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Apple pests and their control in northeastern North America : a review of literature and plans for 1970 field tests.

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A review of literature and plans for

1970 Field Tests

A Report on a Special Problem presented

by

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I. INTRODUCTION

Among the most formidable enemies of apple growers are the insects which annually pose as competitive organisms. These organisms which have diverse shapes and sizes are also divergent in the nature of their damage. Infestations reduce crop yield and quality and increase the cost of production and harvesting, partly by requiring outlays for materials and equipment with which to apply control measures.

Apple trees play host to one of the richest and most varied pest faunas. In most areas it is impossible to produce healthy, clean and marketable fruit, unless the insect pests are controlled.

The primary objective of this literature review was the compilation of a major portion of the pertinent published information on apple insects and their control, particularly in Northeastern North America. Special emphasis was placed on the evolution of control measures and recent advances in integrated control.

II. THE APPLE PEST COMPLEX

The primary pests of apples in North America are the following:

Codling moth, *Laspeyresia pomonella* (Linné)

Red-banded leaf roller, *Argyrotaenia velutinana* (Walker)

Fruit-tree leaf roller, *Archips argyrospilus* (Walker)

Plum curculio, *Conotrachelus nenuphar* (Herbst)

Apple maggot, *Rhagoletis pomonella* (Walsh)

Apple aphid, *Aphis pomi* De Geer

Rosy apple aphid, *Dysaphis plantaginea* (Passerini)

San Jose scale, *Aspidiotus perniciosus* Comstock

European apple sawfly, *Hoplocampa testudinea* (Klug)

The most important non-insect pest is the European red mite, *Panonychus ulmi* (Koch)

Some other insects which can be defined as relatively minor pests are apple leafhoppers which constitute several species of the order Homoptera, family Cicadellidae; the tarnished plant bug, *Lygus lineolaris* (P.de B.); apple red bug, *Lygidea mendax* Reuter; winter moth, *Operophthera brumata* (L.) and the eye-spotted bud moth, *Spilonota ocellana* (D. & S.)

The primary pests will be discussed in detail elsewhere. A look at early apple pests in North America reveals that some of these are capable of changing their pest status. Some of those which have been defined as pests of minor importance or which remained below the economic threshold have become major pests. Among these are oyster-shell scale, red-banded leaf roller, codling moth and European red mite (Pickett,1949). Such changes in the status of a particular pest are mostly influenced by natural and environmental factors. The presence or absence of natural enemies in the form of predators and parasites are vital factors in maintaining sub-economic levels of pest populations.

Geographical distribution of the different pests in the complex always has a great influence on the need for or the success of a particular control measure. It should be recognized that each individual orchard with its environment is a dynamic biological community within which the various components fluctuate according to the various pressures present. It is not always possible to make direct comparisons when so many variables are involved and for this reason a good program in one location may fail in another situation. For example, because plum curculio and European apple sawfly are not serious problems in Nova Scotia, as they are in New England, the use of integrated control worked there as it probably can not work farther south. Integrated control proved successful for cotton and alfalfa in the late 1940's in California, again because conditions made it feasible. The concept, theory and practice of integrated control will be discussed in a subsequent section of this paper.

III. REVIEW OF THE LITERATURE

Evolution of Control Practices

The control procedures used in the mid-nineteenth century were not so complicated as those we have presently. Harris (1852) described a considerable number of apple insects, and in most cases referred to control or preventive measures which were then common. Since synthetic insecticides were not yet developed in the "good old days", much stress was given to cultural practices such as clean cultivation, picking of fallen and wormy apples, and their destruction so as to insure the killing of the larvae, etc. Killing borers (roundheaded apple tree borer) by a wire thrust into the holes made by the borers was a successful method of borer control. Plugging the holes with soft wood after placing camphor in them also provided control.

Various types of tree banding were employed to check the wingless females of cankerworms from ascending the trees to deposit their eggs. Physical barriers in the form of cheap fish oil mixed with melted rubber were used to capture some insect pests or inhibit their movements. Some trees were spared the ravages of insects by dusting with air slaked lime. Jarring or shaking the limbs was common to dislodge the insects (used especially for cankerworms) which would spin down where trays of fish oil were placed as traps (Harris,1852).

Slingerland and Crosby (1914) dealt in great detail with the insect pests of different fruit trees, their life histories, nature of damage and preventive or control measures. This is an excellent source of the pest control practices used at that time.

Cultural and sanitary practices such as burning of fallen leaves, destruction of dropped fruits by plowing, tilling of the orchards, pruning, etc. were employed. Shaking or jarring of the limbs were used to dislocate larvae from the trees so as to cause them to perish on the ground. In certain cases native or imported predators and parasites were also used, e.g., for control of gypsy moth. Banding of the trunks was also done with burlap or sticky bands which prevented wingless females from ascending the trees to oviposit.

Pasturing of sheep in orchards while the infested apples fell on the ground offered a marked decrease in pest injury, and similar benefits to a lesser degree had been noticed where poultry or hogs were similarly used. With the advent of modern insecticides, high labor costs and residue problems, such practices have since been almost totally abandoned.

For chemical control, spraying with arsenical poisons was quite common. Paris green, which was once a standard stomach poison, was largely replaced by arsenate of lead because of its being less phytotoxic. It was often used in combination with lime sulfur or Bordeaux mixture. For contact sprays "Black Leaf 40" (nicotine sulfate) alone or with lime sulfur was used. Other materials used to at least some extent were sprays of whale oil soap, lime sulfur wash, kerosene emulsion, crude oil and miscible oil (Slingerland and Crosby, 1914).

Prior to the Second World War, some plant organics such as rotenone, anabasine, nicotine sulfate and pyrethrum were tested but the importance of the arsenicals did not fade. Of the botanicals, nicotine sulfate was most commonly used, particularly for aphid control.

During the Second World War, a new chapter in pest control was unfolded with the development of more effective and superior synthetic organic materials; some of these are now designated as "hard pesticides" because of their long persistence.

Metcalf et al. (1962) state that the first use of such a material was in 1892 when the potassium salt of 4, 6-dinitro-o-cresol was marketed in Germany as an insecticide. In 1932, with the advent of B-butoxy-B-thiocyanodiethyl ether, there came the first large scale use of a synthetic organic insecticide. During the Second World War the development of DDT showed that this synthetic compound was superior to a variety of inorganic and natural products for many insecticidal uses. The synthetic organic insecticides which are now available are examples of the outstanding triumphs of modern chemistry.

With the availability of such fast-acting, sophisticated and relatively cheap chemicals, fruit growers and farmers leaned heavily on these materials and almost completely abandoned cultural practices which involved the high labor costs, inconvenience and never offered quick results. The large scale use of persistent pesticides presented certain aspects that are now considered objectionable by most people. The suppression of the natural enemies of the pests and the phenomenon of resistance to pesticides which resulted in some of the pest species eventually helped decrease enthusiasm for these materials.

Different materials presently used in countries like the United States, Canada, the West Indies, South Africa, India and Australia have been listed by Hanna (1968a, 1968b). He stated that over 20 insecticides were in use on apples and pears, the most common being dicofol, chlorbenside, tetradifon, azinphosmethyl, dimethoate and malathion.

Although chemical control has many drawbacks, it still cannot be ignored in pest control. In the future, insecticides are expected to play a major role in the man versus pest struggle (Chant, 1964; Hansberry, 1968; Smith, 1969a, 1969b).

Cleveland and Hamilton (1958) and Barnes and Madsen (1961) presented the results of detailed surveys of the insect and mite fauna of apple orchards. Likewise Barnes (1959) and Madsen and Morgan (1970) have reviewed modern research on apple pest control.

Codling Moth - Laspeyresia pomonella (Linné)

The codling moth has been for years one of the most important pests confronting apple growers. About 1935 it began to increase in numbers and within a decade became an important pest (Pickett, 1949), but in several parts of the United States it had been a serious pest prior to 1935.

During the early 1900's inorganics were generally employed for the control of this insect. Sanderson (1908) used a combination of Paris green, arsenate of lead and Bordeaux mixture against the codling moth, and found that the combination of Bordeaux and arsenate of lead reduced the pesticidal effects. Bourne and Whitcomb (1927) found lead arsenate to be the most satisfactory insecticide for codling moth control, and reported that other arsenicals were either less effective, uneconomical, more hazardous or less available than lead arsenate.

Bourne and Whitcomb (1927) discarded nicotine, it being more expensive, and suggested that careful and correct timing of sprays was the key to successful control. Webster and Marshall (1934) discussed the use of nicotine alone or in combination for codling moth control. Driggers and O'Neil (1938) observed the effects of sprays containing lead arsenate, fixed nicotine plus oil, and fixed nicotine alone on larval parasitism by Ascogaster carpocapsae Viereck. Gnadinger et al. (1940) conducted experiments with pyrethrum and oil sprays for controlling pupae and overwintering larvae. The use of pyrethrum dust in conjunction with oil sprays was also tested to control adult moths, eggs and larvae. In general the control was not as good as with lead arsenate cover sprays and the cost of pyrethrum was higher (Gnadinger et al., 1940).

Chemically-treated bands for the control of codling moth larvae were recommended by Siegler et al. (1929).

Parker and Lamerson (1943) observed that in the lead arsenate-zinc sulfate-summer oil emulsion plots, the foliage had fewer arsenical burns than the foliage on the plots sprayed with tricalcium arsenate plus bentonite, lead arsenate plus bentonite, or lead arsenate alone.

Yothers et al. (1943) found that 4-6 dinitro-o-cresol with stove oil and a suitable emulsifier plus penetrant was effective as a dormant spray which killed overwintering larvae in their cocoons on apple trees. Yothers and Carlson (1944a) tested selected materials to destroy the overwintering larvae and found 100 per cent mortality with dichlorethyl ether, while ethylene dichloride gave poor kill at any concentration. No plant injury could be detected from any of the treatments used. However, they concluded that the practical control obtained with any of these materials was problematic. Later (1944b) they assessed the repellent effects of pyrethrum to mature codling moth larvae searching for hibernating quarters, and obtained best results with combinations of 5 per cent pyrethrum extract with either 5 or 10 per cent cotton seed oil emulsified with blood albumin.

The relative ineffectiveness of lead arsenate, due to the resistance problem, in the control of codling moth was observed by Steiner *et al*. (1944). Steiner *et al*. (1944) and Siegler (1944) first recorded the superiority of DDT, a chlorinated hydrocarbon compound, over lead arsenate in laboratory studies. Childs (1947) found that DDT sprays in the orchards reduced bait trap returns by 94 per cent as compared with lead arsenate, when comparisons were made in eight-acre blocks. Hoyt (1960) reported that the addition of urea to DDT reduced the effectiveness against this moth both in the field and in the laboratory. Codling moth resistance to DDT was reported by Cutright (1954) in the United States, and Fisher (1960) in Canada.

Among lead arsenate and DDT substitutes, however, ryania (a botanical) gave good performance for controlling codling moth without causing adverse side affects or greatly affecting populations of beneficial insects (Hamilton and Cleveland, 1957), Thomas *et al*. (1959) indicated that acceptable control of the codling moth, along with satisfactory control of phytophagous mites, was provided by a glyodin (fungicide) - ryania combination. The combination of glyodin with azinphosmethyl (organophosphate), carbaryl (carbamate) or ethion (organophosphate) improved the control (Asquith, 1958). The persistence of azinphosmethyl was reduced when used in combination with petroleum oil, according to Madsen and Williams (1968). Chiswell (1962) reported Sevin and azinphosmethyl as being compatible with DDT, and in observing the side effects of sprays on non-target organisms reported increases in mite populations after such treatments.

Asquith (1970) suggested that selective toxicities of certain materials may be useful in integrating chemical and biological programs and reported that sprays containing phosalone EC definitely roughened the skin of Golden Delicious apples.

Table 1 provides summarized information on the control measures which were recommended in 1914 and 1970 respectively. Also for an up-to-date seasonal program against the codling moth refer to Table 1.

Driggers and Pepper (1936) studied egg parasitism by Trichogramma sp. under various orchard conditions, and found that parasitism was greatly reduced in the orchards sprayed with lead arsenate and oil. Webb and Alden (1940) reported on studies of the parasitism of codling moth eggs by Trichogramma sp. as related to biological control. Pickett (1959) reported an increase in parasites in orchards where selective pesticides were applied, and emphasized certain factors to be considered in order to preserve the native biological control agents. Besides the employment of selective pesticides, Leius (1967) concluded that orchard ground cover was important, and that there was five times more parasitism of codling moths in orchards having wild flowers as compared to the orchards with poor floral undergrowth.

MacLellan (1962) found a positive correlation between the number of mirid predators present with egg predation and mortality of young larvae.

The codling moth has been effectively controlled by the bacterial pathogen Bacillus thuringiensis Berliner in the laboratory (Jaques, 1961). However, it proved inadequate in field tests, although the fruit injury was reduced (Jaques, 1965; Oatman, 1965b).

Tanada (1964) described a naturally occurring granulosis virus of the codling moth. The propagation of the virus was done in codling moth larvae, and apple trees were sprayed with these preparations. There was an appreciable mortality soon after the larvae fed on the treated surfaces. Preliminary results indicated considerable potential for the virus if a technique for mass rearing of the host larvae could be developed (Falcon et al., 1968).

Madsen and Morgan (1970), in their review quoted the work of Arkhipova (1965) who evaluated fungi in the laboratory for their pathogenic effects on the codling moths, and found Beauveria bassiana, B. lobulifera and Metarrhizium anisopliae to be toxic. Further work seems to be needed to elucidate fully the practicability of this means of control.

While trying to explore the possibilities of using the sterile male technique for the control of codling moth, Hathaway et al. (1966) induced a high degree of sterility in both male and female moths by tepa applications, and further suggested that induction of sterility within a field population of codling moth could be done economically with the combination of a chemosterilant with an attractant. Treatments of males had little effect on their mating behavior. However, codling moth eggs, larvae, and pupae were injured or killed by sub-sterilizing doses of tepa (Hathaway *et al*. 1966). Proverbs *et al*. (1966, 1967) reported encouraging results from some of the field tests they conducted with codling moth pupae and adults exposed to gamma radiation. Proverbs *et al*. (1967) further reported that the development of infestation pockets may be encouraged by the simultaneous release of sterile males and females. Chemical sprays to control mites and other insects were selected and timed so as to cause the least possible injury to the sterilized codling moths (Proverbs *et al*. 1969)

The most recent development in the study of attractants is the use of sex pheromone traps (Butt and Hathaway, 1966) to lure male codling moths. Butt *et al*. (1968) reported that heptanenitrile and several other nitriles, used as synthetic chemical sex attractants, caused male codling moths to be attracted or to respond in a sexual manner. McDonough *et al*. (1969) isolated a pure sex pheromone from virgin female codling moths. This compound is an unsaturated alcohol, does not contain a carbonyl group, but does contain at least one other functional group, as was indicated by chemical and chromatographic data.

Barnes *et al*. (1969) reported on the use of light traps in California and Chile for detecting the emergence of early season overwintering broods of codling moth. They suggested that traps might enable growers to reduce the frequency of pesticidal applications from four to two by improving the timing of the treatments.

Red-banded leaf roller, Argyrotaenia velutinana (Walker)

Reports in the literature show that about 30 years ago red-banded leaf roller was only a very minor pest, but with the advent of DDT against codling moths there came a tremendous build-up of this pest and it subsequently emerged as a major pest (Pickett, 1949; Chant, 1964). Prior to this time, treatments were not directed against this pest.

For chemical control of red-banded leaf roller, Oatman and Libby (1965) found Guthion, diazinon and carbaryl spray programs to be most effective. Asquith (1970) tested a number of materials and found azinphosmethyl, Imidan, and phosalone to be relatively effective.

Glass (1958) in his studies on this pest tested a granulosis virus in the laboratory and field. It resulted in an appreciable kill of the larvae but fruit damage was not prevented. He further reported (1963) the parasitism of leaf roller eggs by Trichogramma minutum Riley. Glass et al. (1970) found in their studies of attractants against red-banded leaf roller that a small polyethylene cap proved to be the best "wick" for releasing the attractant at an optimum rate for almost a year, and that black traps were better than white ones. Besides these attempts, the isolation of the female sex pheromone (Roelofs and Feng, 1968), could be a positive clue for biological control of the pest. Such projects will be feasible only when large scale laboratory rearing procedures have been developed. This approach will be further investigated (Roelofs and Feng, 1968).

Fruit tree leaf roller, Archips argyrospilus (Walker)

The fruit tree leaf roller had long been an important apple pest. The intensity of infestation in unsprayed orchards varies greatly from year to year (Oatman, 1966). In years of abundance this insect may devastate 80 to 90 per cent of the apple crop if uncontrolled (Metcalf et al., 1962).

Slingerland and Crosby (1914) reported the difficulty of controlling this insect with arsenical poisons, but thorough applications of miscible oil, made early while the trees were dormant, destroyed over 95 per cent of the eggs. Dormant spraying with oil directed at the egg stage was the only satisfactory control of the fruit tree leaf roller in the 1930's and 1940's and this was also suggested by Peairs and Davidson (1956) and Metcalf et al. (1962). The latter authors suggested the application of DDT spray as the most effective control measure against this pest applied at the pink, calyx and first cover stage to kill the newly hatched larvae.

Madsen and Downing (1968) demonstrated that a pre-bloom spray of azinphosmethyl controlled the fruit tree leaf roller without harming the natural enemies, and that diazinon, parathion and azinphosmethyl provided satisfactory control of this pest when applied in the pink stage. Dormant oil-ethion spray at the half-inch stage of leaf growth was less effective (Madsen, 1969).

Plum curculio - Conotrachelus nenuphar (Herbst)

The plum curculio is a major pest of apples and other deciduous fruits in Midwestern and Eastern North America. Whitcomb (1929) published on the results of an elaborate study of the plum curculio infesting apples in Massachusetts. He described it as the most injurious pest of apples in the state. Along with chemical, biological, cultural and natural control, he recommended the grazing of sheep and hogs in the orchards to feed on infested fallen apples. The latter was also suggested in the recommendations of Bourne et al. (1940).

Whitcomb (1929) and Metcalf (1962) discussed the nature of the damage caused by this pest. These include small, crescent-shaped punctures in the skin of small fruits, some of them with a little round hole opposite the concave side of the crescent, into which an egg is usually deposited. Many of the infested fruits drop during late May and June. The infested apples are often hard and knotty.

Whitcomb (1929), while discussing the timing of sprays, emphasized that the calyx spray could be relatively unimportant in controlling plum curculio, although it is the most important single application and should never be missed. He also reported the significance of the 7-day or first cover spray. Metcalf et al. (1962) recommended petal-fall sprays which should be followed by one or two more applications at 7 to 10-day intervals. Jarring the beetles from the trees in early morning onto sheets placed beneath the trees, and their subsequent collection and destruction was also recommended.

Snapp (1940) was the first to report control of plum curculio by soil treatment with dichlorethyl ether. The use of some of the newer synthetic organic insecticides was first reported by Bobb (1946). He found DDT ineffective at rates up to 25 lbs./acre, but reported 60.9 per cent control with one pound per acre of the gamma isomer of BHC. Snapp (1947, 1948) conducted laboratory experiments with BHC and found it ineffective in preventing the development of the plum curculio in soil.

Chandler (1950) found aldrin and dieldrin highly toxic to the plum curculio. Snapp (1953, 1954) reported good control with aldrin, dieldrin, heptachlor or isodrin. Fluke and Dever (1954) showed that aldrin and dieldrin had a residual toxicity for at least three years when applied to the soil in cage tests. Reasonably low dosages of aldrin, dieldrin, heptachlor or chlordane incorporated in the soil have provided control over periods of several years from a single application (Fluke and Dever, 1954; Snapp, 1957; Stelzer and Fluke, 1958). Oatman and Lichtenstein (1961) indicated the efficacy of endrin for its control.

Chandler (1953) pointed out the importance of pre-bloom sprays for control of this pest. Reference can be made to Table 1 for the most recent control measures in Massachusetts.

Whitcomb (1929) made no encouraging reports on the possibilities of plum curculio control by natural agents. Adult beetles are hard and apparently unpalatable and are generally not attacked by the predators. The immature stages spend their life span in well protected surroundings and do not easily succumb to any natural enemies. Wylie (1954) reported discouraging results of parasitism of adults by Triaspis curculionis (Fitch) because the parasites when reared in laboratory emerged earlier than curculio adults. Thus it can be noted that there is no effective means of biological control of the plum curculio.

Chandler (1958) reported that the lack of a fruit crop, with or without favorable weather conditions, will greatly reduce the numbers of curculio the following year.

The Apple Maggot, Rhagoletis pomonella (Walsh)

Slingerland and Crosby (1914) reported that the apple maggot became a serious apple pest during the past 60 years in the Eastern states and Canada. This pest still holds the status of an important apple pest in Northeastern United States and Southeastern Canada (Madsen and Morgan, 1970).

Table 1 describes the control practices which were common back in the early 1900's. Herrick (1920) emphasized the need of thorough and complete orchard sprays to cut down on the migration of apple maggot flies from untreated trees. Bourne et al. (1940) recommended lead arsenate sprays to control this pest, to be applied twice around July 10 and 25, and also removal or spraying of the abandoned trees in the vicinity of the treated orchard. Maxwell et al. (1963) found two sprays of lead arsenate ineffective for controlling the apple maggot. Neilson et al. (1968) indicated the possibility of arsenic acting as a chemosterilant on the adults when sprayed in the form of lead arsenate.

Oatman (1959) found endrin giving best results as a soil insecticide, when applied to the sod for controlling soil inhabiting stages of the maggot. Poison bait sprays of malathion were not found to be satisfactory (Neilson and Maxwell, 1964).

Reference to Table 1 will show the insecticides currently recommended for apple maggot control in Massachusetts.

The studies of Hodson (1943) on lures indicated that household ammonia, ammonium sulfate and ammonium acetate attracted apple maggot flies in the orchard and this could be a possible means of supplementing the control.

Lathrop and Dirks (1945) found a correlation between rainfall and emergence earlier in the season in their observations on the seasonal cycle of this pest. Oatman (1964b), while studying adult emergence and seasonal activity in Wisconsin, observed important correlations between temperatures, rainfall and fly emergence. High temperatures and low rainfall tended to result in early emergence and a shorter emergence period.

It appears from Hodson's (1943) work that the glycine-NaOH lure is a tool which could be more widely exploited in the timing of treatments.

Hodson's (1948) development of an ammonium carbonate trap could be useful in surveys for other flies of the genus Rhagoletis.

Oatman (1964a) reported on his observations of apple maggot light traps, and concluded that red was the most attractive color for apple maggot adults and was more effective than the best bait or chemical attractant on the basis of unit area of trapping surface, cost of maintenance and ease of operation. He further suggested that home orchardists could use this technique to check both first appearance and emergence period of the apple maggot.

Kring (1970) observed in his experiments on trapping the flies that their preference was for red spheres alone, or for a sphere plus a yellow panel, as compared with the panel alone. Further investigations are needed to explain the failures of the traps to capture all the flies in their surroundings.

Metcalf et al. (1962) recommended the destruction of apple maggot larvae in infested fruits by placing such fruits in cold storage for four or five weeks, and frequent picking up of all premature fallen fruits, which may be fed to hogs so as to destroy many of the larvae before they leave the apples.

The Apple Aphid, Aphis pomi De Geer

The apple aphid can be controlled with insecticides directed against overwintering eggs, but reinfestation in the spring and summer sometimes warrants foliage sprays.

Pielou and Williams (1961b) reported rapid infestations of apple aphids following insecticidal treatments with Thiodan, diazinon or Guthion. Carbaryl gave residual action for 17 days, as indicated by Pileou and Williams (1961a), but the systemic insecticides mevinphos and dimethoate gave the best control (Pielou, 1961). Holdsworth (1970) found that azinphosmethyl was destructive to the major aphid enemies, but that ryania and lead arsenate (though not aphicides they may suppress aphids and thus were used in these investigations) proved innocuous to them.

Natural control factors have a great influence on the mortality of apple aphids. Oatman and Legner (1961) reported that a number of predators including syrphids, lacewings, anthocorid nymphs and coccinellids attack these aphids and eventually reduce their populations. Evenhuis (1961) discussed the dipterous enemies of aphids and reported that Leucopis sp. were important predators of both rosy and apple aphids. No assessment was made regarding their practical utility.

Westigard and Madsen (1964) suggested that extremes of weather in the fall contribute to the mortality of these aphids, because at this time both sexual and parthenogenetic forms are present. They also reported that pruning reduces the number of overwintering eggs.

Referring to Table 1, we note that in 1914 non-chemical control was advocated through judicious pruning to remove the eggs, as well as by crushing the eggs on young trees. For chemical control, spraying with "Black Leaf 40" or nicotine sulfate was employed. In the 1970 recommendations, with the availability of new synthetic organic compounds, there are no non-chemical control recommendations. However, endosulfan, phosphamidon, demeton, TEPP, dimethoate, Imidan and phosalone are all mentioned for chemical control.

The Rosy Apple Aphid, *Dysaphis plantaginea* (Passerini)

It is not very common for the rosy apple aphid to become destructively abundant. Dormant sprays of oil, as well as dinitrocresol or dinitrocyclohexylphenol, easily control these aphids but may be injurious to cover crop plants (Madsen and Morgan, 1970). Madsen and Bailey (1959) reported no damage to cover crops by combinations of oil plus either ethion or carbophenothion, which also gave a satisfactory control of the aphids.

Metcalf *et al*. (1962) recommended spraying with demeton, diazinon, Guthion, parathion, malathion or TEPP when aphids became abundant. Hough (1963) reported from his studies on fall sprays that parathion or endrin applied in November against egg-laying females gave better than 95 per cent control the following year.

Rosy apple aphids are preyed on by many predators such as lady beetles, syrphids and aphid lions, and in the warmer part of spring these natural enemies become populous and help to control the aphids (Metcalf _et al._, 1962). Madsen and Morgan (1970) concluded that parasites were of little significance in controlling these pests, and that predators offered only limited control.

Referring again to Table 1, we note that in 1914 non-chemical control was stressed, whereas in 1970 chemical control with a wide variety of modern insectides was advocated.

The San Jose Scale, _Aspidiotus perniciosus_ Comstock

This is often the most troublesome species among the scale insects in the temperate areas of the world. However, comparatively little work has been done on the San Jose scale on apples and pears in North America during the past decade (Madsen and Morgan, 1970).

Metcalf _et al_. (1962) recommended spraying during the dormant stage with 2 to 3 per cent mineral oil emulsions, including commercial miscible oils and superior oils. In the seasonal spray program, this scale may be controlled by spraying when the crawlers are present about the second, sixth and seventh cover sprays with parathion, malathion, Guthion, or Sevin. Parathion should not be applied to McIntosh and closely related varieties.

Madsen and Morgan (1970) reported that petroleum oil or wettable powder formulations of organophosphorous compounds such as parathion or diazinon are mainly used for the control of San Jose scale. The oils are applied in the dormant and up to the tight cluster bud stage. There have been no confirmed reports of any resistant strains of this scale against parathion (Madsen and Morgan, 1970).

Some attention has been given to biological control of San Jose scale in the recent past. Flanders (1960) reported that with parasitization of San Jose scale by different parasites, populations of this pest do not often go above the economic threshold. In their review, Madsen and Morgan (1970) mentioned the difficulty of combining biological and chemical controls for the San Jose scale, but pointed out that integrated programs are being developed as more is discovered about the effects of chemicals on parasites and predators.

According to Table 1, in 1914, lady beetles were reported as natural enemies of scales. Also a thorough job of spraying and pruning of the long sprawling branches of the infested trees were recommended. Since 1914, fumigation of nursery stocks with HCN gas, spraying apple trees with kerosene emulsion, and treating old apple trees with crude petroleum have all been advocated. The 1970 Massachusetts recommendations mention spraying apple trees with superior oil in the half-inch green stage of growth.

European Apple Sawfly, Hoplocampa testudinea (Klug)

This sawfly was first recorded in North America from Long Island, N. Y., in 1939, and Vancouver Island, British Columbia, in 1940 (Pyenson, 1943), who also discussed its biology and described the damage caused by this pest.

In discussing the chemical control of apple sawfly, Kirby and Gambrill (1953) mentioned the failure of lead arsenate and rotenone, and the success achieved with parathion and several chlorinated hydrocarbons; they also obtained satisfactory control with nicotine. Kirby and McKinlay (1953) proposed that failures with nicotine were largely related to its short residual effect during periods when cool weather delays hatching. He further observed that none of the materials used (nicotine, DDT, BHC, aldrin, dieldrin, toxaphene, chlordane and parathion) had any ovicidal action, but that they acted as larvicides.

Dicker (1953) reported oviposition by this pest in open blossoms. Dicker and Tew (1957) suggested that soil-incorporated insecticides might have a place in the control of this pest and that aldrin, endrin, toxaphene, etc., are effective as sod sprays.

Reference can be made to Table 1 for recent control recommendations in Massachusetts.

Mites

There are about 10 important species of tetranychid and eriophyid mites which infest apple trees, and almost all of them at times feed on the fruit. Boudreaux (1963) gave an exhaustive review of the biological aspects of phytophagous mites and included discussions on life cycles, diapause, physiology, dispersion, predators and insecticide problems. A recent review of the ecology of the tetranychid mites by Huffaker et al. (1969) includes a long discussion of mite predators. They point out how these, along with other factors, influence the abundance and control of phytophagous mites.

Madsen and Morgan (1970) contend that because of the ability to develop strains quickly, mites may become resistant to chemicals, particularly organophosphates, and thus pose further problems for orchardists.

European red mite, Panonychus ulmi (Koch)

Lienk et al. (1952) reported that European red mite populations had developed resistance to parathion and Kelthane. Likewise mite resistance has been noted to tetradifon (Asquith, 1964) and carbophenothion (Lienk, 1968). The resistance problem initiated the use of new formulations of older materials, particularly petroleum oils, for the control of red mites (Chapman et al., 1962; Bobb, 1969).

Chapman and Pearce (1949), testing oil sprays for their ovicidal efficacy, found that the susceptibility of eggs increased as the interval between spraying time and hatching was reduced. Chapman et al. (1952) gave a comprehensive description of spray oils, their uses and advantages in insect and mite control. Chapman and Lienk (1966), Lienk and Chapman (1967), and Rock (1969) found dormant oils quite effective against overwintering mite eggs. Meyer (1969) felt that good coverage with spray oils was more important than the viscosity, but found 70 viscosity oil gave better control than 60 viscosity oil.

Effects of pre-blossom miticides and subsequent insecticides were studied by Oatman (1965a), who observed that the suppression of the European red mite on Red Delicious apple trees by pre-blossom miticides in 1959 was followed by a rise in mite populations on the same trees in 1960 when pre-blossom spraying was not done. The mite populations were not adversely effected by the application of Captan; ryania and lead arsenate had some adverse effects,whereas carbaryl had an apparent effect in increasing the populations of phytophagous mites by almost eliminating the predacious mites. Studies of Oatman (1965a) further indicated that the use of pre-blossom miticides should be continued annually or there could be mite damage to the orchard.

Forsythe (1965) listed prospective acaracides, including some new carbamates, for the control of European red mite. Madsen and Falcon (1962) concluded that the use of Tedion is more a preventive measure than a control. Madsen et al. (1964) tested selected materials against red mites and felt that Morestan showed the most promise. Batiste and Berlowitz (1969) stated that no detrimental effects were observed on trees which received treatments of Morestan during four consecutive years for mite control.

Hamstead (1966) found a reduction in the oviposition potential when mites received a treatment of Niagara 9203. Asquith (1968) tested 25 acaricides against red and spider mites. He found that Plictran was highly effective to both, whereas Omite was only useful for red mite control. Zambelli et al. (1968) reported the control of mites with Plictran on apples and pears in Italy, without any adverse effect on the important predators. Holdsworth (1968) reported that ryania and lead arsenate were harmless to the predators (mirids and chrysopids) of the red mite, but that azinphosmethyl and carbaryl had detrimental effects on them. He also noted that naturally occurring predators reduced the red mite populations and also the number of overwintering eggs.

Boulanger (1963) advocated frequent applications of the fungicide glyodin to reduce the populations of P. ulmi. Of the combinations tested, none of the fungicides significantly altered the efficacy of an acaricide or vice versa (Hamstead and Barrat, 1967).

Jeppson and Complin (1967) concluded that changes in the weather or host physiology may result in increased vigor in mites, rather than true resistance, so as to adversely affect the success of chemical applications. Further study is desirable to ascertain the factors which produce these susceptibility variations.

Specht (1965) studied the effect of water stress on the reproduction of European red mite, and observed a considerable retardation in growth due to inability of the mites to secure sufficient food supplies in dry weather. Herne (1968) concluded that frequent or prolonged wet periods delay the build-up of mite infestations.

Effects of chemical treatments on predacious mites

Lord et al. (1958) emphasized the importance of using sprays which are innocuous to predators, and argued that such practices minimize damage from phytophagous mites. Downing (1966) screened certain miticides against predacious mites, and found binapacryl and dinocap to be highly toxic. Nickel and Wong (1966) found that azinphosmethyl (Guthion) was more effective against predacious than phytophagous mites. Sanford (1967) and Sanford and Herbert (1967) investigated the effects of different spray materials on predacious mites in apple orchards in Nova Scotia. They found that ovex, tetradifon, chlorbenside and Animert-V-101 were relatively safe to natural enemies, whereas parathion and dicofol were toxic. Morris (1968) found an increase in the populations of red mites resulting from spraying, due to reduced predator populations.

An intensive survey was made by Horsburgh and Asquith (1968) to record the naturally occurring predators of red mites.

From studies on methods for estimating populations of predacious and phytophagous mites, including the brushing machine designed by Henderson and McBurnie (1943), Morgan et al. (1965) concluded that the use of this equipment was more efficient than other procedures in making mite counts. Photography was introduced as a further refinement in the Henderson and McBurnie mite sampling technique to facilitate correct counting (Asquith, 1965).

Concept and practice of dormant sprays for control of phytophagous mites

Chapman and his associates are among the pioneer workers in the field of dormant spraying, since they have engaged in this type of research in both field and laboratory for more than a quarter of a century.

Petroleum oil sprays have not so far given rise to resistance problems and are relatively safe with regard to human health hazards. For these reasons Chapman et al. (1952) recommended them for wider use. Many papers have been published on their use and application, and also the factors pertaining to the efficiency of oils in dormant spraying (Pearce et al., 1941; Chapman et al., 1941 a & b, 1943; Chapman, 1959; Fiori et al., 1963).

Oberle (1944) studied the physiological responses of deciduous fruit trees to petroleum oil sprays, and noted both retarded development of new growth and decreased respiration. Wave (1969) found a measles-like bark nocrosis on Delicious apple trees following the use of oil sprays.

The concept of integrated control

Wigglesworth (1945) wrote: "It may well be that in the long run an insecticide which kills 50% of the pest insect and none of its predators or parasites, may be far more valuable than one which kills 95% but at the same time eliminates its natural enemies."

Now this quotation is more appreciated and practiced under the concept of "Integrated Control" (Bartlett, 1956; Stern et al., 1959; Pickett, 1962; Smith, 1968). Integrated control of deciduous fruit pests, as thought of today, began about 25 years ago in Nova Scotia. Pickett et al. (1946) stressed their conviction that ecological concepts and methods must be applied to the problems of controlling insects. The term integrated control apparently was first proposed by Bartlett in California in 1956 (Bartlett, 1956). Smith (1968) quoted the definition of integrated control as " a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury".

In the 1940's Strickland (1945) anticipated troubles with the widespread use of DDT. Pickett (1949), in his critique on chemical control of insects emphatically suggested that the use of highly specific chemical warfare against insect pests should be made. In other words, instead of using chemicals which kill many species, attempts should be made to discover chemicals which are highly specific for particular pests, and that over-all estimations of the side effects should be made.

By her dramatic writing Rachel Carson (1962) definitely influenced public attitudes toward pesticides and directed attention toward non-chemical pest control research.

The theory, practice and importance of biological control as a partial substitute for chemical control has been discussed by a number of workers, including Simmonds (1956, 1959) and Turnbull and Chant (1961). MacLellan (1959) pointed out the importance of woodpeckers as natural enemies of overwintering codling moth larvae.

Stern et al. (1959) and van den Bosch and Stern (1962) suggested the integration of chemical and biological control of arthropod pests, using only selective or specific chemicals. Pickett (1959) stated that most of the materials used for pest control can be fitted into a program of specific sprays, and that successful integrated programs result.

Chant (1964) advocated the theory of integrated practices for developing rational control measures. A number of workers have expressed their views on the concept and philosophy of "Integrated Control" or "Pest Management", including Geier (1966) and Smith (1968, 1969b). Geier (1966) while discussing pest management, stated that it emphasizes the comprehensive nature of the approach and its reliance on ecological principles; it also carries the concept of the intelligent manipulation of nature for man's benefit. Pest management, like integrated control, implies the continued existence of potentially harmful species at sub-economic levels. Like integrated control, it recognizes that the future solution to pest problems may be in allowing pest populations to live at sub-economic levels than completely eradicating them (Geier, 1966).

On apples, the broad spectrum insecticides used for codling moth control precluded the widespread use of pest management practices, according to Madsen (1968). Hoyt (1969) successfully planned an integration of chemical control of insects with biological control of mites by proper choice of selective materials.

In the earlier days, acarologists preferred to use broad spectrum materials (Barnes, 1959). Currently the trend is toward specific chemicals which check the target pest only, and which are innocuous to its natural enemies (Pickett, 1962; LeRoux, 1964; Oatman, 1966).

An integrated program in Swiss orchards for a period of six years allowed the reduction of about half of the chemical treatments normally needed in a chemical spray program (Mathys and Baggiolini, 1968).

Therefore, it can be stated that the concept of integrated control is coming into practice. Research is going on in this area in many parts of the world. An encouraging factor is the amount of research now being devoted to integrated control in universities and government research stations. For its success, more studies are needed on the ecology and biology of the pests, as well as the beneficial insects and mites, which help keep pests in check.

IV. EQUIPMENT AND PROCEDURES

Two orchards at the University of Massachusetts Horticultural Research Center, Belchertown, are being used in the 1970 field tests. One is a mature orchard, perhaps 40 years of age. The other was planted in 1963. The mature orchard is being used to compare the efficiencies of two different kinds of sprayers. The other orchard is being utilized for comparative testing of eight different insecticide or acaricide treatments.

The chemicals which have been or are being used for experimental purposes are described in Table 2. The equipment consists of three different types of orchard sprayers, and a mite brushing machine along with a binocular microscope which are utilized in the laboratory. A brief description of each follows.

Equipment

In the world of pesticide sprayers, the Kinkelder mist sprayer is somewhat of a revolutionary development. The most essential aspect of spraying is penetration and coverage, and this appears to have been achieved with this sprayer. It throws a gentle fog-like spray by means of atomizing nozzles and spinning discs. The mist seems to provide better, more uniform plant coverage. Also it is claimed that there is a saving of up to 30 per cent in chemicals, up to 90 per cent in water and at least 50 per cent in fuel. Since this equipment utilizes concentrated amounts of chemicals with much lower amounts of water, fewer trips to and from the source of water are required, resulting in a significant savings in time and labor costs.

The Kinkelder sprayer consists of an efficient high precision air turbine, an extra strong gear box, and a dependable low-pressure high-volume centrifugal pump. It has spray heads with vacuum spray jets, which eliminate clogging even at the highest concentrations. The uniformly fine droplets and extremely even distribution offer a minimum residue at harvest.

Speed sprayer - The speed sprayer is a conventional air blast sprayer. Air blast sprayers utilize a relatively large volume of high velocity air to break up the spray droplets and to carry them to the target. Two types of air blast sprayers are generally found and one of them is the spray blower. A number of large spray blowers are much used commercially for orchard spraying of which the Speed sprayer is perhaps the best known.

In this machine, the liquid is broken up by hydraulic nozzles and carried to the target by an air blast. With this equipment, from 50 to 500 gallons per acre can be applied. It delivers up to 45,000 cubic feet per minute of air with nozzle pressures of 50 to 70 pounds per square inch and pump capacities of 55 to 140 gallons per minute. There are from 58 to 264 swirl spray nozzles which deliver the spray.

Hydraulic sprayer - This equipment is a small hydraulic unit which is handy for small-scale use. It has a piston-type pump which operates at a pressure of 200 to 300 pounds per square inch and a tank of 25 gallons capacity. This sprayer is mounted on a pickup truck. Spraying to the point of run-off was accomplished with a dual nozzle hand gun.

Mite brushing machine - For rapidly counting mites and mite eggs, the device described by Hendersen and McBurnie (1943) was used with some modifications. This machine consists of two 3/4-inch spiral brushes which are rotated in opposite directions by an electric motor. A small metallic turntable mounted under the brushes is also operated by the motor, and on this a spherical glass disc of five inch diameter is placed. The brushes revolve at the rate of 1,400 to 1,600 rpm. A metallic cup-like structure encloses the revolving brushes and delimits the area on the glass disc.

The apparatus brushes the mites and eggs downward on the glass disc that is evenly coated with an emulsifiable oil that immobilizes the mites as they land on the plate as the infested leaves are passed between the brushes. In brushing, each infested leaf is passed twice from each end of the leaf to insure removal of mites and eggs. As the glass disc on the turntable is revolved at a constant rate of speed, the distribution of mites and eggs is relatively uniform over the glass surface.

To facilitate counting, the glass disc is placed on a counting grid and examined under a binocular microscope at 1 X and 4 X. The counting areas are divided as in Figure 1. In counting 20 per cent of the area is represented by the squares in both directions, i.e., one direction represents 10 per cent. The counted number of mites is then multiplied by either five or ten to establish the total number in the sample. When low mite populations are encountered the total area is counted.

Field Tests

The chemicals used for the 1970 field tests are detailed in Table 2. The purpose of the test was to assess the relative effectiveness of the different materials used (as listed in Table 2) on the apple pests of Red Delicious and McIntosh varieties of apples, and also to evaluate which chemicals are least toxic to the natural enemies of common apple pests.

The randomized complete block design (Steel and Torrie, 1960) was chosen. There were nine treatments including the untreated control. There were 90 trees in all with 45 of each of the two apple varieties. Each treatment was applied to 10 replicated single-tree plots of which five were McIntosh and five were Red Delicious. Each tree (replicate) was assigned a random number, and treated with the chemical assigned the same random number. Each tree, excluding controls, received approximately one and a half gallons of spray.

Spraying was done with the hydraulic sprayer, fitted with a hand gun,to the point of run-off. For the mite counts, 100 leaves were randomly picked weekly, within the periphery of each tree at a conveniently located height. The leaves were run through a mite brushing machine (Henderson and McBurnie, 1943), and the eggs and mobile stages were counted under a binocular microscope.

To date the mite counts are very low, partly because of the dormant oil treatment on the trees, and partly because of the tendency of mite populations to build up in the latter part of the summer (Asquith, 1970; Oatman, 1966). This being the case, it is not at all practical to run any statistical test on these data. Therefore only the theory of the proposed statistical analysis is discussed below.

The present tests involve two factors, one being the different chemical treatments and the other apple varieties. The statistical treatment is to be an analysis of variance, using Duncan's multiple range test (Steel and Torrie, 1960). Hopefully the data on the effects of these materials on the natural enemies can also be statistically analyzed to find out which of these materials are least toxic to the natural enemies.

In the mature orchard the McIntosh trees were sprayed with two different types of sprayers, the Kinkelder and the Speed Sprayer, as described earlier. Leaf samples were taken in the same manner as described above, and the available data, shown in Table 3, are used to determine if there is a difference between the control obtained by use of the two machines.

Since the data are limited, the analysis of variance was computed by use of the "t" test to determine whether the difference in spraying efficiency of the two machines is significant.

V. STATISTICAL ANALYSIS AND RESULTS

Using the data on the number of European red mite eggs, as presented in Table 3, an analysis of variance was computed to determine whether or not the sprayers showed statistically significant differences in their spraying efficiency for mite control.

The analysis of variance indicated that there was no significant difference between the spraying efficiency of the two sprayers at the .05 confidence level.

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TABLE 1

1914 Recommendations for Control of Apple Pests 1970

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Material & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Lepidoptera 1. Codling moth	Natural enemies Parasitization of eggs by a chalcid fly, Trichogramma pretiosa and a mite, Trombidium sp. Larvae are attacked by hymenopterous parasites, Pimpla annulipes; Macrocentrus delicatus; Ascogaster carpocapsae and a few others.	Spraying with arsenical poisons (arsenate of lead) Paris green (not commonly used), one pound of Paris green or four-six pounds arsenate of lead in 100 gals./water.	Two weeks after petal fall. Spraying for second brood varies greatly, may be late July and Aug.	-	Gardona* 75% WP, 2/3 - 1 lb. or Imidan* 50% WP, 1 to 1 1/2 lbs. or phosalone 3 EC, 1 to 1 1/2 pts.	First & second cover sprays	
					Guthion* 50% WP, 1/2 lb. carbaryl 50% WP, 1 to 2 lbs.	Third, fourth, sixth & seventh covers	Carbaryl should not be applied until third cover or at least 30 days after bloom to avoid thinning effects on apples.

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control: Materials & amounts in 100 gals./water	Chemical Control: Time	Non-chem. cont.	Chemical Control: Material & amounts in 100 gals./water	Chemical Control: Time	
	Birds are effec- predators. Banding the trunks with strips of burlap.				Gardona* <u>or</u> Imidan* <u>or</u> phosalone	Third, fourth, sixth & seventh covers	Same formulation in same dosages as for first and second cover sprays.
2. Leaf rollers							
Red-banded	-	-	-	-	Guthion* 50% WP, 1/2 lb. <u>or</u>	Pink, petal fall & first cover	Red-banded leaf roller became an important pest after the advent of DDT.
Fruit tree	-	Miscible oil, one part in 19 parts of water (for destruction of eggs) Arsenate of lead, 6 lbs. (for killing	Spray while trees are dormant. First		Gardona* 75% WP, 2/3 to 1 lb. <u>or</u> Imidan* 50% WP, 1 to 1 1/2 lbs.		Guthion*, Imidan*, Gardona* and phosalone applied in an up-to-pink spray will kill

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control: Materials & amounts in 100 gals./water	Chemical Control: Time	Non-chem. cont.	Chemical Control: Material & amounts in 100 gals./water	Chemical Control: Time	
		caterpillars)	application as soon as buds burst & Second, when blossom buds & cluster begin to separate.		or phosalone 3 EC, 1 to 1 1/2 pts.		adults of red-banded leaf roller. Guthion* and Gardona* will also control larvae of fruit tree leaf roller.
					Same as above plus Carbaryl 1 lb. active.	Fifth to seventh cover sprays	
Coleoptera Plum curculio	Practicing clean cultivation to reduce hibernating quarters, destroying and burning all trash.	Spraying with arsenate of lead alone or in combination with a fungicide.	Just after petal fall & three weeks	-	As recommended for codling moth. Can also use methoxychlor 50% WP, 3 lbs. in petal fall only.	Petal fall; first, second and third covers	Petal fall Proper timing, just ahead or at beginning of period of hot weather is essential.

(cont'd).

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control: Materials & amounts in 100 gals./water	Chemical Control: Time	Non-chem. cont.	Chemical Control: Material & amounts in 100 gals./water	Chemical Control: Time	
	Pruning the trees to admit more direct sunlight which is fatal to grubs within the fallen fruits. Tilling and plowing of soil to destroy pupae. Jarring trees in early morning when beetles are relatively inactive to dislodge them from tree; subsequent collection and destruction.		later. In severe infestations additional sprays may be necessary.	-			First Cover Make this application as soon as max. temperature reaches 75° F. Second Cover 7 days after first cover spray (fruits are exposed to curculio attack whenever temperature reaches 75° F or above). Dieldrin can also be used with permission of Pesticide Board, but is more toxic to bees.

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PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control: Materials & amounts in 100 gals./water	Chemical Control: Time	Non-chem. cont.	Chemical Control: Material & amounts in 100 gals./water	Chemical Control: Time	
Diptera Apple maggot	Orchards kept well cultivated, provide minimum protection to overwintering pupae.	Fruit and foliage covered with arsenate of lead spray.	At fly emergence in early July.	-	Carbaryl - 1 lb. active or Guthion* 50% WP, 1/2 lb. or Gardona* 75% WP, 1 lb.	Usually early July. Fourth through seventh cover sprays.	Spray all young and non-bearing trees during fly emergence (late June to Aug. 15 or later).
					or Imidan* 50% WP, 1 to 1 1/2 lbs. or phosalone 3 EC, 1 to 1 1/2 pts. or carbophenothion 25% WP, 1 lb.	Use carbophenothion only once from fourth cover on.	Do not use carbophenothion before bloom or in combination with ethion or Kerathane*.

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Materials & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Homoptera							
1. Rosy apple aphid	Judicious pruning, especially on young trees for removal of eggs. Crushing eggs on young trees with fingers or thin wooden paddle.	Spraying with "Black Leaf 40" (tobacco extract) 3/4 pt., adding 3 lbs. of soap/ 100 gals.	In spring	-	Superior oil, 2 gals.	Half-inch green.	Available as 60 or 70 sec. less probability of phytotoxicity with 60 sec. oil.
					Guthion* 50% WP, 1/2 lb.	Up to pink.	For best control of this and other aphids use Guthion* (50% WP, 1/2 lb.) or add ethion (25% WP, 1 lb.) to oil.
2. Green apple aphid	Same as above.	Same as above.	Same as above	-	Inclusion of one of following materials in regular application.	Second cover spray	Often appears early. Cover sprays as needed. Two or more applications may be needed.
					endosulfan 50% WP, 1 lb.		

(cont'd)

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PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Materials & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Homoptera (Cont.) Green apple aphid					phosphamidon 8 lbs./gal., 1/4 pt.		Will also control codling moth; gives some suppression of mites.
					demeton 26.1% SC, 1/2 pt.		Before leaves harden.
					parathion 15% WP, 1 lb.		Not on McIntosh, Cortland or related varieties.
					TEPP* 40% EC, 1/4 pt.		Should not use TEPP during very hot/humid weather since fruit-injury may result.
					dimethoate 2.67 lbs./gal. EC., 1 pt.		
					Imidan* 50% 1 to 1 1/2 lbs.		Trial basis only.
					phosalone 3 EC, 1 to 1 1/2 pts.		

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control: Materials & amounts in 100 gals./water	Chemical Control: Time	Non-chem. cont.	Chemical Control: Material & amounts in 100 gals./water	Chemical Control: Time	
Homoptera (Cont.) Green apple aphid					Same as second cover spray. NOTE: dosages are from N. Y. recommendations.	Third through fifth covers	Demeton very effective if applied thoroughly in third and fourth cover sprays.
3. San Jose scale	Lady bird beetles act as natural enemies. Judicious pruning away of tops & long sprawling branches of infested trees will often enable or orchardist to do more thorough work in spraying.	Fumigation with HCN gas of nursery stock. Several applications of 10 to 15% kerosene emulsion spray on apples. 25% crude petroleum emulsion spray on old apple trees.	During summer When buds are swelling in spring	-	Superior oil, 2 gals.	Half-inch green showing.	Oil each block at least once every three years, but preferably every year, to prevent build-up of scale. Where scale is already established increase oil to 3 gals. and repeat every year until controlled. Complete coverage essential.

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PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Materials & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Hymenoptera							
European apple saw-fly	-	-	-	-	Guthion* 50% WP, 1/2 lb. or Gardona* 75% WP, 1 lb. or Imidan* 50% WP, 1 to 1 1/2 lbs.	Petal fall Apply sprays before calyx cups close since both oviposition & hatching occur early.	
Acarina							
European red mite	—	—	—	—	Superior oil, 2 gals.	Half-inch green tip	Early control of red mite is very desirable to maintain full food producing

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Materials & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Acarina (Cont.) European red mite							capacity of leaves during period of bud formation. Less possibility of phytotoxicity with 60 sec. oil.
					Use of demeton 6 lbs./gal. EC, 1/4 pt.; Kelthane* 35% WP, 1 to 1 1/2 lbs.; ethion 25% WP, 1 lb.; tetradifon 1 lb./gal. EC, 1 qt.; or Acaralate 25% EC, 1 1/2 to 2 pts. suggested as miticides. NOTE: dosages are from N.Y. State recommendations.	First & second cover sprays.	Cover sprays as needed. Imidan* and phosalone will suppress mites if used in the seasonal program.

(cont'd)

PESTS	Slingerland and Crosby "Manual of Fruit Insects" (1914)			Agricultural Extension Service University of Massachusetts 1970			REMARKS
	Non-chem. control	Chemical Control		Non-chem. cont.	Chemical Control		
		Materials & amounts in 100 gals./water	Time		Material & amounts in 100 gals./water	Time	
Acarina (Cont.) European red mite					Use of demeton very effective (until leaves harden).	Third cover	Continue regular examination of leaves to check mite build-up.
					2 or 3 applications, 5 to 7 days apart, using tetradifon EC or ethion, Kelthane* or Acaralate* (dosages as above).	Fifth cover	Red mite may start to increase. Check intervals allowed before harvest for each material, especially before treating early varieties.
					Same as above	Sixth & seventh covers.	Spray undersides of leaves all through tree centers and tops.

* Trade Name

TABLE 2

Pesticides for Field Testing - 1970

No.	Materials[a]	Formulations[b]	Type	Manufacturer	Use[c]	Dosage Amts./ 100 gals. water	Where and when to apply	Days to harvest	Remarks
1	Plictran*	50% WP	Miscellaneous compounds	Dow Chemical Co.	M	5 oz.	Petal fall; one or two summer sprays	-	On experimental basis. Does not have complete registration.
2	Acaralate*	2E	DDT relatives (Diphenyl aliphatics)	Geigy Agr. Chemical	A	2 pints	Thorough coverage of tree. Pre-bloom or cover sprays. Repeat applications as needed.	14	Do not apply in combination with spray oils as injury may occur.
3	Animert*	W-20	-	Thomson-Hayward Chem. Co	A	1 lb.	Pink; during blossom time if necessary	82	On experimental basis. Has ovicidal-larvicidal effect on spider mite. Low toxicity to warm blooded animals. Will not harm bees or beneficial insects.

(cont'd)

2

No.	Materials[a]	Formulations[b]	Type	Manufacturer	Use[c]	Dosage Amts./ 100 gals. water	Where and when to apply	Days to harvest	Remarks
4	Galecron*	4 EC	Non-phosphate	Ciba Agro-Chem Co.	M,I	1 pint	Full coverage spray when mites first appear.	-	For bearing trees as a dormant spray up to silver tip only.
5	Furadan*	4 F	Carbamate	Niagara Chem. Div	I	1 pint	Seasonal spray	-	Controlls mites also.
6	Imidan*	50% WP	Organophosphate	Stauffer Chem. Co.	I,A	1 1/2 lbs.	Pre-pink, petal fall & seasonal spray program	7	Relatively less hazardous
7	Tedion*	1 Miscible	Sulfones	Niagara Chem. Div	M	2 pints	Thorough coverage of tree. Pink, petal fall and cover sprays	-	Do not make more than four applications after petal fall and not more than 500 gals. of spray/ acre application. Do not feed pomace from treated apples to livestock.

(cont'd)

No.	Materials	Formulations	Type	Manufacturer	Use	Dosage Amts./ 100 gals. water	Where and when to apply	Days to harvest	Remarks
8	Kelthane*	18.5% EC	DDT relatives (Diphenyl aliphatics)	Rohm & Haas	M	2 pints	Thorough coverage of tree, especially undersides of leaves. Petal fall to second cover.	7	Innocuous to bees and beneficial insect predators. Do not use with glyodin (fungicide) in late cover sprays.
9	R-10044	65% WP	-	Stauffer Chem. Co.	I	1 lb.	Thorough coverage of tree	-	Not registered for commercial use. For experimental purpose only. Controls mites also.
10	Guthion*	50% WP	Organophosphate	Chemagro Corp.	A, I	Read remarks	Full coverage spray	15	1 lb./10 gals. water when used in Kinkelder mist sprayer and 1 lb./100 gals. water when used in Hardie speed sprayer. Do not use more than eight times a season.

(cont'd)

No.	Materials [a]	Formulations [b]	Type	Manufacturer	Use [c]	Dosage Amts./ 100 gals. water	Where and when to apply	Days to harvest	Remarks
11	Cyprex	65% WP	-	American Cyanamid Co.	Fung.	Refer to remarks	From pre-bloom through first cover application at 5- to 7-day intervals or as needed.	7	3/4 lb./10 gals. water when used in Kinkelder mist sprayer and 1/2 gal./ 100 gals. water in Hardie speed sprayer. Subsequent cover sprays as needed and for dosage consult label. Suppresses development of European red mite.
12	Thiram*	65% WP	-	DuPont Co.	Fung.	Refer to remarks	Pre-bloom calyx and early cover sprays	-	1 1/4 lbs./10 gals. water when used in Kinkelder mist sprayer and 1 lb./ 100 gals. water in Hardie speed sprayer.

(a) = Trade Name

(b) WP = Wettable powder; EC = Emulsifiable concentrate (liquid);
E = Emulsifiable solution; F = Flowable paste;
W-20 = 20% WP.

(c) M, A = Miticide, Acaricide; I = Insecticide; Fung. = Fungicide
Above information from respective chemical labels.
For further details the respective chemical labels should be examined.

TABLE 3

Counts of European red mites and their eggs collected from apple leaf samples following chemical treatments with two different sprayers. Belchertown, Mass. 1970.

Date of collection	Kinkelder sprayer [1]		Speed sprayer [1]	
	Motile stages	Eggs	Motile stages	Eggs
May 29, 1970	-	49	-	43
June 5, 1970	-	42	-	75
June 11, 1970	69	200	29	18
June 17, 1970	41	139	11	54

[1] Each figure below indicates the number of mites or mite eggs collected from a 100-leaf sample with mite-brushing machine.

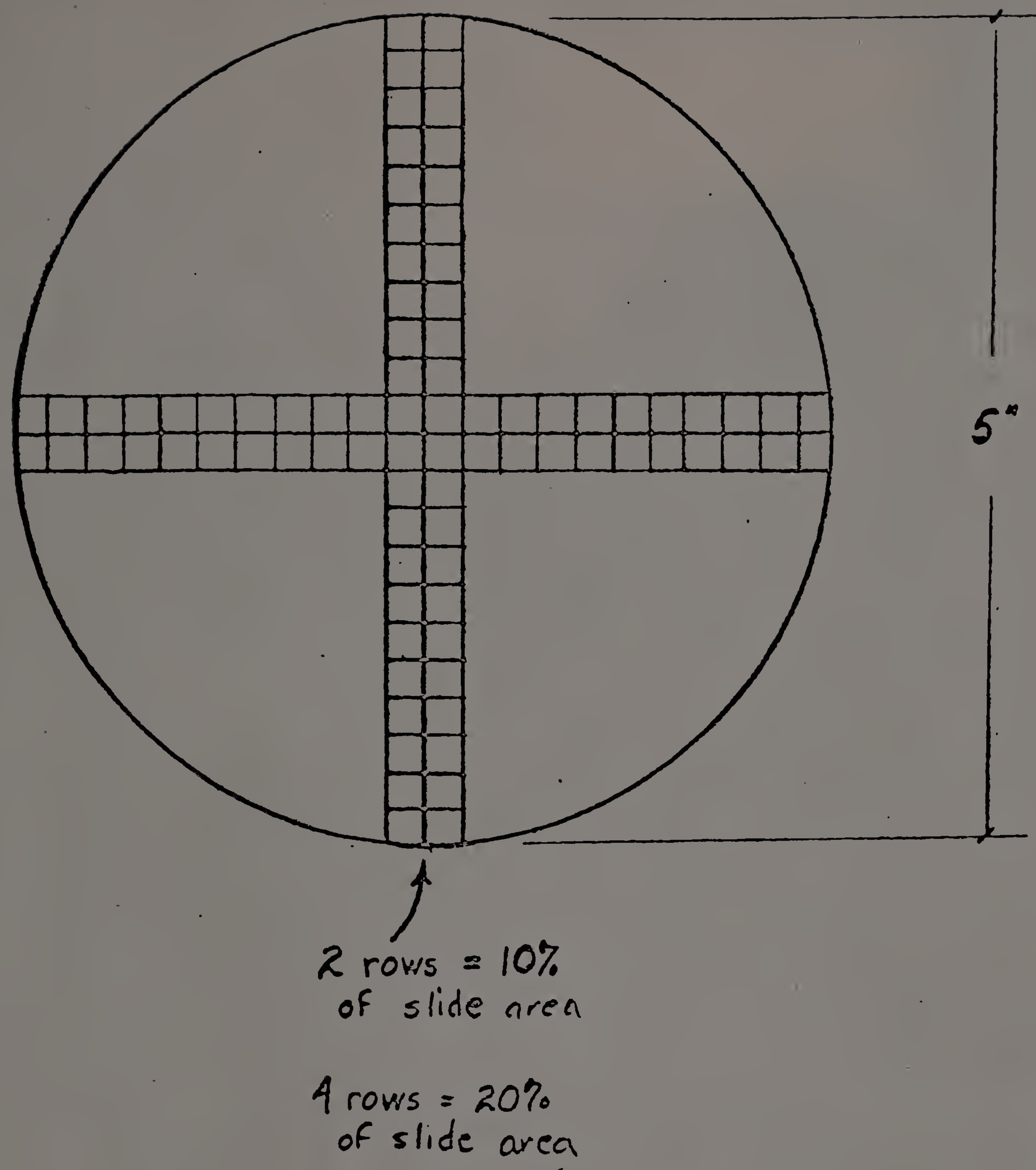

Figure 1. Diagram of counting grid with the mite-brushing machine