. Peak populations developed on all test trees by July 26 and then began to decline rapidly. The decline was due to lack of food resulting from the extensive foliage injury and the development of high populations of predaceous phytoseiid mites.

It was difficult to assess the control from single sprinklings because of the uncertain influence of the phytoseiid mites on the rate of decline of the McDaniel spider mites.

Treatment #1 - Active stages of McDaniel spider mites declined 76.3% during the 24-hour sprinkling on July 21 (Table 19). Numbers of mites on the check tree declined 26.8% during the same period. Although phytoseiids were present in about the same numbers on each tree, there were four times the number of McDaniel spider mites on the check tree as the sprinkled tree. The rate of decline of McDaniel spider mites on the check tree would be much less than on the sprinkled tree because of the poorer predator-prey relationship. Consequently I could not determine what degree of control resulted from the sprinkling because of these variables.

Treatment #2 - Active stages of McDaniel spider mites declined 30.0% during the sprinkling period on July 23 (Table 20). Numbers of mites declined 27.0% on the check trees during the same period. The initial population density of McDaniel spider mites was nearly the same on the sprinkled trees and check trees but there were twice the number of phytoseiids on the check tree. The decline in numbers of mites on the treated tree must have been influenced to some degree by the sprinkling for one would normally expect a much more rapid decline to occur on trees with higher numbers of phytoseiid mites. This did not occur during this experiment. As in treatment #1, I could not ascertain to what degree sprinkling controlled the mites because of the uncertain influence of phytoseiids on the rate of decline of McDaniel spider mites.

Treatment #3 - A more favorable situation developed in this set of trees that permitted measurements of mite control during two sprinkling periods. Phytoseiids were absent from the sprinkled tree at the beginning of the test, and McDaniel spider mites increased during the first 11 days of the experiment (Table 21). Active stages of McDaniel spider mites decline 19.9% during a 10-hour sprinkling on July 15. Mites on the check tree remained unchanged (+2.7%) during the same period. A 10-hour sprinkling on July 29 resulted in a reduction of 23.6% on the sprinkled tree. Numbers of mites on the check tree increased 11.4% during the 12-hour period. Phytoseiids began to develop on the sprinkled tree during the latter part of July but a cyclic predator-prey response occurred a few days earlier on the check tree than on the sprinkled tree. It was likely not caused by the sprinklings but it was due to the higher predator-prey ratio that existed on the check tree at the beginning of the experiment.

This series of tests was terminated July 30 because phytoseiids had nearly destroyed the population of McDaniel spider mites and foliage injury was too severe to support another mite infestation.

Because of the interference of phytoseiids, I could not show any differences in control between the three treatments.

Sprinkling apparently did not adversely affect the phytoseiids for they increased as rapidly on sprinkled as on non-sprinkled trees.

At high population densities, the rapid rate of increase of McDaniel spider mites nearly masks the control afforded by sprinkling. This suggests that sprinkling to control mites must begin when populations are low.

The foliage on sprinkled trees looked less damaged, even on trees that

Table 19 - The effect of medium-size sprinkler droplets on populations of McDaniel spider mites and phytoseiid mites.[1,2]

Sprinkled Tree #1

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/9/69	#1	2436	1076	52	52
	#2	2012	908	56	64
24-hour sprinklings					
7/21/69	#1	563	914	66	48
	#2	430	1350	70	120
24-hour sprinkling					
7/22/69	#1	143	200	33	57
	#2	215	337	47	67

Check Tree #1

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/9/69	#1	4350	1710	10	5
	#2	1935	1265	5	25
7/21/69	#1	1746	5033	113	73
	#2	1000	3355	105	30
7/22/69	#1	690	3435	87	90
	#2	965	2715	215	45

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1. Sprinklers were fitted with 1/8-inch nozzles and operated at 30 psi for 24 hour durations.

2. Numbers recorded are mites per 20 leaf samples.

Table 20 - The effect of small sprinkler droplets on populations of McDaniel spider mites and phytoseiid mites.[1,2].

Sprinkled Tree #2

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/11/69	#1	9060	3235	6.7	10
	#2	5610	2510	5.0	17.5
31-hour sprinkling					
7/23/69	#1	4610	6960	50	50
	#2	2140	4385	40	35
31-hour sprinkling					
7/24/69	#1	3160	4445	70	20
	#2	2565	3495	70	115

Check Tree #2

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/11/69	#1	6940	2275	5.0	0
	#2	7520	2755	5.0	5.0
7/23/69	#1	1473	4836	28	82
	#2	550	5610	55	70
7/24/69	#1	705	3305	85	115
	#2	590	4325	110	90

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1. Sprinklers were fitted with 3/32-inch nozzles and operated at 50 psi for 31 hour durations.

2. Numbers recorded are mites per 20 leaf samples.

Table 21 - The effect of large sprinkler droplets on populations of McDaniel spider mites and phytoseiid mites.[1,2].

Sprinkled Tree #3

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/15/69	#1	9100	3040	0	0
	#2	6800	4140	0	0
Sprinkled 10 hours					
7/15/69	#1	6200	2505	0	0
	#2	6940	3250	0	0
7/26/69	#1	1548	4675	45	70
	#2	1455	4900	10	20
Sprinkled 10 hours					
7/29/69	#1	440	2715	60	38
	#2	1305	2950	60	55
Sprinkled 10 hours					
7/30/69	#1	1215	2025	95	85
	#2	905	2305	30	20

Check Tree #3

		McDaniel Spider Mites		Phytoseiid Mites	
Date	Limb No.	Eggs	Active	Eggs	Active
7/15/69	#1	4380	3605	35	20
	#2	3750	4935	0	15
7/15/69	#1	4060	4205	10	15
	#2	4020	4570	0	5
7/26/69	#1	1625	5305	110	80
	#2	235	2300	165	85
7/29/69	#1	110	1675	90	115
	#2	27	667	53	107
7/30/69	#1	360	2075	75	115
	#2	10	535	65	125

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1. Sprinklers were fitted with 7/32-inch nozzles and operated at 20 psi for 10 hour durations.
2. Numbers recorded are mites per 20 leaf samples.

A second series of experiments for McDaniel spider mite control was started July 31, 1969. Two pairs of Delicious apple trees were selected that had low populations of McDaniel spider mites and little, if any visible leaf injury. Each two-tree plot was sprinkled with 6 overtree sprinklers at 10 day intervals until 4 irrigations had been completed.

Treatment #1 was the standard sprinkling rate. Sprinklers were fitted with 1/8-inch jets, giving a rate of application, at 30 psi and a 20 by 40 ft. spacing, of 0.3 inches per hour or 7.2 inches during a 24 hour sprinkling period.

Treatment #2 was the high rate of application, 7/32-inch jets were used to give an application rate of 0.70 inches per hour. A 10 hour sprinkling period applied 7 inches of water, or nearly the same amount of water as in Treatment #1.

Two limbs on each of the two trees were sampled just before each sprinkling and again just after. Two limbs on each of the 4 check trees were also sampled. The check trees were located just a row or two beyond the throw of the sprinklers. Check tree 1-B was occasionally wetted when there was a breeze blowing from the west.

All the sprinkled and check trees were sprayed with 2 pounds of Ethion 25WP and 1½ pounds of Sevin 80S per 150 gallons of water on August 1. The purpose of the Sevin spray was to eliminate the phytoseiids and thus permit the McDaniel spider mites to increase unrestricted. The Ethion was applied to control European red mites, or more exactly, to reduce them to a low level so there would be no competition with McDaniel spider mites. On August 22, a second application of Sevin 80S at 1½ pounds per 100 gallons, was made to assure complete elimination of phytoseiids.

The first set of trees was sprinkled on August 5 and every 10 days thereafter until the experiment was terminated on September 12. Although the experiment was set up primarily to measure the control over a five-week period, mites were counted before and after each sprinkling in order to measure the control from single sprinklings.

Out of a total of 32 individual tests (4 sprinklings and 8 samples per sprinkling), there were reductions in numbers of mites in 25 or, in other words, results were positive 78% of the time. Of the seven negative tests, five involved very low mite populations, mostly 1 to 2 mites per leaf. Results were more consistent as numbers of mites increased.

The percent control of active forms of McDaniel spider mites varied greatly with each sprinkling and extreme variation in control occurred between limbs on the same tree. There was no significant difference in control between the standard rate of sprinkling and the high rate when the data were subjected to a t-test to paired data. When analyzing the rates of increase over the 5 week period, mites in treatment #1 increased 1.04 times (Fig 5) while the average increase for treatment #2 was only 0.40 times (Fig 6). Whether or not this difference is fully attributable to the high rate of water application is not certain. Treatment #2 trees carried higher numbers of European red mites than did treatment #1 trees. In fact, there were higher numbers of European red mites than McDaniel spider mites in treatment #2 throughout the 5 week period. Competition between the two species may partially account for the difference between treatments. But comparable numbers of European red mites on the check trees did not prevent McDaniel spider mites from reaching very high levels.

Sprinkling also removed large numbers of eggs of the McDaniel spider mites.

Here again, the results were variable in individual tests. Positive results were obtained in 22 of 32 samplings, or 69% of the time. The fact that eggs <u>are</u> removed by sprinkling must account for the greater degree of control sprinkling has on McDaniel spider mites than European red mites. Although active forms of European red mites were reduced in number each time the trees were sprinkled, the effects were only very temporary. The rate of increase over the 5 week period did not differ materially from the check trees. The rate of increase of McDaniel spider mites over the 5 week period was much higher on the check trees than on the sprinkled trees. Treatment #1 checks increased 17.2 times over the pre-treatment counts while treatment #2 checks increased 11.3 times. The sprinkled trees increased 1.04 and 0.40 times respectively during the same period.

Extensive foliage injury could be observed on the #2 check trees by the end of the experiment. Little, if any, visible foliage injury occurred on the sprinkled trees.

Fig. 5 Comparison of average numbers of mites per leaf on 2 apple trees irrigated with overtree sprinklers and 2 trees irrigated with conventional undertree sprinklers. Standard rate of application.

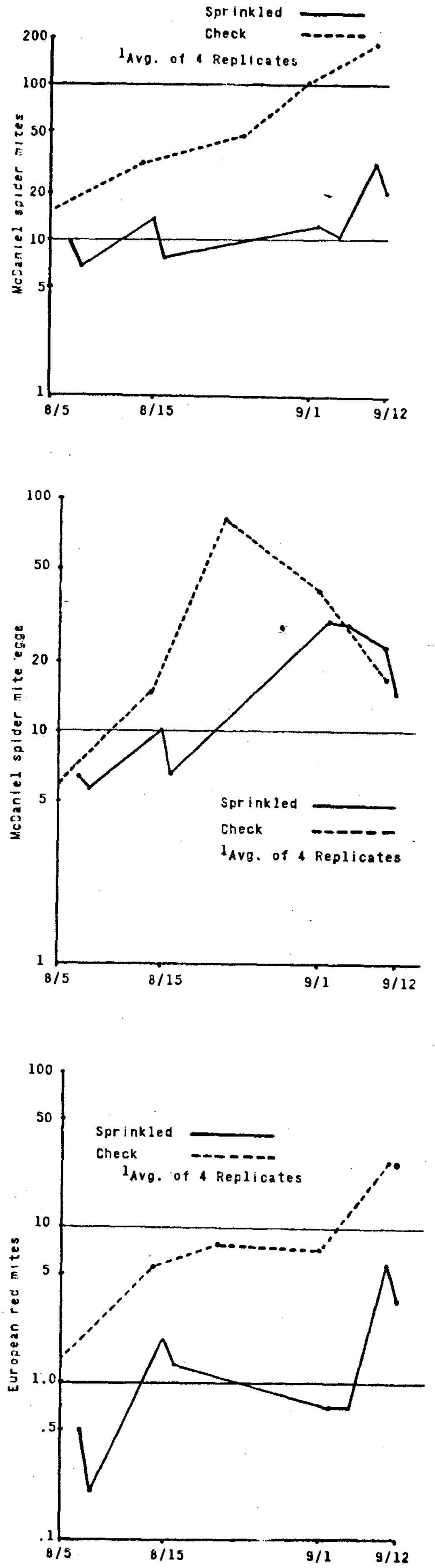
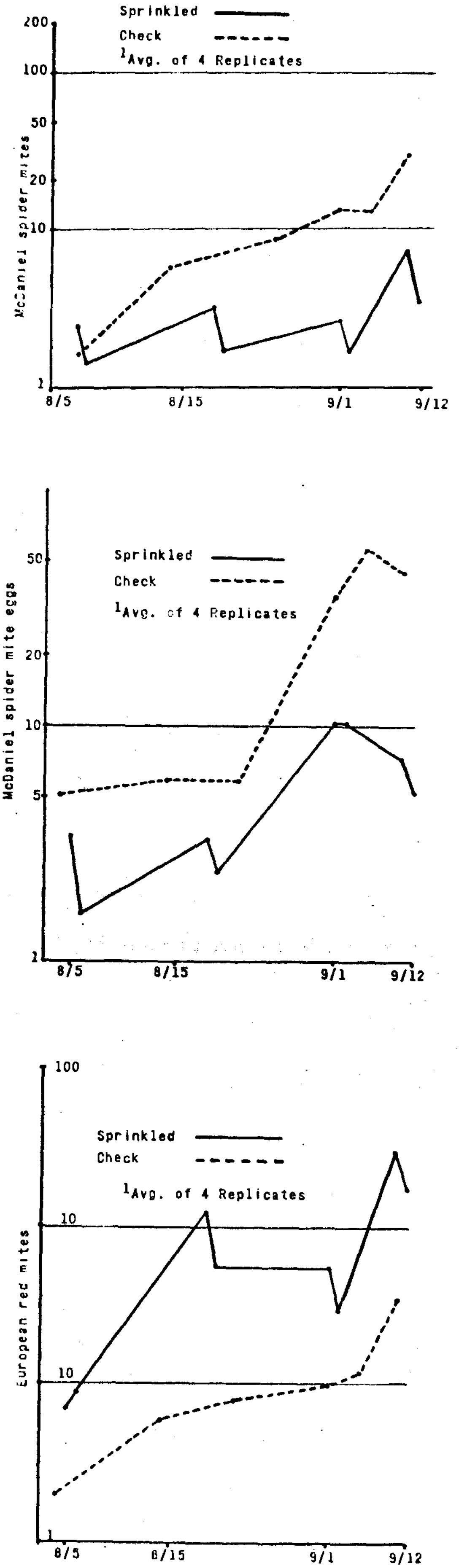


Fig. 6 Comparison of average numbers of mites per leaf on 2 apple trees irrigated with overtree sprinklers and 2 trees irrigated with conventional undertree sprinklers. High rate of application.



e. Commercial Orchard Trials

Mite populations were compared in overtree and undertree sprinkled blocks in 3 commercial apple orchards during 1968 and 1969. One orchard was sampled for mites in 1968 at Yakima, Washington. During 1969 two orchards were sampled; one at Summerland, B.C. and the second orchard near Naramata, B.C. All three orchards had overtree sprinkler systems installed on a portion of the orchard and conventional undertree sprinklers installed on the remaining portion.

The purpose of these trials was to find out to what degree overtree sprinklers controlled mites under actual orchard conditions by comparing mite populations in overtree sprinkled and undertree sprinkled blocks.

Fifty leaf samples, 10 leaves from each of 5 trees, were picked from spurs on marked limbs. The orchards were sampled every 2 weeks beginning June 1 and continuing until September 9. During 1968, weekly samples were taken after July 1. Each leaf sample was kept in an ice cream carton and refrigerated, then brushed and counted using the method described by Henderson and McBurnie (1943).

Allan Brothers Orchard - Yakima, Washington

This orchard was a block of 22 year old Red Delicious apples planted 28 feet by 28 feet. One half of the orchard was irrigated with overtree sprinklers spaced 56 feet by 56 feet. The sprinkler heads were Rainbird 30 fitted with a 1/8-inch front jet and a 3/32-inch rear jet. Sprinkler heads were mounted on 14 foot-high risers. Each sprinkler was operated at 50 psi and delivered 5.15 gpm. The orchard received 9 irrigations beginning about June 1. The duration of each irrigation was 12 hours or 24 hours depending on the soil moisture and weather conditions. Twelve-hour irrigations applied 1.92 inches of water and 24 hour irrigations applied 3.84 inches of water.

The undertree sprinkled block was irrigated with portable low-level sprinklers and received the same number of irrigations and approximately the same amount of water as the overtree sprinkled block. Cultural practices and spray programs were the same in both blocks.

Spray Program

Dormant spray	March 22	Volk oil + Ethion	7½ gal./acre
First cover	May 31	Diazinon 25 wp.	8 lbs/acre
Second cover	June 30	Diazinon 25 wp.	8 lbs/acre

The McDaniel spider mite population peaked at 1.6 mites per leaf on July 8 (Fig. 7) in the overtree sprinkled block and then remained less than 1 mite per leaf the rest of the season. Although the McDaniel spider mite population in the undertree block was comparable to that in the overtree block on June 1, the mites in the undertree sprinkled block reached an average of 35.0 mites per leaf on July 29. There was visible leaf injury on many of the trees in the undertree sprinkled block but predaceous phytoseiid mites prevented the McDaniel spider mites from increasing during August and September.

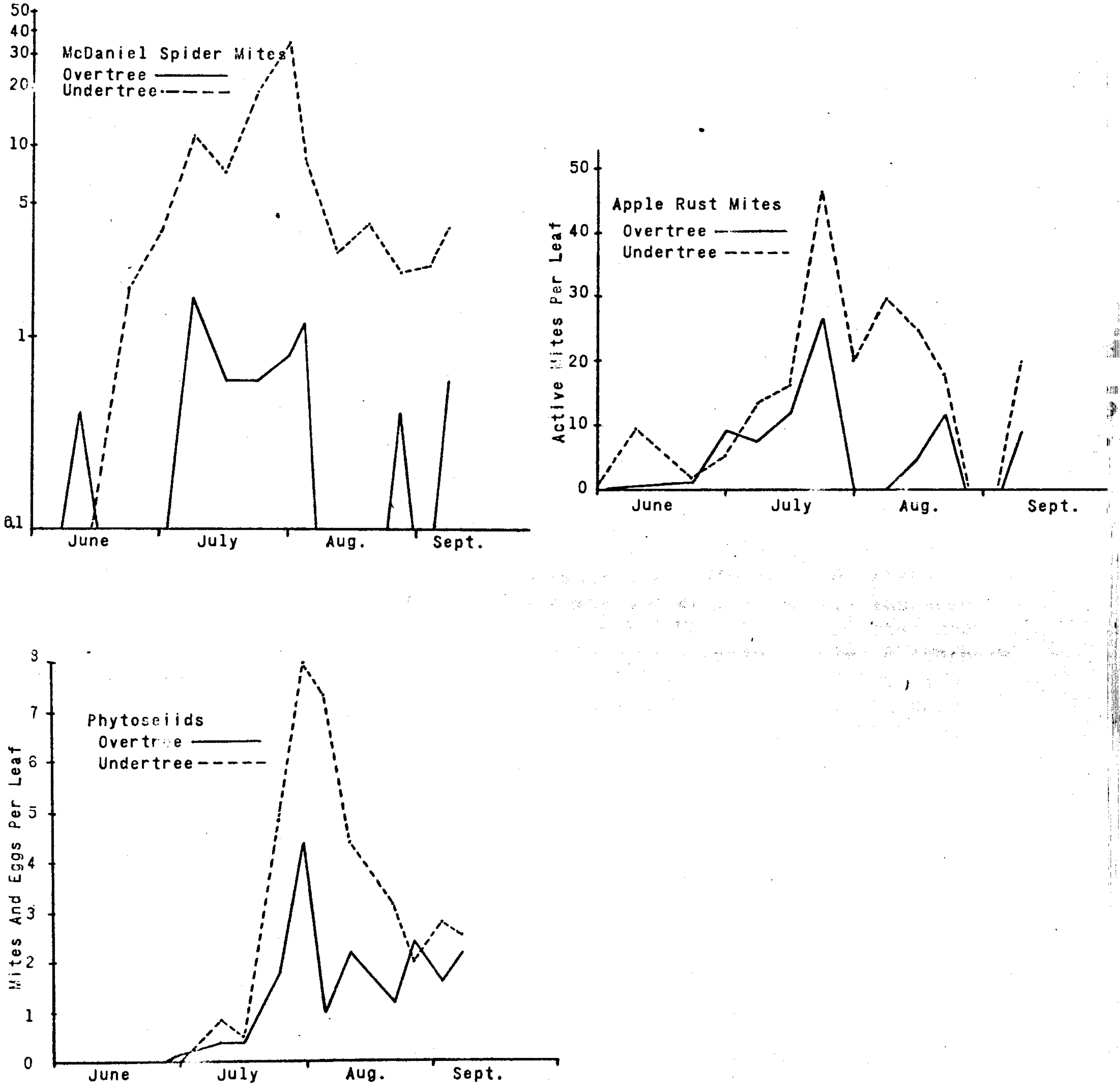
Apple rust mites also reached higher numbers in the undertree sprinkled block. But their numbers were also reduced in August and September by phytoseiid mites. No acaricides were applied during the season in either the overtree or undertree sprinkled blocks.

The average number of mites per leaf from 14 samplings was as follows:

	Overtree Block	Undertree Block
McDaniel spider mite	0.4	7.3
Apple rust mite	5.6	14.7
T. occidentalis	1.3	2.6

European red mites did not appear in the overtree sprinkled block and made only a brief appearance in the undertree sprinkled block.

Fig. 7 Allan Bros. Orchard. Average numbers of mites per leaf on Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers.



Nettleton Orchard - Naramata

This plot consisted of 65 trees of varying age which have been overtree sprinkled for the past 20 years. Sprinklers were spaced 60 x 60 feet on a diagonal pattern with risers up through the centers of the older, larger trees. Sprinklers were the large, impact-type, Rainbird 40 with a 5/32-inch and a 3/16-inch nozzle. Dole, 8 gpm flow regulators were installed under each sprinkler. The sprinklers were on 24 foot risers which jetted the water well above the tops of the largest trees.

Five large old Delicious trees and five smaller trees (about 10 year olds), were sampled from this block and similar trees were sampled in an adjoining apple block which was sprinkled with an undertree, portable sprinkler system.

Both the sprinkled and non-sprinkled trees received the same spray program and cultural practices were the same in each block.

Spray Program

Dormant spray	April 16	Dormant oil + Ethion	8 gal/acre
Pink spray	May 6	Guthion 50% WP	1¼ lbs/acre
First cover	May 28	Guthion 50% WP	1¼ lbs/acre
Second cover	June 19	Guthion 50% + Omite	1¼, 4 lbs/acre
Third cover	July 16	Ethion 25% WP	4 lbs/acre
Fourth cover	Aug. 5	Ethion 25% WP	4 lbs/acre
Fifth cover	Aug. 14	Ethion 25% WP	4 lbs/acre

European red mites reached injurious levels in both blocks and an intensive chemical control program was required to prevent economic damage from occurring. Although the overtree sprinkled block did not need the August 5 and August 14 sprays, it was, nevertheless, sprayed along with the rest of the orchard to assure consistency. Poor timing of chemical sprays and poor coverage probably accounted for the ineffectiveness of the chemical control program.

Active stages of European red mites reached a peak on July 14 in the overtree sprinkled block of 31.4 mites per leaf in the old trees (Fig. 8) and 14.0 mites per leaf in the young trees (Fig. 9). In the undertree block, European red mites peaked on July 28 with 64 and 178 mites per leaf, respectively.

The initial infestation on June 1 was the same in both blocks of large trees (0.6 actives per leaf) but was somewhat higher initially in the smaller trees of the undertree block than the ones in the overtree sprinkled block. (0 actives and 2 eggs in overtree - 0.7 actives and 17 eggs in the undertree block.)

The average numbers of European red mites per leaf from 8 samplings was as follows:

	Overtree Block	Undertree Block
Large trees	7.3	20.3
Small trees	4.9	35.3

Apple rust mites reached higher levels in the undertree sprinkled block and the seasonal average was much higher than in the overtree block.

Rust mites peaked at 175 and 247 per leaf in the overtree block and 442 and 528 mites per leaf respectively in the undertree block.

The average number of rust mites per leaf during the season was as follows:

	Overtree Block	Undertree Block
Large trees	93	280
Small trees	96	312

McDaniel spider mites made only a brief appearance reaching a level of only 0.5 mites per leaf on a single count.

Phytoseiid mites were present in relatively large numbers throughout the season in both blocks which probably accounts for the lack of McDaniel spider mite infestation.

Although phytoseiids were present in large numbers in both blocks, they did not feed on European red mites to any extent until fairly late in the season.

Foliage injury was moderate to severe in all trees in the undertree sprinkled block while only one tree showed visible leaf injury in the overtree sprinkled block.

Fig. 8 Nettleton Orchard. Average numbers of mites per leaf on large Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers.

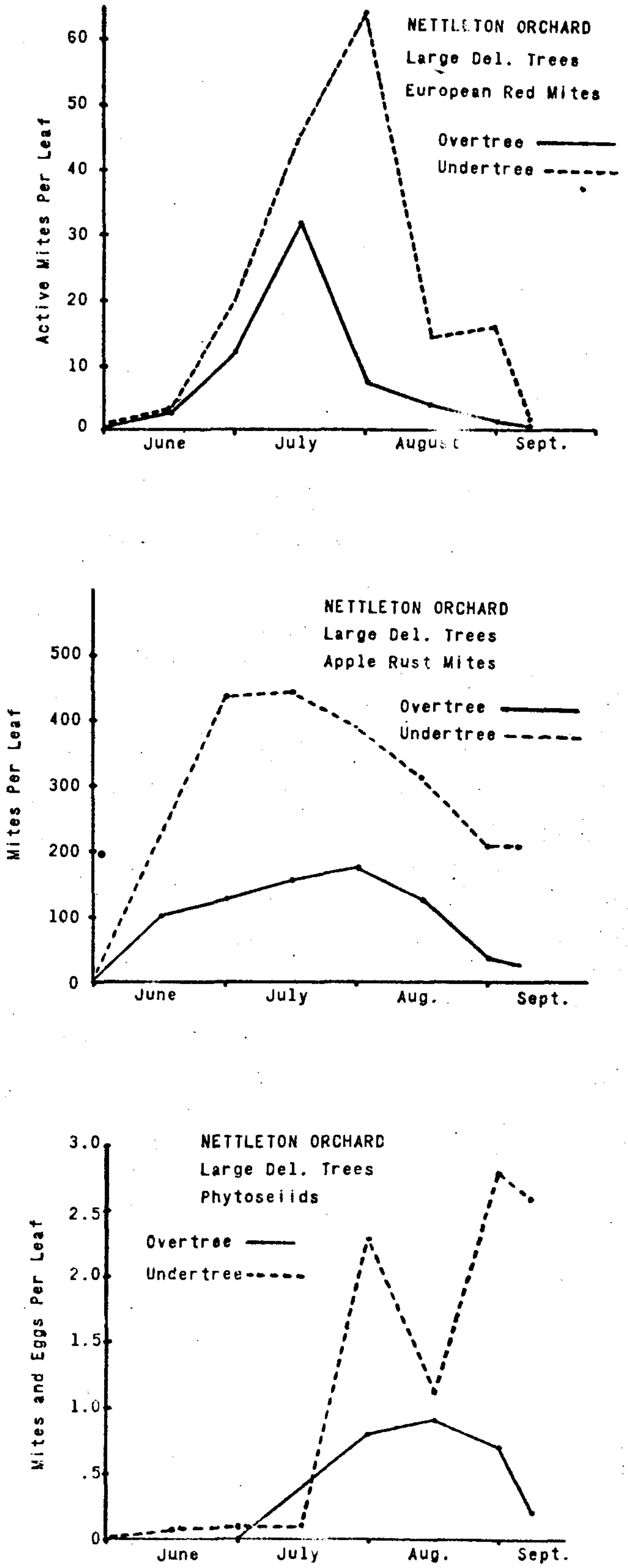
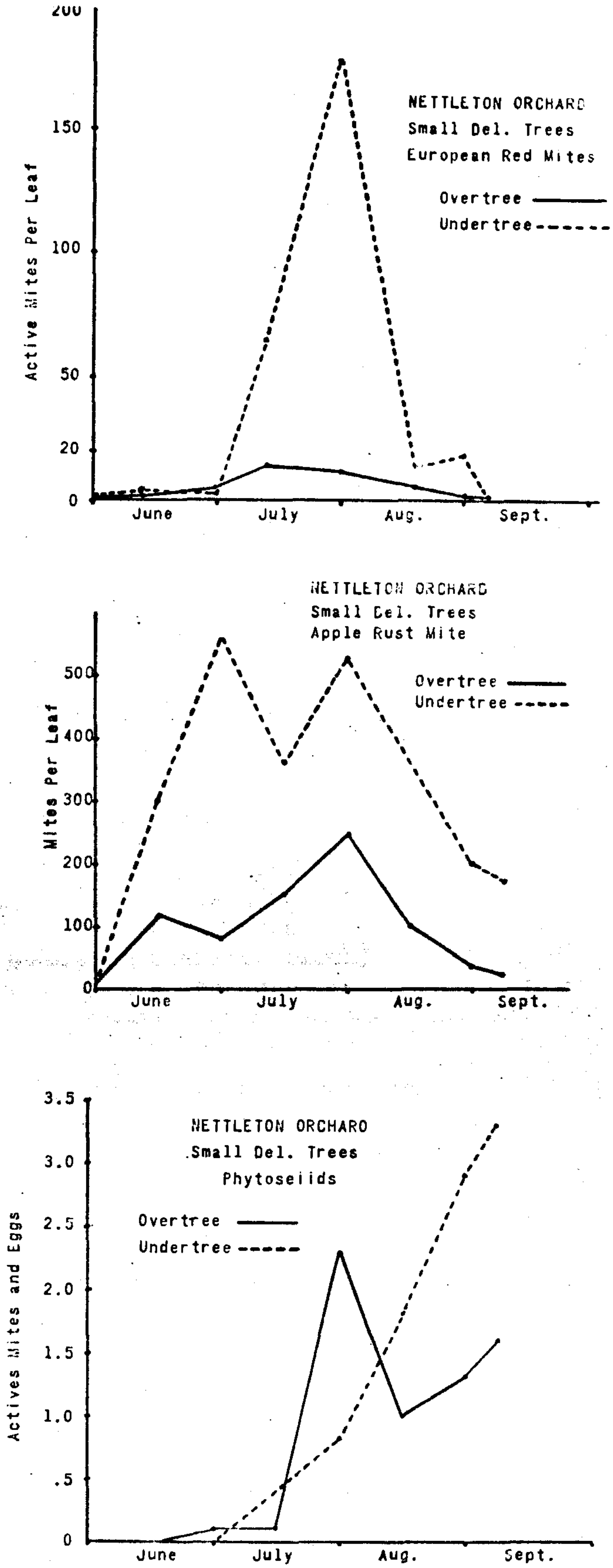


Fig. 9 Nettleton Orchard. Average numbers of mites per leaf on small Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers.



Croft Orchard - Summerland

Permanent overtree sprinklers were installed in early 1969 in 10 acres of a $15\frac{1}{2}$ acre apple orchard. The remainder was irrigated with a conventional undertree portable sprinkler system. Trees were 10 to 12 year old Red Delicious and Spartan planted $7\frac{1}{2}$ x 15 feet with sprinklers spaced 45 x $52\frac{1}{2}$ feet. Single nozzle Buckner model 860 sprinklers were used on 10 foot risers. Single 5/32-inch nozzles operating at 40 psi delivered 5 gpm from each sprinkler. Each sprinkling was 12 hours duration and the interval between irrigation was 6 days.

Five Red Delicious trees and five Spartan trees were sampled in each block. A total of eight, 50-leaf samples were taken from each block beginning June 1 and ending September 8. The spray program was identical in each block and other orchard practices were the same.

Spray Program

Dormant spray	dormant oil	8 gal/acre
First cover	Imidan 50% WP	4 lbs/acre
Second cover	Imidan 50% WP	4 lbs/acre
	(+ Thiodan 4 lbs/acre on overtree block)	
Third cover July 15	Omite 50% WP	4 lbs/acre
	(except overtree Spartans)	

A single application of Omite was made to the orchard on July 15 to control European red mites. McDaniel spider mites made only a brief appearance, reaching 10 mites per leaf in the undertree sprinkled Delicious trees on July 14 but had nearly disappeared 2 weeks later.

European red mites peaked at 16.2 mites per leaf on the overtree irrigated Delicious (Fig. 10) and 3.0 mites per leaf on the Spartans (Fig. 11).

In the undertree sprinkled block, European red mites peaked at 20 mites per leaf on Delicious and 11.3 on Spartans.

The average number of European red mites per leaf from 8 samplings is listed below:

	Overtree Irrigated	Undertree Irrigated
Delicious	4.5	5.7
Spartan	1.5	2.3

Apple rust mites also remained at a lower population level throughout most of the season in the overtree irrigated block than in the undertree irrigated block.

Seasonal Average of Apple Rust Mites Per Leaf

	Overtree Irrigated	Undertree Irrigated
Delicious	105	155
Spartan	97	132

The differences in mite population were not great, but numbers of mites were consistently higher in the undertree sprinkled block. Had Omite not been applied and the mites permitted to go through a natural cycle, the difference would likely have been enhanced.

There was very little visible leaf injury from mites in either block. Leaf hoppers caused extensive damage, however, particularly to Delicious during first generation. Second generation leaf hoppers caused considerable injury throughout the orchard.

Fig. 10 Croft Orchard. Average numbers of mites per leaf on Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers.

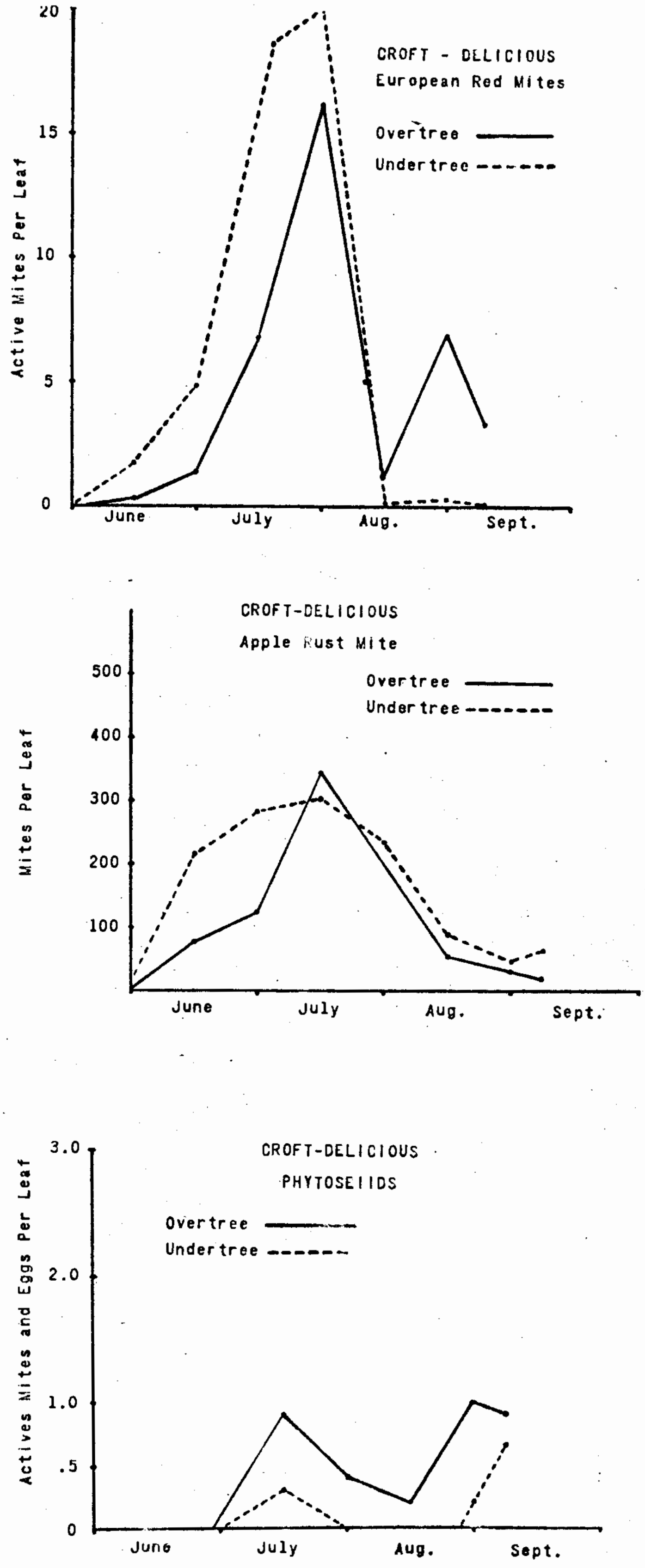
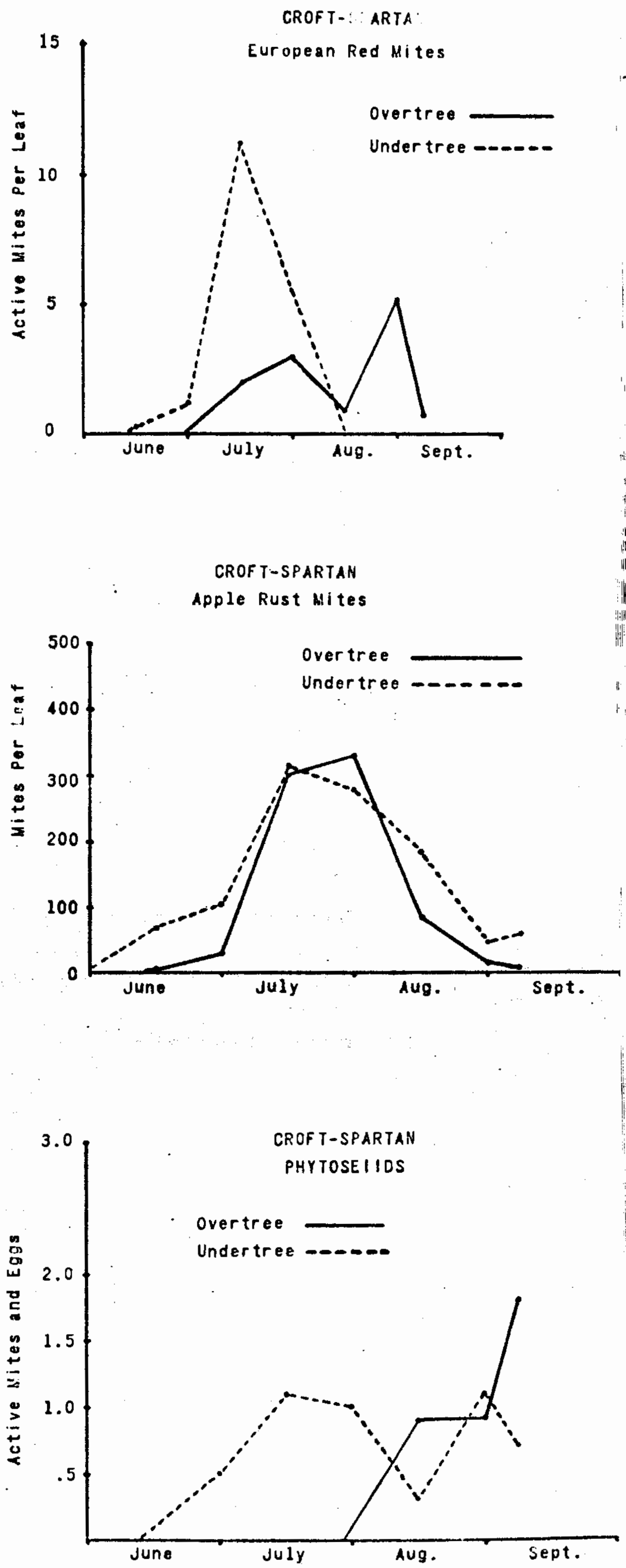


Fig. 11 Croft Orchard. Average numbers of mites per leaf on Spartan apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinkler



The commercial orchard trials demonstrated that overtree sprinkling systems, when used in a normal irrigation schedule, can effectively reduce the population density of phytophagous mites.

Sprinkling prevented the McDaniel spider mite from reaching injurious levels but did not prevent the European red mite nor the apple rust mite from reaching damaging numbers. Although sprinkling did not control the latter two species, population densities of these mites did not reach the levels attained in the undertree sprinkled blocks.

The population densities of phytoseiid mites responded to changes in prey numbers. Consequently these were higher numbers of phytoseiids in the undertree sprinkled trees than in trees that were irrigated with overtree sprinklers.

5. Discussion and Conclusions

I have shown that the most damaging orchard mite, the McDaniel spider mite can be controlled by the application of water through an overtree irrigation system. Furthermore, tests show that sprinkling suppresses the development of populations of European red mites and apple rust mites but does not directly affect phytoseiid mites that prey on orchard mites.

Although initial tests did not always show positive results, as work progressed and more experience gained in the use of suitable plot design and sampling techniques, results become more consistent and the data more meaningful.

The problem of testing overtree sprinklers for mite control is difficult in that the physical control of mites from a single sprinkling period is comparatively small, with maximum reductions ranging from 40 to 60 percent. The common techniques employed by researchers, such as those used to evaluate acaricides, are considered by most authorities to be, at the most, 75 percent accurate (Morgan, personal communication). This presents no problem when testing acaricides because the differences between treated and untreated material are much greater, usually 80 to 100 percent. When one attempts to show differences of 50 percent or less and the biological variation is 25 percent, experimental design and sampling techniques become very critical.

In the early season, uneven distribution of mites is a primary cause of variation between samples. Variation in distribution of mites occurs between trees, between branches of the same tree, and between leaves on the same spur on the same branch of a tree.

Fluctuations in population density are another cause of variability since there is no stable population of mites. These fluctuations are the result of many factors, including completion of generations, dispersal, predation, and diapause. Huffaker et al (1969) reviews the problems in sampling and studying mite populations.

Experiments using detached leaves greatly reduced the problem of variability due to sampling error. Some basic information was obtained with this method which provided a basis for further experimentation. These tests showed that control of the active stages of European red mites and McDaniel spider mites on trees would probably not exceed 60 percent from each sprinkling. Immature stages of European red mites were more easily washed from leaves than adults, which suggested that sprinkling might be most effective if done when only immature mites were present. Adult European red mites migrated to the lower surface of leaves where they were more protected from sprinkler water.

Adult McDaniel spider mites did not show this response to sprinkling.

Nearly all McDaniel spider mite eggs were washed off the upper leaf surface after only a short period of sprinkling. But European red mite eggs were not washed from leaves, even after 24 hours of continuous sprinkling. These differences, observed on detached leaves, probably account for the different responses of these two mite species in the larger scale field trials.

Generally, the results obtained from sprinkling and sampling entire trees were the same as in the detached leaf experiments but results from entire trees were much more difficult to interpret because of the extreme variability encountered in orchards.

Variability due to sampling error was reduced by marking individual spurs and always resampling from the same spurs. The method was time-consuming and was not suitable for long-term experiments because the spurs were denuded of uniform-sized leaves after the second or third sampling. Even detailed marking of spurs did not eliminate variability. The May 20 experiment is an example. European red mite eggs showed a 35% reduction on the sprinkled tree in a 2½ hour period. Since it was shown earlier that eggs were not washed from the leaves by sprinkling, and the eggs were not yet hatching, the reduction can only be accounted for by sample variability.

Variability was greatly reduced in the May 21 experiment with European red mites. The population consisted entirely of adults which developed from overwintered eggs. The females were easily seen with the naked eye and were counted without removing the leaves from the tree. After sprinkling, the remaining mites were again counted on the same leaves. The error in visual counting was probably less than 10% which is greater accuracy than with the brushing method. The method was very time-consuming and there are only a few days each year when only the adult stages of European red mites are present on the trees.

In later experiments, sample variability was kept to an acceptable level by carefully selecting and marking small sections of branches for sampling. The marked sections were only large enough to provide the required number of uniform-sized spur leaves for the duration of a test period.

Variability was less of a problem late in the season. The distribution of mites was then quite uniform between leaves in the same area of the trees and results during August and early September were consequently more consistent.

Predation by phytoseiid mites also made it difficult to interpret the results. In the June 6 test with European red mites, it was impossible to separate the influence of sprinkling and the influence of phytoseiids on the rapidly declining population of European red mites. The same situation occurred in the July 9 experiment with McDaniel spider mites. Although sprays had been applied earlier to rid the trees of phytoseiids in the latter test, they soon recovered and eventually destroyed the population of McDaniel spider mites. Phytoseiids had evidently acquired a high degree of resistance to standard rates of DDT and Guthion in the test orchard. Two sprays of Sevin 80S at 1½ lbs. per 100 gallons of water, applied 3 weeks apart, completely destroyed a population of phytoseiids and prevented their resurgence during the series of tests from August 1 to September 12. The best results were obtained from the latter experiment.

The important fact brought out in tests where phytoseiids were present was that overtree sprinkling did not retard their development. Furthermore, sprinkling did not reduce their effectiveness as predators. The population density of phytoseiids is highly dependent on the abundance of suitable prey. Whether an orchard is overtree sprinkled or not seems of little importance. The fact that phytoseiids are found primarily on the lower surface of leaves apparently favored their survival.

Apple rust mites survived overtree sprinkling in large numbers in both of the commercial orchards sampled in 1969. The abundance of rust mites in the Nettleton orchard, which has been overtree irrigated for the past 20 years, would indicate that apple rust mites will continue to be an important food source for phytoseiid mites in these orchards.

One unanswered question, and one that warrants further research is whether the European red mite will become a more serious problem in orchards that are overtree irrigated. Although individual sprinklings gave fairly good control of active stages of European red mites, the eggs were not affected and egg laying was not retarded. The rate of increase of European red mites did not differ from non-sprinkled trees in the July 31 to September 12 test. Although the two commercial orchards had fewer European red mites in the sprinkled blocks than in non-sprinkled blocks both required summer chemical control measures. The situation may be similar to that which now exists in orchards under integrated mite control programs. When populations of McDaniel spider mites are destroyed by T. occidentalis, European red mites become the dominant species and, unless pre-bloom sprays are applied, populations will reach damaging levels (Hoyt, 1969b). Timing of overtree irrigations to intercept the larvae and protonymph stages of the first summer generation may provide substantially better control since only active mites are present at that time. As the period from hatching of winter eggs to the deposition of the first summer eggs is critical for a population to develop a decimation of the first generation would curtail the potential development of European red mites much more effectively than would be the case in a later generation. Further research is needed in this area.

Of the species studied, the greatest effect from overtree sprinkling was on McDaniel spider mites. Although populations of McDaniel spider mites did not develop in the two commercial orchards in 1969, good results were obtained in test plots in which populations were artificially stimulated.

The July 31 to September 12 test showed that McDaniel spider mites can be kept below injurious levels over a 6 week period by irrigating in a normal manner with overtree sprinklers. The population increased only 40% and 104% in the sprinkled treatments while 11-fold and 17-fold increases were measured on check trees during the same period. It was not demonstrated that a high rate of water application provided better control than the standard rate. Further research should be done in this area. Since the terminal velocity of raindrops increases with drop diameter (Table 22) the impact with the leaf surface would be greater for large droplets than small droplets. The same would be true for sprinkler droplets.

Table 22 - Terminal Velocity of Raindrops in Still Air

Diameter	Rate of fall		Type of drop
u	ft/min	m/sec	
5,000	1,750	8.9	Large raindrop
1,000	790	4.0	Small raindrop
500	555	2.8	Fine rain or large drizzle
200	300	1.5	Drizzle

from Petterssen (1941)

Whether overtree sprinkling can prevent McDaniel spider mites from reaching injurious levels during an entire season is uncertain. It is unlikely that overtree sprinkling, unassisted by phytoseiids, is effective enough during periods of high summer temperatures to prevent McDaniel spider mites from reaching economic injury levels. The presence or absence of phytoseiids is probably far more important in regulating populations of McDaniel spider mites than are overtree sprinklers. Fortunately the two complement one another. Overtree sprinklers would probably enhance biological control of McDaniel spider mites by phytoseiid mites in sound integrated programs.

The main limitations of overtree sprinkling as a physical control agent is that mites on the lower surface of leaves are not greatly affected. The lower leaf surfaces remain dry even after prolonged irrigation. It has already been mentioned that European red mites crawl to the lower surface of leaves in response to moisture. Infestations of all three phytophagous species begin on the lower leaf surface. Only when the population density increases do they move to the upper leaf surface.

C.V.G. Morgan of the Summerland Research Center has studied the seasonal distribution of mites on apple trees for the past several years. Included in the data he has collected to date is the seasonal distribution of mites on upper and lower leaf surfaces. Morgan's data for 1968 may be briefly summarized as follows:

The seasonal distribution of McDaniel spider mites on Delicious apple leaves, though wide variations occurred, was largely on the lower leaf surface. A high percentage of the leaves were infested on the lower surface with no mites at all on the upper surface. Conversely, few leaves had mites on the upper surface and no mites on the lower surface. A large number of leaves had damaging numbers of mites on the lower leaf surface and no mites on the upper surface. My observations in 1969 agree with Morgan's conclusions. The absence of McDaniel spider mites from upper leaf surfaces, even at high population densities, was very striking. This does not agree with observations I have made of the distribution of McDaniel spider mites at Yakima where a much larger proportion of the mites inhabit upper leaf surfaces. There was also a noticeable lack of webbing on infested leaves at Summerland compared to the Yakima strain. These differences are probably due to inherent difference between the mites in the two areas and not to a seasonal peculiarity.

European red mites were fairly equally distributed on upper and lower leaf surfaces except at low populations where many leaves had mites only on the lower surface. Apple rust mites were also nearly equally distributed on upper and lower leaf surfaces except at low population densities.

Phytoseiids were found almost entirely on the lower leaf surface, even at high population densities. But Hoyt (personal communication) found that the distribution of phytoseiids on leaf surfaces changes according to the time of day that the sampling is done. A greater proportion of phytoseiids were found on the upper leaf surface in the early morning and evening than at mid-day.

The implications of these studies of mite distribution are apparent. When mites occur predominantely on lower leaf surfaces, control with overtree sprinklers will be less effective than when mites inhabit the upper leaf surface. Hoyt's recent finding on the diurnal changes in the distribution of phytoseiids implies that daytime sprinkling might have a less adverse effect on phytoseiids than nighttime sprinkling since fewer of the predators would be washed from the foliage during the day.

The injection of surface-active agents into the sprinkler system should also be investigated as a means of enhancing mite control. Reducing the surface-tension of the water could result in more rapid and uniform wetting of foliage and cause mites to become immobilized and unable to escape the water droplets or even prevent them from grasping the leaf surface. The addition of surface-active agents may also cause the water to creep and to wet the under surface of leaves, possibly further enhancing control.

The advantages of using overtree sprinkling for mite control on apples far outweigh the disadvantages. The method is economical and safe for the operator and can reduce the need for pesticide applications. The fear that some workers expressed in the early literature that overtree sprinkling might cause an environment favorable for the spread of disease has, so far, not materialized. Growers who have installed overtree irrigation systems report less incidence of apple powdery mildew, Podosphaera leucotricha. Sprinkling evidently prevents secondary infections by washing the air-borne spores from the foliage.

The incidence of apple scab, *Venturia inaequalis*, has not increased in orchards in the Southern Okanagan as a result of overtree sprinkling (Lopatecki, 1969), but fire blight, *Erwinia amylovora*, has been observed. Although fire blight does little damage on apples in British Columbia, foreign trade could be affected as these markets assume apples shipped from British Columbia to be free of this disease organism.

Williams (1961) and Pielou *et al*. (1962) showed that residual deposits of the insecticides Guthion and Sevin are rapidly removed from apple foliage when the trees are irrigated with overtree sprinklers. These results indicate that, when overtree sprinklers are used, irrigation should be delayed as long as possible after spraying.

The problems associated with overtree irrigation have, thus far, been minor ones. But horticulturists, entomologists and pathologists should keep a watchful eye for problems that may ultimately develop.

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7. APPENDIX

Table 1 - Average number of mites per leaf on an apple tree irrigated 4 times with overtree sprinklers. Standard rate.[1]

Tree 1 - A North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/7/69	0.6	0.2	1.8	0.8	0	0
* 8/8/69	0.1	0.1	0.8	0.[illegible]	0	0
8/15/69	0.1	0	0.9	1.1	0	0.1
* 8/16/69	0.1	0.1	0.9	1.6	0	0.2
9/2/69	0	0	2.1	0.6	0	0
* 24 hour delay in resample because of rain						
9/4/69	0.2	0.2	3.2	0.3	0	0
9/11/69	0.1	0.7	3.4	1.0	0	0
* 9/12/69	0	0.4	2.1	2.9	0	0

Tree 1 - A South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/7/69	2.2	0.3	2.4	4.4	0.1	0
* 8/8/69	2.5	0.3	3.0	1.3	0	0
8/15/69	0	1.8	3.5	8.2	0	0.1
* 8/16/69	0.1	1.2	0.8	2.9	0	0
9/2/69	2.4	0.3	7.1	2.3	0	0
* 24 hour delay						
9/4/69	8.0	0.6	9.4	1.6	0	0
9/11/69	10.3	11.1	10.3	5.7	0	0
* 9/12/69	3.2	5.2	4.1	7.5	0	0

[1] = 0.3 inches per hour

* = sprinkling period

Table 2 - Average number of mites per leaf on an apple tree irrigated 4 times with overtree sprinklers. Standard rate.[1]

Tree 1 - B North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/7/69	3.5	0.8	6.1	13.8	0	0
*						
8/8/69	1.7	0.2	2.9	10.3	0	0.1
8/15/69	0.4	2.7	12.5	22.7	0	0
*						
8/16/69	0.2	0.5	8.7	8.8	0	0.1
9/2/69	9.8	1.3	47.1	24.8	0	0
*	24 hour delay					
9/4/69	20.1	0.95	39.0	16.5	0	0
9/11/69	6.4	4.0	32.2	61.8	0	0
*						
9/12/69	4.9	3.8	17.3	35.3	0	0

Tree 1 - B South Side

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/7/69	8.0	0.8	15.1	19.9	0.1	0.1
*						
8/8/69	9.3	0.1	15.7	14.0	0.1	0
8/15/69	0.1	3.1	23.7	22.6	0.1	0.1
*						
8/16/69	0.3	3.5	15.9	18.2	0	0
9/2/69	17.3	1.1	63.0	21.0	0	0
*	24 hour delay					
9/4/69	13.5	0.84	64.0	23.4	0	0
9/11/69	5.6	7.4	46.0	56.2	0	0
*						
9/12/69	2.9	4.0	32.7	34.3	0	0

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[1] = 0.3 inches per hour

* = sprinkling period

Table 3 - Average number of mites per leaf on an apple tree irrigated 4 times with overtree sprinkler. High rate.[1]

Tree 2 - A North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	11.6	0.4	2.9	2.4	0	0
*						
8/6/69	11.0	0.6	2.1	1.3	0	0
8/18/69	2.9	7.1	1.9	3.2	0	0
*						
8/19/69	2.5	6.0	0.8	0.6	0	0
9/1/69	25.9	3.5	8.7	2.6	0	0
*						
9/2/69	31.9	1.7	3.4	0.6	0	0
9/12/69	5.1	22.6	3.9	3.0	0	0
* 6 hours only						
9/12/69	7.4	16.0	8.4	4.8	0	0

Tree 2 - A South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	11.9	0.8	3.9	3.4	0.3	0
*						
8/6/69	6.1	0.2	1.4	0.7	0	0
8/18/69	3.0	11.2	2.3	2.1	0.1	0
*						
8/19/69	3.9	5.1	0.4	0.6	0.1	0.1
9/1/69	20.8	0.8	4.5	1.2	0	0
*						
9/2/69	25.1	1.9	10.9	1.0	0	0
9/12/69	7.5	23.6	4.1	1.4	0	0
*						
9/12/69	10.0	15.3	1.2	0.4	0	0

[1] = 0.7 inches per hour

* = sprinkling period

Table 4 - Average number of mites per leaf on an apple tree irrigated 4 times with overtree sprinklers. High rate.[1]

Tree 2 - B North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	13.9	1.1	2.1	1.3	0	0
*						
8/6/69	10.1	1.1	1.5	1.8	0	0
8/18/69	2.1	18.6	3.6	3.4	0	0
*						
8/19/69	2.6	6.1	1.3	2.7	0	0
9/1/69	54.6	12.7	9.5	1.8	0	0
*						
9/2/69	39.5	4.3	9.7	1.7	0	0
9/12/69	12.0	52.5	5.4	6.6	0	0
*						
9/12/69	6.7	22.0	3.3	3.7	0	0

Tree 2 - B South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	11.1	0.5	2.2	2.8	0	0
*						
8/6/69	11.4	1.5	1.5	1.7	0.1	0
8/18/69	5.7	12.1	5.3	4.2	0.2	0
*						
8/19/69	6.3	5.1	7.1	2.9	0	0.1
9/1/69	31.2	5.4	18.6	5.3	0	0
*						
9/2/69	25.2	4.2	17.1	3.4	0	0
9/12/69	5.7	20.5	15.5	19.0	0	0
*						
9/12/69	7.6	17.2	8.4	5.0	0	0

1. = 0.7 inches per hour
* = sprinkling period

Table 5 - Average number of mites per leaf on an apple tree irrigated 4 times with conventional, undertree sprinklers. Check Tree.

Tree 1 - A North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/4/69	2.5	0	3.6	1.6	0.2	0.1
8/14/69	0	0.6	3.7	3.7	0	0.2
8/21/69	0.7	0.7	8.2	7.5	0	0.1
9/1/69	6.2	1.6	49.0	18.5	0	0
9/4/69	4.4	1.2	62.9	17.9	0	0
9/11/69	4.6	3.9	74.0	68.5	0	0

Tree 1 - A South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/4/69	2.1	0.8	7.1	2.2	0	0.1
8/14/69	1.2	1.6	11.8	14.4	0.1	0
8/21/69	2.7	1.5	10.5	14.5	0.2	0.2
9/1/69	17.1	1.4	61.4	19.4	0	0
9/4/69	5.0	2.7	98.0	19.2	0	0
9/11/69	5.7	6.7	62.0	35.0	0	0

Table 6 - Average numbers of mites per leaf on an apple tree irrigated 4 times with conventional, undertree sprinklers. Check tree.

Tree 1 - B North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/4/69	0.2	0	5.1	2.0	0.1	0
8/14/69	0	0.1	5.9	4.5	0	0.1
8/21/69	0.9	0.6	3.5	10.5	0	0
9/1/69	0.1	0.1	21.2	13.5	0	0
9/4/69	2.5	0.4	43.0	13.0	0	0
9/11/69	0.2	0.3	61.3	13.0	0	0

Tree 1 - B South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/4/69	2.5	0	4.6	0.7	0.2	0
8/14/69	0.1	0.1	2.2	0.9	0	0
8/21/69	3.2	0.4	0.8	3.3	0	0.1
9/1/69	3.9	0.8	12.1	3.0	0	0
9/4/69	3.6	0.4	24.0	2.5	0	0
9/11/69	1.8	2.9	15.4	6.8	0	0

Table 7 - Average number of mites per leaf on an apple tree irrigated 4 times with conventional, undertree sprinklers. Check tree.

Tree 2 - A North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	7.3	1.0	1.7	6.4	0.1	0
8/14/69	1.7	3.1	12.3	15.1	0	0
8/21/69	4.5	2.5	58.6	28.4	0	0
9/1/69	29.0	5.0	32.0	85.0	0	0
9/11/69	8.8	21.8	25.0	141.0	0	0

Tree 2 - A South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	7.1	0.1	3.9	12.9	0.4	0
8/14/69	0.7	2.9	15.8	23.7	0.1	0
8/21/69	0.7	3.5	91.0	38.0	0	0
9/1/69	14.0	1.5	47.5	91.0	0	0
9/11/69	4.3	14.3	16.5	164.0	0	0

Table 8 - Average number of mites per leaf on an apple tree irrigated 4 times with conventional, undertree sprinklers. Check tree.

Tree 2 - B North Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	38.0	3.6	9.8	10.0	0.2	0
8/14/69	1.3	13.5	15.0	24.5	0	0
8/21/69	30.0	11.3	96.0	44.0	0	0.33
9/1/69	82.0	13.8	73.0	125.0	0	0
9/11/69	9.5	50.0	16.5	221.0	0	0

Tree 2 - B South Limb

Date	European Red Mites		McDaniel Spider Mites		Phytoseiid Mites	
	Eggs	Active	Eggs	Active	Eggs	Active
8/5/69	20.2	0.8	7.9	31.4	0.2	0
8/14/69	3.2	3.4	16.4	62.2	0	0
8/21/69	27.0	14.3	83.0	80.0	0	0
9/1/69	21.5	8.3	20.8	121.0	0	0
9/11/69	5.5	19.5	9.5	212.0	0	0

Table 9 - Allan Bros. Orchard. Average number of mites per leaf on Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers. 1968.

Overtree	6/1	6/10	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/3	9/9
McDaniel spider mite	0	0.4	0	0	1.6	0.6	0.6	0.8	1.2	0	0	0.4	0	0.6
European red mite	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apple rust mite	0	0.2	1.0	9.2	7.6	12.0	26.8	0	0	5.0	12.0	0	0	0.0
Phytoseiids	0	0	0	0.2	0.4	0.4	1.8	4.4	1.0	2.2	1.2	2.4	1.6	2.2

Undertree	6/1	6/10	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/3	9/9
McDaniel spider mite	0.2	0	1.8	3.6	11.4	7.3	19.6	35.0	8.8	2.8	4.0	2.2	2.4	3.8
European red mite	0	0	0	0	0	0.3	0.6	0.4	0	0	0	0	0	0
Apple rust mite	0	9.8	1.4	5.2	13.6	16.3	46.8	20.0	30.0	25.0	18.0	0	0	20.0
Phytoseiids	0	0	0	0	0.8	0.5	4.8	8.0	7.4	4.4	3.2	2.0	2.8	2.6

Table 10 - Nettleton Orchard. Average numbers of mites per leaf on large Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers. 1969.

Large Delicious - Overtree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel Spider Mite	Active	0	0	0	0.1	0.14	0.08	0	0
	Eggs	0	0	0	0	0.32	0.16	0	0.04
European Red Mite	Active	0.6	2.3	11.3	31.4	7.2	3.6	1.0	0.56
	Eggs	5.6	56.0	41.0	175.0	4.1	16.8	1.7	1.1
Apple Rust Mite		3.8	100.0	125.0	156.0	174.0	126.0	34.0	24.0
Phytoseiids	Active	0	0.04	0.04	0.3	0.62	0.72	0.36	0.4
	Eggs	0	0.04	0	0.1	0.24	0.16	0.3	0.04
Large Delicious - Undertree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel Spider Mite	Active	0	0	0	0.1	0.3	0.35	0	0.04
	Eggs	0	0	0	0	0.8	0.12	0.07	0.04
European Red Mite	Active	0.6	2.7	19.7	45.0	64.0	14.0	15.3	1.2
	Eggs	6.6	58.0	80.0	89.0	15.7	47.7	18.0	6.7
Apple Rust Mite		13.0	234.0	436.0	442.0	388.0	312.0	209.0	208.0
Phytoseiid	Active	0	0.12	0.07	0.1	1.7	1.0	2.2	2.3
	Eggs	0	0.04	0	0	0.6	0.2	0.6	0.28

Table 11 - Nettleton Orchard. Average numbers of mites per leaf on small Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers. 1969.

Small Delicious - Overtree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel spider mite	Active	0	0	0.02	0	0.11	0.02	0.04	0
	Eggs	0	0	0	0	0.22	0.04	0	0
European red mite	Active	0	1.3	4.5	14.0	11.4	4.8	1.8	1.5
	Eggs	2.0	21.0	21.0	96.0	5.2	45.0	2.3	4.4
Apple rust mite		10.0	118.0	79.0	152.0	247.0	103.0	36.0	26.0
Phytoseiid	Active	0	0.04	0.02	0.58	1.8	0.92	1.08	1.2
	Eggs	0	0.04	0.06	0.58	0.46	0.12	0.28	0.40

Small Delicious - Undertree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel spider mite	Active	0	0	0	0.4	0.2	0.45	0.04	0
	Eggs	0	0	0	0.2	0.6	0.25	0	0
European red mite	Active	0.7	3.4	3.2	65.0	178.0	13.6	18.0	0.56
	Eggs	17.0	60.0	126.0	136.0	23.6	104.0	17.0	6.0
Apple rust mite		7.1	304.0	565.0	360.0	528.0	358.0	201.0	172.0
Phytoseiid	Active	0	0	0.08	0.2	0.7	1.4	2.4	3.3
	Eggs	0	0	0	0.2	0.1	0.35	0.47	0.08

Table 12 - Croft Orchard. Average number of mites per leaf on Delicious apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers. 1969.

Delicious - Overtree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/9
McDaniel spider mite	Active	0	0	0.16	0.12	0.17	0	0.04	0
	Eggs	0	0.16	0.20	0.04	0	0	0.32	0.08
European red mite	Active	0	0.3	1.4	6.8	16.2	1.1	6.9	3.3
	Eggs	2.2	7.6	13.6	33.0	20.0	18.0	7.0	2.9
Apple rust mite		2.5	74.0	121.0	345.0	197.0	54.0	30.0	19.0
Phytoseiid	Active	0	0	0.02	0.68	0.28	0.12	0.52	0.64
	Eggs	0	0	0.06	0.24	0.06	0.12	0.52	0.3

Delicious - Undertree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/9
McDaniel spider mite	Active	0	0	0.48	10.0	1.5	0	0	0.04
	Eggs	0	0.04	0.16	2.7	0.96	0.02	0	0
European red mite	Active	0.08	1.8	4.9	18.6	20.0	0.12	0.28	0.12
	Eggs	2.2	25.0	28.0	79.0	11.8	1.6	0.2	0.52
Apple rust mite		13.0	213.0	281.0	301.0	236.0	89.0	48.0	61.0
Phytoseiid	Active	0.04	0	0	0.2	0	0.02	0.08	0.40
	Eggs	0	0	0	0.13	0	0.02	0.08	0.32

Table 13 - Croft Orchard. Average number of mites per leaf on Spartan apple trees irrigated with overtree sprinklers and trees irrigated with undertree sprinklers. 1969.

Spartans - Overtree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel spider mite	Active	0	0	0.02	0.08	1.9	2.1	1.2	0.2
	Eggs	0	0	0.02	0.08	2.4	3.5	1.2	0.2
European red mite	Active	0	0	0.10	2.0	3.0	0.86	5.2	0.68
	Eggs	0.3	0.16	0.62	6.4	3.0	10.4	5.6	2.2
Apple rust mite		0.2	5.6	29.0	303.0	330.0	84.0	16.0	7.2
Phytoseiid	Active	0	0	0	0	0.06	0.3	0.52	1.36
	Eggs	0	0	0	0.04	0.08	0.6	0.4	0.44

Spartans - Undertree		6/2	6/16	6/29	7/14	7/28	8/11	8/24	9/8
McDaniel spider mite	Active	0	0	0.04	0.6	0.08	0	0	0.04
	Eggs	0	0.04	0	2.7	0.12	0.08	0	0
European red mite	Active	0.04	0.28	1.2	11.3	5.5	0.02	0.04	0.04
	Eggs	0.7	0.4	7.8	39.0	2.8	1.4	0.2	0.4
Apple rust mite		4.5	68.0	104.0	314.0	278.0	182.0	49.0	57.0
Phytoseiid	Active	0	0.04	0.25	0.6	0.28	0.3	0.72	0.52
	Eggs	0	0.08	0.16	0.5	0.68	0	0.36	0.24