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Integrated Pest Management of Insects and Mites Attacking Pears in Southern Oregon

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Contents

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Integrated Pest Management of Insects and Mites Attacking Pears in Southern Oregon

Peter H. Westigard, Porter B. Lombard, and Donald W. Berry

Introduction

This publication deals with the development of integrated pest management of insect and mite species that attack pears in southern Oregon. Since about 1900, when the pear industry became firmly established in this area, losses from arthropod pests have been an important and occasionally limiting factor to the continuous production of high-quality fruit. As is true of other agricultural crops, the pest control tactics utilized by pear growers have passed through distinct stages. In southern Oregon, these control stages can be categorized as (1) utilization of marginally effective inorganic pesticides combined with labor-intensive cultural control methods (ca. 1900-1945), and (2) nearly sole reliance upon synthetic organic pesticides applied on a calendar or preventative schedule (1945-present).

Both stages have had associated problems, including sub-economic control (primary stage 1), environmental contamination (stage 1 and 2), illegal chemical residues (primarily stage 1), pesticide resistance (stage 2), and destruction of beneficial species and subsequent resurgence of nontarget secondary pests (primarily stage 2).

Over the years, these problems periodically have threatened the survival of the pear industry either directly through lack of control, caused by resistance, or to the absence of effective chemicals, or indirectly by pesticide legislation attempting to reduce the threats to user or consumer safety or to the environment. More recently, an attempt has been made to resolve the contradictory demands of a society that on the one hand asks for a constant supply of high-quality fruit free of pest injury, but on the other is concerned with the potential negative side effects of pesticide usage. This approach to pest control has been referred to as integrated pest management (IPM). The objectives of this system are "to optimize pest control in terms of overall economic, social, and environmental values" (Glass, 1975). The pest management system of control techniques attempts to utilize an array of suitable control techniques rather than relying on a single disruptive tactic. The tactics suggested in IPM include the use of biological control agents (predators, parasites, and pathogens), host plant resistance, cultural controls, pesticides, and behavioral controls. Summarizing the studies conducted in southern Oregon over the last 15 years, we will attempt to show the applicability of the various control tactics tested to each major pest.

Another important difference between IPM and the stage-two approach to pest control lies in the acceptance of sub-economic pest densities under IPM, rather than demanding nearly total elimination as a criterion for successful control. This idea is most basic to integrated pest management as, for example, the utilization of biological control agents as a viable control tactic depends upon residual pest levels to insure the survival of natural enemies.

The above concept, however, demands that a new type of data base be developed before any control tactic is chosen, namely the establishment of an economic injury level and of an economic injury threshold for pest density. The economic injury level has been defined by Stern et al. (1959) as "the lowest population density that will cause economic damage. Economic damage is the amount of injury that will justify the cost of artificial control measures . . ." These same authors define economic threshold as "the density at which control measures should be determined to prevent an increasing pest population from reaching the

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economic injury level." The establishment of economic injury or economic threshold densities is, however, not an easy calculation as crop value varies dramatically from year to year, orchard to orchard, and variety to variety. Estimates of these values are given on pages 35-38 and in the sections dealing with individual pest species.

Another requirement for IPM that relates to economic injury thresholds and pest damage levels is sampling. Sampling of pests and for their natural enemies in an IPM program requires a methodology that relates pest density to potential economic loss. With a high-value crop such as pears, the economic tolerance for injury is quite naturally low and, given the variability encountered in pest distribution, the required sample size is often large and sometimes economically prohibitive. Sampling procedures then are another critical aspect of IPM implementation and are discussed in some detail for each major pest.

In addition to the entomological aspects of integrated pest management, several important non-entomological imputs may determine to a great extent the feasibility of IPM implementation. These include horticultural and economic considerations, which are discussed on pages 35-39 as limited data and background permit.

Though the data base for pear pests is far from complete, it is hoped that it is sufficient to emphasize the holistic and necessarily complex nature of the IPM concept.

References

The scope of this study is purposefully limited to the development of a data base to promote the implementation of an IPM program for pears in southern Oregon. Our principal sources of information are drawn from studies conducted in the area between 1963 and 1978. In some cases we have used data from other geographic areas where the information has been tested and appears to fit southern Oregon conditions. In addition to the specific references cited, we have made use of several review articles, especially those by Hoyt and Burts (1974), Madsen and Morgan (1970), and Barnes (1959), which deal with integrated pest control in orchard ecosystems.

Codling Moth

The codling moth, *Laspeyresia pomonella* Linn., has been a key pest in pear orchards since the earliest days of pome fruit production in southern Oregon's Rogue River Valley. Records from the area between 1916 and 1945 indicate that despite the use of chemical control programs, damage attributed to this species resulted in losses of between 5 and 30 percent of the pear crop annually (Cordy, 1977). During this early period, the complete program included six or seven summer sprays of inorganic insecticides applied by hand using high-pressure equipment.

When DDT first was introduced in 1946, results were spectacular, reducing the level of wormy fruit to near 0 with 3 to 4 applications. This low infestation level, with few exceptions, has been maintained to the present day. As described below, the codling moth, though presently well-controlled, stil remains the most important arthropod pest in southern Oregon pear orchards.

Figure 1. Codling Moth Larva

Life History

The codling moth can be considered to be oligophagous. It attacks a variety of tree crops ranging from nut crops to stone and pome fruit crops. The basic life history of *L. pomonella* is similar on all hosts. The species overwinters as a diapausing mature larva. This stage is found predominately in cracks or crevices or under loose bark on the major scaffold limbs or trunk of the host tree. Some overwintering larvae also may be found in soil in close proximity to the tree crown.

With diapause termination in late winter, the mature fifth instar larvae pupate and, depending upon temperature, adults begin to emerge in early spring. First adult flight in southern Oregon usually occurs in mid- to late April. The flight pattern of the adult is directed by abiotic factors, including temperature. California workers have found moth flight restricted by temperatures below 55° F or above 80° F (Batiste et al., 1973). These parameters also seem to fit conditions in southern Oregon. Since they determine the pattern of codling moth flight, these factors are important considerations in the interpretation of adult monitoring devices used to time the application of control tactics directed toward this stage.

After emergence and mating, the female moth begins to deposit eggs on or near fruit. Our observations indicate the presence of fruit is a necessary stimulus for oviposition. Few eggs are laid in harvested orchards or in orchards where fruit has been lost because of spring frosts.

Eggs are laid singly on leaves or fruit and pass through distinct developmental stages. When first laid, eggs are translucent but change in appearance as the embryo develops. On pears, the majority of eggs are laid on the underside of leaves with decreasing numbers laid on fruit, fruit stems, or on the upper leaf surface (Table 1).

Table 1. Ovipositional sites of the codling moth on the 'Bartlett' pear variety, 1970-1971

	1970	1971	Average
Number of eggs	254	212	233
Percent found on			
underside of leaf	58.2	89.6	73.9
upper side of leaf	8.5	4.7	6.6
woody portion of fruit spur	11.7	1.4	6.6
base of stem	1.1	0.9	1.0
on fruit	19.6	3.3	11.4

Upon hatching, the first instar larva begins a pattern of search for a suitable fruit entry site. There appears to be a significant difference between pear host varieties in the success of larvae to enter fruit. These differences and their meaning to IPM are covered in more detail on page 7.

When the immature larva has successfully entered the fruit, it will generally penetrate to the seed cavity. After completion of four molts, the larva is mature and will leave the fruit to seek a pupation site.

Under southern Oregon conditions, codling moths usually complete two generations per year. A partial third generation has been reported in the area (Yothers and Van Leeuwen, 1931). A summary of the average time for appearance of

Table 2. Phenological events of the codling moth in southern Oregon (After Yothers and Van Leeuwen, 1931)

Phenological event	Range in date for *maximum* appearance of stages 1918-1922
Overwintering	
Pupation of larvae	April 20-May 8
Emergence of adults	May 7-June 4
1st summer generation	
Oviposition	May 12-June 17
Egg hatching	May 28-June 26
Pupation	June 19-July 21
Moth emergence	July 9-Aug. 5
2nd summer generation	
Oviposition	July 14-Aug. 30
Egg hatching	July 27-Aug. 30
Pupation	Aug. 6-Aug. 23
Moth emergence	Aug. 22-Sept. 7
3rd summer generation	
Oviposition	Aug. 25-Sept. 12
Egg hatching	Sept. 1-Sept. 21

the various stages is given in Table 2. The data given in Table 2 represent the range in dates over a five-year period when the maximum number of a particular stage was present. The time span indicating the first or last appearance of stages is naturally much greater.

Since temperature is an important parameter describing codling moth development, researchers in California (Pickel, 1976) and Michigan (Riedl et al., 1976) have attempted to construct a predictive model to relate codling moth phenology to temperature regimes. These models have been tested under southern Oregon conditions and appear to offer some promise in predicting important phenological events (Table 3).

Table 3. Phenological events of the codling moth in 1976 as predicted by temperature models compared to observed events under southern Oregon conditions

Event	Dates predicted: Univ. Calif. Model	Dates predicted: Michigan State	Dates observed
First moth in Pheromone traps		....	April 20
1st Oviposition	April 30	April 30	May 12[1]
1st Egg hatch	May 12	May 15	May 13
1st larval spin in bands	June 22	July 4	June 30
1st emergence summer moths	July 10	....	July 19

[1] The first egg was found in 'black head,' or late stage of development, indicating oviposition having occurred some time prior to the date indicated.

Damage

The damage caused by the codling moth is inflicted by the larva in its penetration into the pear flesh (Figure 1). These entries are not only unattractive to consumers but also cause problems in sorting and storage of fruit. The allowable damage by the codling moth as determined by the various grade standards set for the fresh fruit market is nearly zero (page 37). In essence, fruit infested with codling moth damage to offset present control costs is in the range of 1 percent fruit loss (page 38).

Sampling

Several types of population monitoring have been used for the codling moth, including, for adults, the use of fermenting bait traps, blacklight traps and, most recently, sex pheromone baited traps. These devices have been used primarily as an aid in the timing of pesticide treatments. Recently, the pheromone traps also have been shown to be useful in determining the need for treatment based on estimates of population density.

Adult Sampling for Timing

The proper timing of treatment depends upon the type of activity exhibited by the control agent along with the availability and sensitivity of sampling devices to determine the pest stages present. In the case of the codling moth, the adult and egg stages represent non-injurious forms which, if properly monitored, can forecast the proper treatment timing prior to injury expression. Historically, the adult stage of the codling moth has been used in this manner. Field detection of eggs is time consuming, especially at low-density levels.

Treatment timings in southern Oregon usually take the form of detecting, with pheromone traps, the time of the first substantial flight of the overwintering and of the first summer generation male moths. When these are detected, a pesticide treatment usually is recommended. Overwintering adults emerge for about two months and, with a 2- to 3-week residual effect of available pesticides, an additional spray routinely is applied about 30 days following the initial treatment. Depending upon the harvest period of the pear variety involved, an additional 1 or 2 sprays are applied for the first-generation summer moths which begin to appear in mid- to late July.

A typical preventive spray program utilizing pheromone trap catches for proper timing is presented in Figure 2.

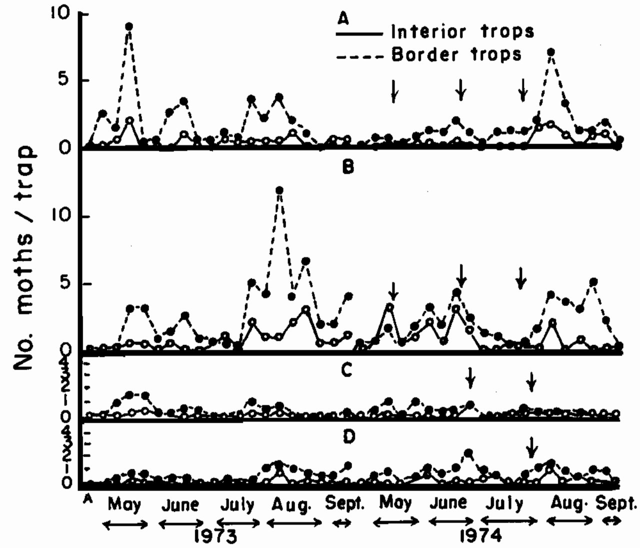

Figure 2. Codling moth catches in sex pheromone baited traps in four southern Oregon pear orchards. Arrows in 1974 indicate date of pesticide application. Orchards A and B represent typical preventive programs. Modified programs used in Orchards C and D were based on catches exceeding economic threshold of 2 moths/interior trap/week. Dashed lines are catches in border traps and are thought to represent immigrating males.

Adult Sampling for Treatment Need

Though the pheromone traps have been useful in proper pesticide timing, their main contribution to IPM is made by relating the magnitude of moth catch to potential larval damage and forecasting the need for treatment. As will be discussed in other sections, a reduction in the number of pesticide sprays needed for control of the codling moth will enhance the survival of several important predators and parasites of other pear pests.

Preliminary work in southern Oregon to evaluate the relationship between pheromone trap catches of male moths and damage followed work by Madsen and Valenti (1973). In these Canadian tests, one trap was used to monitor about two acres of orchard area and if catches exceeded 2 moths per trap per week a spray was recommended. The above system was modified to suit southern Oregon conditions. The initial modifications included the placement of traps along orchard borders to intercept immigrating males. This change was necessitated by the high numbers of abandoned trees in southern Oregon. Using the above system in 1973-74, it was shown the number of codling moth sprays could be reduced as much as 75 percent compared to a standard preventive program (Figure 2).

To adjust for non-entomological grower practices such as irrigation schedules and for differences in varietal susceptibility to codling moth damage, other modifications have been made in the codling moth monitoring program. Work in 1975-76 showed that economic damage was avoided on the Bartlett cultivar by postponing sprays until an average of 10 moths per interior trap had been accumulated. On the D'Anjou variety, a level of 20 moths per trap could be tolerated (Table 4). In these studies, the total number of moths caught was accumulated until the above levels were reached, then a chemical treatment was applied. Following treatment, moth accumulation started again after a 14-day period. This 14-day interval represents the approximate period of time toxic chemical residues would be present on fruit and foliage and moths caught during this time would not represent an economic threat. The somewhat tentative criteria for treatment levels for the codling moth are given in Table 5.

Table 4. Codling moth damage to Bartlett and D'Anjou fruit after treatment schedule based on pheromone trap catches of different magnitudes

	Percent infested fruit when treated at number of moths per trap	
Pear variety	10 moths per trap	20 moths per trap
Bartlett	0.55	1.05
D'Anjou	0	0.30

Table 5. Tentative criteria for the need to apply chemical treatment for economic supression of the codling moth

		Accumulated moth catch/interior trap		
		Variety		
Period	♂ moths accumulated from	Bart-lett	D'-Anjou	Treat-ment
1st spray period ca May 10-20	1st ♂ catch	> 10 < 10	> 20 < 20	yes no
2nd spray period ca June 10-20				
A. treated 1st spray period	14 days after 1st spray	> 10 < 10	> 20 < 20	yes no
B. not treated 1st spray period	1st ♂ catch	> 10 < 10	> 20 < 20	yes no
3rd spray period ca July 20-August 5				
A. treated 1st or 2nd spray period	14 days after last spray	> 10 < 10	> 10 < 10	yes no
B. not treated 1st or 2nd spray period	1st ♂ catch	> 10 < 10	> 10 < 10	yes no

Control Tactics

Biological Control

In the absence of chemical treatments, the codling moth is attacked by a variety of biological agents. These include egg, larval, and pupal parasites and predators as well as disease organisms. Unfortunately, these are unable to maintain the species under a commercially acceptable degree of control. Studies in an unsprayed Bartlett pear orchard from 1964-1971 showed codling moth infestation ranged from 22 to 81 percent and averaged 42 percent (Table 6). In the above tests, the mortality to eggs and early larval instars was assessed. Egg mortality averaging 26 percent was measured and attributed primarily to the activity of parasites and predators (Table 7). Mortality to the first instar larvae averaged 55 percent and was thought to be primarily due to host plant resistance (antibiosis). The natural mortality to other codling moth stages was not measured in these tests.

Table 6. Codling moth damage to unsprayed 'Bartlett' pears during the years 1964-1971, Medford, Oregon

Year	Percent infested fruit at harvest
1964	54
1965	41
1966	23
1967	49
1969	22
1970	81
1971	27
Average	42.4

Chemical Control

As described previously, the natural controls operating on the codling moth are unable to maintain population density at a level below the current injury threshold of about 1 percent. Therefore, this pest has required the use of artificial controls, namely insecticides. From the early 1900s to the mid 1940s, growers relied upon inorganic chemicals to achieve codling moth control and from the 1940s to the present, upon synthetic organic pesticides. Both types of compounds have produced problems related to the side effects of their use. These are discussed below.

1. Inorganic Insecticides

From the early 1900s to the introduction of DDT in 1945, arsenical insecticides were the principal chemicals used for codling moth suppression. For a short period, 1943-1945, cryolite was used commercially on a limited basis. The problems

Table 7. Field mortality of egg and first instar larvae of codling moth on 'Bartlett' pear, 1970-1971, Medford, Oregon

Year	Eggs					1st instar larvae			Total egg & larval mortality
	Number found	Number parasitized	Number shriveled	Number disappeared	Percent mortality	Number entering fruit	Number lost	Percent mortality	
1970	85	7	9	1	20	16	52	76	81
1971	90	13	8	9	33	39	21	35	57
X	87.5	10	8.5	5	26.5	27.5	36.5	55	69

associated with use of the arsenicals included relatively poor control (infestations of 10 percent were not uncommon in treated orchards), excess residues on fruit (the growers developed a special fruit wash to remove arsenic residues), and the buildup of toxic residues of these compounds in the soil.

2. *Chlorinated Hydrocarbons*

DDT was the only chlorinated hydrocarbon insecticide used for codling moth control in southern Oregon. This compound was used for the first time in 1945 and by 1947 had essentially replaced the inorganic compounds. Because of DDT's persistance and mode of action, the number of applications required to obtain control was reduced from 6 or 8 using inorganic chemicals to 2 or 4. In addition, the use of DDT also reduced the amount of damage attributed to the codling moth to near zero compared to the 5 to 30 percent losses experienced with the previously used inorganic compounds.

a.) Residues. No significant problems with DDT residues on pear fruit were experienced in southern Oregon during its period of use (1947-1960). This was due primarily to the lowered number of applications necessary to achieve control and to the relatively high residue permitted by law (7 ppm). Buildup of DDT and its metabolites in the soil, however, has been of concern. In 1960, it was estimated that nearly one-half the DDT used had accumulated in the orchard soil. By 1965, five years after the discontinuance of DDT in pear orchards, the residue had decreased by only 50 percent, and in 1975, by 75 percent (Table 8).

Table 8. DDT and metabolites in pear orchard soil in southern Oregon in 1975[1]

Total applied per acre 1946-1967	DDT and Metabolites present in 1975 as percent of 1967 level
169 lbs. a.i.	30.3 percent

[1] Analysis made by Kiigimagi and Terriere, Oregon State University, Corvallis.

b.) Effects on non-target species. It is somewhat difficult to assess the total effect of DDT on non-target species in southern Oregon pear orchards. On the one hand, the increase in spider mite levels was dramatic with the two-spotted mite becoming an annual rather than an occasional pest. On the other hand, the incidence of damage due to so-called minor pests such as fruit trees leaf roller, pear thrips, and green fruit worms decreased in severity.

3. *Organophosphorus Chemicals*

Only two organophosphate compounds, Azinphosmethyl (Guthion®) and Phosmet (Imidan®) have been used widely in southern Oregon for codling moth control. As was the case for DDT, both phosphate compounds have produced negative as well as beneficial effects in the management of pear pests. First introduced in the late 1950s, azinphosmethyl gave excellent control of the codling moth and of the recently introduced pest, the pear psylla. Imidan was first used commercially in 1967.

a.) Residues and resistance. No problems have been experienced in the accumulation of excess residues on harvested pears nor to resistance by the codling moth to the phosphates pesticides.

b.) Effects on non-target species. The two phosphate insecticides used for codling moth control have been useful in the establishment of an integrated control program for spider mites on pears. This program developed as a result of the selectivity exhibited by azinphosmethyl in providing control of the codling moth but not eliminating the important spider mite predator, *Metasielus occidentalis* Nesbitt (see section on spider mites, pages 9-18). The organophosphates also have been effective in the suppression of several non-target phytophagous species.

On the negative side, the use of the organophosphates has caused the destruction of a great many parasitoids and has resulted in the increased density of the pear psylla. This has become especially evident with the failure of these chemicals to provide direct psylla suppression (Table 9).

Table 9. Effect of Azinphosmethyl (Guthion) and Dimilin® treatments on codling moth control and upon selected predators and parasites of the pear psylla. Applied May 4, June 5, July 12, 1977

Treatment rate a.i./acre	Percent codling moth infested fruit	Percent post treatment reduction in parasitoids of pear psylla[1] compared to untreated	Percent pear psylla injured fruit
Dimilin® 0.5	6	20	19
Azinphosmethyl 1.0	1	50	58
Untreated	79	....	28

[1] Includes *Trichnites* sp., *Chrysopa* sp., *Deraeocorus brevis*, *Nabis* sp., *Anthocoris* sp., and *Coccinellids*.

4. *Chlordimiform*

With the appearance of resistance by the pear psylla to phosophate pesticides in the early 1970s, southern Oregon pear growers shifted to chlordimiform as the material of choice for control of both the above pest and for codling moth.

a.) Effects on non-target species. Chlordimiform is highly toxic to predaceous mites and with the widespread use of this chemical, beginning in 1970, the integrated program using *M. occidentalis* to achieve commercial suppression of spider mites was essentially destroyed. In addition, the exclusive use of this compound during the summer months led to increased damage from the San Jose scale, a pest apparently suppressed by the organophosphate materials previously used.

5. *Experimental Synthetic Compounds*

While many dozens of experimental compounds have been screened for their effectiveness on the codling moth, most of these have belonged to the chemical groups mentioned above. Two recently tested chemicals, however, bear some consideration because they may be registered for commercial use.

a.) Pyrethroid insecticides. Three synthetic pyrethroid compounds have been tested in southern Oregon pear orchards. These chemicals appear to have about the same range of effectiveness and produce about the same type of disruptions to non-target species. In general, the pyrethroids have (1) provided excellent codling moth control at unusually low dosages, (2) given commercially acceptable pear psylla control and (3) caused dramatic increases in spider mite levels. Table 10 gives an example of the effects measured following the use of two such pyrethroids.

b.) Dimilin. Dimilin 1-(4-chlorphenyl)-3-(2,6-diflurobenzoyl) urea acts on the egg stage of the codling moth, preventing successful completion of embryonic development, and for that reason can be considered an insect growth regulator (IGR). Control of the codling moth with this chemical has been effective if it is applied before egg laying. This requires more precise timing of application and may require the use of the temperature-phenology model described earlier (page 3). Compared to other compounds, Dimilin does not appear to cause major disruptions to non-target beneficials. Table 9 presents data dealing with the use of Dimilin for codling moth control and effects on non-target species as compared to that resulting from the standard azinphosmethyl program.

Table 10. Control of the codling moth with two synthetic pyrethroids and effects on the two-spotted spider mites. Treated May 7, June 7, July 12, 1977

Material and rate a.i./100 gallon water	Percent codling moth infested fruit	Average Number 2-spotted mites/ leaf post treatment
Permethrin 0.2	0	15.6
Fenvalerate 0.05	0	18.2
Chlordimiform 0.5 (standard)	1.0	0.2
Untreated check	10.3	3.4

Host Plant Resistance

In the section dealing with biological control of codling moth, it was shown through the use of a modified life table that about 70 percent of the eggs and first instar larvae do not reach maturity. Of this, more than 75 percent was attributed to first instar larval mortality. In subsequent studies, it was suggested this mortality was caused by the inability of the young larva to enter the pear and it was found this was not only greater on pears than on apples but also varied with the pear cultivar being attacked and with time. Examination of Figures 3 and 4 will show that of the pear varieties tested, the Bartlett cultivar was the most susceptible, followed by Bosc, Comice, and, finally, by the D'Anjou variety. The phenology of resistance shows that a period of relatively moderate tolerance is followed by a longer period of high tolerance and then by a period of high susceptability. The difference measured in host suitability is explained by the formation of "stone cells" below the epidermal layer. This process of lignification usually occurs in early June in southern Oregon. Stone cells are present until the ripening process is initiated. This would account for the early season susceptibility of all varieties, followed by decreased ability of larvae

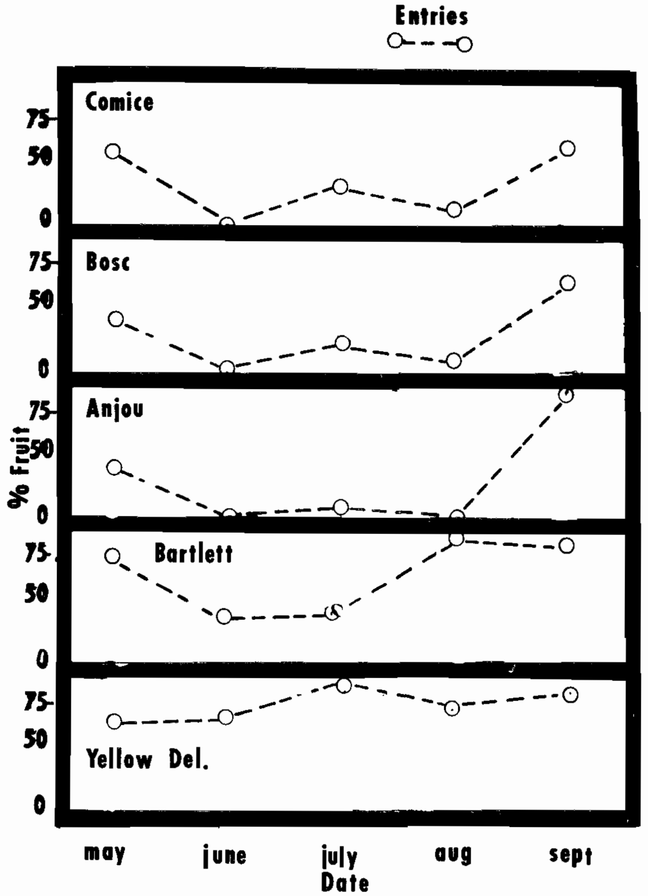

Figure 3. Relative susceptability of pear and apple varieties to entry by first instar codling moth larvae. Laboratory tests.

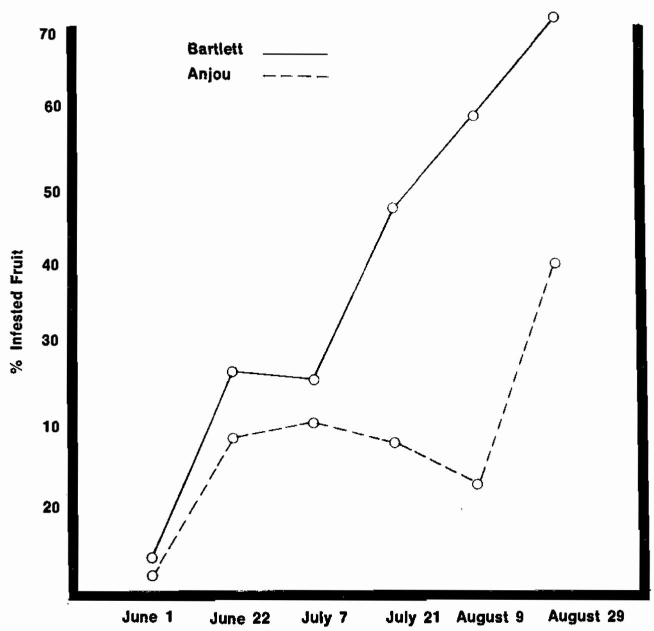

Figure 4. Relative infestation by codling moth of two pear varieties under 1972 field conditions.

to enter fruit and, finally, by increased susceptibility toward harvest period.

From a IPM standpoint, the above findings have allowed the establishment of a higher economic injury threshold for the D'Anjou cultivar and offer the potential for lowering the number of chemical treatments required on the winter pear varieties.

Cultural Control

As mentioned in the introduction, several non-entomological considerations bear on the potential for implementation of an IPM program. Those most pertinent to codling moth control in southern Oregon include irrigation scheduling, overtree irrigation and orchard sanitation practices.

1. Irrigation Schedules

The orchard land in southern Oregon requires summer irrigation to maintain tree vigor and to properly (commercially) size the pear fruit. Typically, growers apply four and possibly five flood irrigations between early June and late August. Because of heavy soil types in the area, once an irrigation has begun it is virtually impossible for heavy orchard equipment, such as air blast sprayers, to be transported through the orchards. This prevents, to some extent, the use of curative spray treatments and forces growers to rely upon the more disruptive practice of preventive spray scheduling. Pest control decision-making periods during the late spring and summer months are therefore limited and, once made, must provide predictable and commercially acceptable control for a minimum three-week period. In addition, irrigation scheduling makes it difficult to utilize some of the important, finely timed pest management tools such as the codling moth temperature-phenology models developed in California and Michigan which allow for more precise timing of pest control procedures.

2. Overtree Irrigation

A major limiting factor in the production of pears in southern Oregon is the nearly annual occurrence of severe spring frosts. To minimize frost damage, growers have employed orchard oil heaters, wind machines, and, more recently, overtree sprinklers. The latter type of frost prevention is a multi-purpose installation also used for summer irrigation and tree cooling. The use of the overtree irrigation in summer months has been found to have deleterious effects on pesticide residues, in-

Table 11. Comparison of pesticide deposits on pear leaves following 14 hours of overtree irrigation

Treatments			Deposit remaining after 24 hours (Percent)		Net loss due to sprinkling Percent
	Active rates				
Material	(per ha)	(per acre)	Non-sprinkled	Sprinkled	
Azinphosmethyl 50% wp	1.4 kg	1.25 lb.	97	66	31
Azinphosmethyl + Biofilm[1]	1.4 kg / 5.9 liter	1.25 lb. / .63 gal.	81	65	16
Azinphosmethyl + Volck Supreme Oil	1.4 kg / 37.4 liter	1.25 lb. / 4 gal.	99	65	34
Azinphosmethyl + Biofilm + Volck Supreme Oil	1.4 kg / 5.9 liter / 9.4 liter	1.25 lb. / .63 gal. / 1 gal.	89	59	40

[1] Biofilm is a product of Colloidal Products with the active ingredients of alkylarylpolyethoxy ethanol, fatty acids, glycol ethers, di-alkyl benzenedicarbonoxylate, and isopropanol.

cluding those needed for codling moth control. Table 11 shows the effect of washing from overtree irrigation on deposits of several materials registered for codling moth control. The reduction in deposit has not been related to an increase in codling moth damage. At least a partial solution to this problem was found by reversing the normal spray-then-irrigate pattern. This in turn demanded that other orchard practices be modified. That is, in place of clean cultivation, orchard rows were planted to sod, making possible the use of orchard spray equipment soon after irrigation.

3. *Orchard Sanitation*

Figure 2 presented the codling moth catches recorded in pheromone traps in several Rogue Valley orchards. These catches are divided between those found in pheromone traps placed in the inside of the orchards and those found in traps placed around the orchard periphery. These border traps captured nearly 80 percent of the moths recorded. This situation has been typical of most orchards monitored in southern Oregon and is thought to be caused by immigration of codling moths from abandoned pear trees to commercial orchards. In the early 1970s a program of abandoned tree removal was initiated by southern Oregon pear growers. If successful, it will reduce the pest innoculum harbored in these abandoned blocks.

Spider Mites

Four species of tetranychid mites are pear pests in southern Oregon. These are the two-spotted, *Tetranychus urticae* (Koch); European red, *Panonychus ulmi* (Koch); yellow, *Eotetranychus carpini borealis* (Ewing); and McDaniel, *Tetranychus mcdanieli* (McGregor) spider mites. Of these, the two-spotted mite is the most widespread and the most important economically. Efforts to build an integrated pest management program for spider mites have dealt predominately with *T. urticae* (Figure 5) and in-depth data concerning the other species are lacking.

The two-spotted mite first was reported as a pest of pears in 1924 but formal identification was not made until 1937. From that time until the mid 1940s, this species caused sporadic but oc-

Figure 5. Two Spotted Spider Mite

casionally severe damage. With the introduction of synthetic organic pesticides in 1945, and to the present time, the two-spotted mite can be classified as an annual pest that now receives 2 to 3 summer acaracide treatments in most commercial orchards.

The second most common and destructive spider mite is the European red mite which was not reported from southern Oregon pear orchards until 1953. At present, it is controlled by an application of petroleum oil in the dormant period and by summer sprays primarily directed toward the two-spotted mite.

The final two species of spider mites are found only in a few scattered orchards and only during some years. The yellow mite first was identified in 1938 and the McDaniel mite in 1972. Commercial control measures for these species rely upon acaracides, usually the same ones used for the two-spotted mite.

Life History

Though the life histories of these tetranychid mites are similar, several differences are important to their management. Variations in biological attributes determine (1) suitable timings for control tactics, especially chemical controls; (2) reproductive potential which influences damage potential; (3) intra- or inter-tree distribution as it bears on sampling procedures; and (4) behavioral differences, especially those dealing with species vagility.

Except for the European red mite, the spider mites attacking pears overwinter as diapausing adult females. These forms are found in cracks, crevices, and behind bark flakes on the trunk, on major scaffolds, or on smaller limbs. Depending upon temperatures, the three species move from overwintering sites about late March or early April. This period coincides with the opening of pear buds, the initial feeding sites. Chemical treatments applied during the dormant or delayed dormant period for control of other pests rarely have depressing effects on populations of the above three spider mite species.

The European red mite overwinters in the egg stage, exposed on fruit spurs and on smaller, newer pear wood. Chemical treatment can be applied with success against this species in the prebloom period. Hatching of the overwintering eggs occurs about mid-April and normally coincides with the bloom period of the various pear cultivars. As is the case with the other spider mite species, the initial feeding area is on leaves in fruit clusters.

From the time of habitation of the fruit cluster and until over-wintering begins in the early fall, all spider mite species feed on leaf tissue in various locations on the tree.

Reproductive Potential

The reproduction potential of spider mites is quite variable even under controlled conditions. For instance, laboratory tests conducted in 1969 compared the fecundity of the yellow mite with that of the two-spotted mite. As seen in Figure 6, the two-spotted mite laid nearly six times more eggs than the yellow mite. Though we have not conducted studies of the other spider mite species, a similar degree of variation would be expected. In addition to the innate rate of reproduction, several biotic environmental factors influence the rate of actual population increase. Of these, temperature is probably the most important. Several studies show the direct relationship of increased temperature to increases in spider mite population growth (For example, see Nickel,

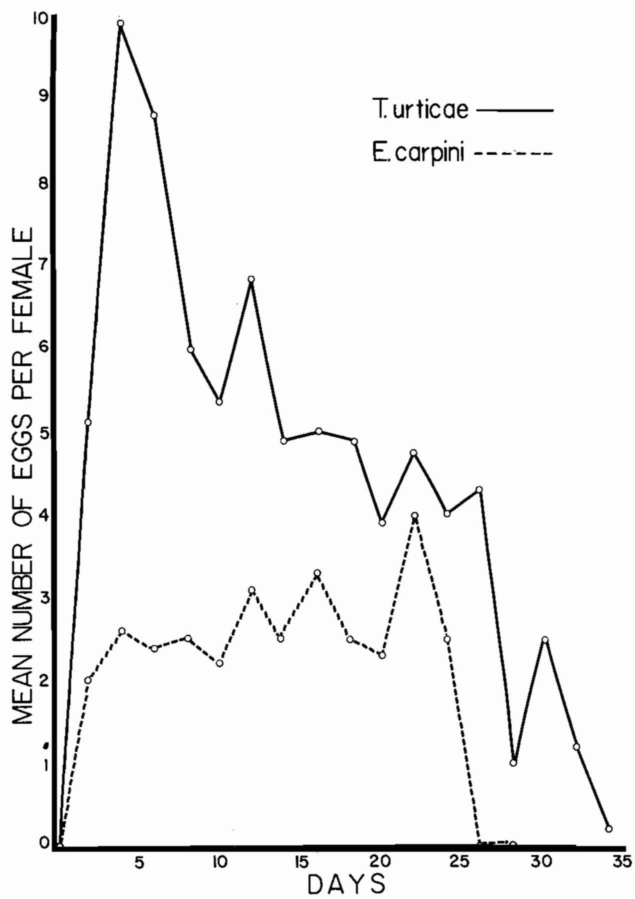

Figure 6. Comparison of fecundity of the two-spotted spider mite and yellow mite reared on detached pear leaves at 80° F.

1960). Our own experience has been similar, and in Table 12 and Figure 7, we relate the population trends of the two-spotted mite during 1963 and 1964, at least in part, to variation in July and August temperatures. Since temperature is an important input into population density potential, it becomes an important aspect of pest management not only for the spider mite group but for other pest species as well. Unfortunately for the practice of pest management, the day-to-day temperature changes that influence pest levels are not accurately predictable and must be dealt with in a hypothetical manner. This "what if?" interpretation of pest potential generally leads to overuse of pesticides but until more accurate long-term weather forecasts are available, it will probably benefit the pest management consultant to make decisions regarding appropriate control tactics based on possible but reasonably expected extremes rather than on average temperature accumulated over a several-year period.

Intra-tree Distribution

Knowledge of the intra-tree distribution of mite species on pears is important to the development of sampling procedures usable in an IPM program. In 1966, a comparison of the dispersion of the yellow mite and the two-spotted spider mite was made on mature D'Anjou pear trees. These data (Tables 13 and 14) show that despite a high degree of species overlap, differences occurred in both vertical and horizontal planes. In general, *T. urticae* mites were more commonly found on leaves in close proximity to the major scaffold limbs of the tree, while *E. carpini* was found more frequently on leaves attached to the smaller limb units. While the dispersion patterns of the other two spider mites have not been quantified, observations would suggest that *P. ulmi* is distributed most frequently on leaves on the younger shoots while *T. mcdanieli* is found on those near the larger limbs. Additional data on distribution are given in the section on sampling.

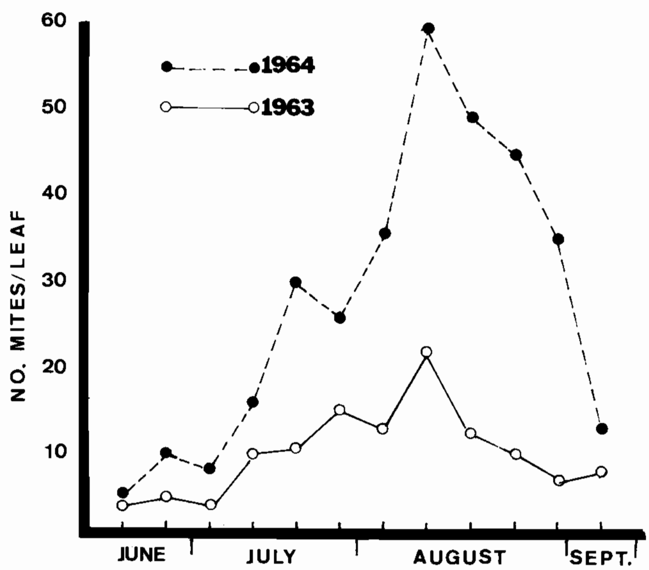

Figure 7. Population trends of *T. urticae* from D'Anjou pear orchard. Medford, Oregon, 1963 and 1974.

Table 12. Number of days maximum temperature exceeded 90° F or 100° F for July and August 1963, 1964

Year	Month		Number of days over	
			90°	100°
1963	July		5	0
	August		11	0
		Total	16	0
1964	July		10	4
	August		13	1
		Total	23	5

Table 13. Pattern of horizontal distribution of 2 species of spider mites on D'Anjou pear trees, Medford, 1966

Species	Average number mites per leaf at indicated distance from major scaffold limb in feet				
	0–3	3–6	6–9	9–12	12–15
			Mar. 6		
E. c. borealis	8.60	8.68	3.81	1.11	0.27
T. urticae	2.20	0.92	0.44	0.18	0.02
			Mar. 26		
E. c. borealis	14.10	12.33	10.09	2.34	2.16
T. urticae	4.13	2.43	2.88	0.21	0.14

Table 14. Pattern of vertical distribution of two species of spider mites on D'Anjou pear trees, Medford, Oregon, April 26, 1966

Species	Average number mites per leaf at indicated distance from ground in feet						
	3	5	6	9	10	12	15
	Sample from scaffold limbs						
E. c. borealis	1.60	......	16.70	17.84	......	11.78	14.72
T. urticae	3.52	......	2.00	3.12	......	5.62	6.64
	Sample from secondary limbs						
E. c. borealis	......	8.17	....	....	7.94	....	7.70
T. urticae	......	0.79	....	....	0.84	....	3.52

Migration

As previously described, the movements of the codling moth from outside sources into commercial orchards are important to the practice of IPM.

Immigration of spider mites have also been noted, not only by passive flight of adults, but also by movements from ground litter or cover crops. Table 15 shows that about one-half the population density of the two-spotted mite on pear trees may be attributed to these upward movements from ground cover sources. Wind drift by the two-spotted mites has also been recorded (Table 16) but the contribution of this factor to eventual spider mite density has not been measured.

In terms of pest management, spider mite immigration is capable of dramatically altering the expected mite density calculated from consideration of initial pest levels, reproductive capacity, and temperature regimes. Thus, with the possibility of substantial immigration occurring, spider mite levels must be continually and frequently monitored to avoid underestimates of population density.

Damage

Spider mites are considered indirect pests of pears. They inflict damage to leaves that in turn reflects on fruit or on other aspects of tree productivity. However, spider mites also may affect pear quality directly by feeding on the epidermis of the pear fruit and causing russetting and downgrading.

As is true with other pear pests, spider mite density determines actual damage to the pear crop. This factor was studied during 1963-1965 using the two-spotted spider mite on the D'Anjou pear host. It was found that two-spotted mite damage influenced several aspects of pear tree productivity and that the degree of damage was density-dependent. Tables 17, 18, and 19 present data from 1963-1965 on the effect of four density levels of the two-spotted mite on several economically important tree characteristics. Of the tree responses evaluated, *fruit set* (the number of fruit to reach maturity per 100 fruit clusters) was the most responsive to mite feeding. This effect, however, was expressed the year following mite damage. *Fruit size* also was affected by mite feeding but the only consistent differences were those measured between the completely untreated plot and the plot kept below 5 mites/leaf. Increases in *preharvest fruit drop* also were noted in untreated

Table 15. Populations of the two-spotted spider mite on banded and unbanded trees, Southern Oregon Experiment Station Orchard, Medford, 1964

	June 9	July 2	July 16	July 29	Aug. 19	Sept. 4
	Number mites per leaf					
Banded	0.02	0.33	0.62	4.99	5.19	25.8
Unbanded	0.10	2.26	1.61	8.62	8.87	31.4

Table 16. Aerial drift of the two-spotted mite as measured on platform trees, 1964[1]

Date	Eggs	Nymphs	Adults
May 23	1	0	1
May 30	0	0	0
June 6	0	0	0
June 13	0	0	0
June 25	2	2	0
July 2	0	0	0
July 10	0	0	0
July 17	0	0	0
July 24	16	0	4
July 29	15	0	3
August 7	2	0	2
August 14	88	2	18
August 21	36	0	18
August 28	14	0	10
September 4	0	0	0
September 11	0	0	0

[1] Trees changed weekly and treated with oil. Mite-free trees used to replace infested trees.

Table 17. Influence of various levels of two-spotted spider mite on tree and fruit condition of Anjou pear, 1963

Treatment level	Terminal shoot length	Leaves per fruit	Fruit size	Pre-harvest fruit drop	Yield (40-lb. lugs)	Fruit finish (U.S. No. 1)
Mites/leaf	*cm*	*No.*	*cm*	*%*	*No.*	*%*
5	32.1	50.4 a[1]	7.11 a	1.8	15.4	63
10	27.5	40.6 ab	6.89 ab	2.1	13.6	67
25	26.8	36.8 bc	6.78 b	2.9	13.9	58
Untreated	25.9	26.9 c	6.82 b	3.0	13.2	77
Significance level	N.S.	5%	5%	N.S.	N.S.	N.S.

[1] Means which are not followed by the same letters are significantly different. Read vertically.

plots. *Fruit finish* also was affected by two-spotted mites where a 20 percent reduction in U.S. No. 1 fruit was noted between the untreated and lowest mite density plot.

Another aspect of spider mite damage to pears is the relationship between the time of attack and the potential crop loss. Again, using the two-spotted mite on the D'Anjou host, studies were conducted to measure this relationship. Seven time intervals were chosen (Table 20) during which mites were allowed to feed and reproduce unchecked. Preceeding or following these periods the trees were kept as mite-free as possible. The mite densities in each plot and the effect on fruit quality, size, and tree yields are given in Tables 21 to 24. Fruit finish was found to be influenced by late-season feeding while fruit size was more influenced by early summer injury. No relationship was found between fruit set characteristics and a particular time of mite abundance. Rather, it appeared that plots with the greatest summer mite densities, regardless of time of attack, were the plots where set and, therefore, yield was the lowest.

Sampling

Sampling of spider mite populations usually begins after bloom and is carried out through the late spring and summer months. These samples may be used to determine presence or absence of the various spider mite species and to calculate their density levels. Spider mite detection is important because there are differences between species in their susceptibility to various chemical acaricides.

Estimates of spider mite density are used to determine the need for treatment and to evaluate previously utilized controls. The sample unit used to make estimates of summer mite density is the mature pear leaf. Using this unit, a sampling methodology has been developed for use in commercial pear orchards of southern Oregon. In this system, five mature pear leaves are taken from each sample tree. Because of the differences between mite species in their intra-tree dispersion (see page 11), one leaf is taken from 5 different locations along a single major scaffold limb beginning near the tip and extending to near the trunk area. All leaves are collected at a height of between 5 and 6 feet.

Table 18. Influence of various levels of two-spotted spider mite on tree and fruit condition of Anjou pear, 1964

Treatment level	Fruit set (fruit per 100 clusters)	Terminal shoot length	Leaves per fruit	Fruit size	Pre-harvest fruit drop	Yield (40-lb. lugs)	Fruit finish (U.S. No. 1)
Mites/leaf	*No.*	*cm*	*No.*	*cm*	*%*	*No.*	*%*
5	24.6 a[1]	30.2 a	53.1 a	6.41 a	2.3 a	16.8 a	57 a
10	22.0 ab	27.3 ab	52.0 a	6.29 ab	2.4 a	14.9 ab	48 b
25	18.2 ab	26.0 ab	27.0 b	6.22 ab	1.1 a	15.2 ab	49 b
Untreated	13.8 b	24.2 b	29.6 b	6.08 b	6.7 b	9.9 b	36 c
Significance level	5%	5%	5%	5%	5%	5%	5%

[1] Means which are not followed by the same letters are significantly different. Read vertically.

Table 19. Influence of 1964 mite levels on fruit set and yield of D'Anjou pear trees in 1965

Previous treatment level	Fruit set (fruit/100 clusters)	Yield (40-lb. lugs)
Mites/leaf	*No.*	*No.*
5	19.7 a[1]	18.5 a
10	18.4 ab	18.1 a
25	16.0 ab	17.8 a
Untreated	10.8 b	7.5 a
Significance level	5%	5%

[1] Means which are not followed by the same letter are significantly different. Read vertically.

Table 20. Periods of spider mite infestation used to measure the effect of feeding by the two-spotted mite on D'Anjou pear variety

Plot	*Unchecked period*	*Treated period(s)*
1	None	March—Harvest (Sept.)
2	August 15—Harvest	March—August 15
3	July 15—Harvest	March—July 15
4	July 1—Harvest	March—July 1
5	March—July 1	July 1—Harvest
6	March—July 15	July 15—Harvest
7	March—August 15	August 15—Harvest

Table 21. **Population trends (mites/leaf) of the two-spotted spider mite under various acaricide programs. Southern Oregon Experiment Station Orchard, Medford, 1965**

Number acaricide treatments	Plot	Date applied	March	April	May		June		July		August			
			22[1]	20	11	25	7	21	5	19	2	11	18	30
2	4	3/24 4/30	4.03	0.01	0.05	0.02	0.05	0.24	2.31	5.82	20.88	15.12	32.79	34.85
3	3	3/24 4/30 6/8	5.44	0.01	0.02	0.07	0.03	0.06	0.76	2.18	5.09	5.86	25.82	40.15
4	2	3/29 4/30 6/8 7/13	1.51	0.00	0.08	0.02	0.03	0.32	0.36	0.16	1.03	2.07	4.70	5.86
5	1	3/24 4/30 6/8 7/13 8/4	2.35	0.03	0.04	0.36	0.15	0.06	0.35	0.47	1.03	0.37	1.08	0.61
2	5	7/13 8/4	2.40	0.07	0.35	1.54	10.44	9.62	36.85	0.32	0.77	0.46	1.14	0.58
2	6	7/13 8/4	3.29	0.04	0.43	0.09	4.14	6.25	26.35	0.34	1.09	0.29	0.51	0.87
1	7	8/12	3.76	0.06	0.42	0.75	3.18	4.74	27.26	19.21	28.28	11.10	9.74	1.43

[1] Mites per fruit bud.

Table 22. **Effect of time of feeding of the two-spotted mite on D'Anjou fruit size**

Plot	Period kept mite-free as possible	Packout size[1] (fruit per carton)
		No.
1	March—harvest (September)	131.7 c[2]
2	March—August 15	136.7 bc
3	March—July 15	134.8 bc
4	March—July 1	142.7 ab
5	July 1—harvest	141.4 ab
6	July 15—harvest	142.8 ab
7	August 15—harvest	148.4 a
	Significance level..............	1%

[1] Large numbers indicate smaller average diameter of fruit.
[2] Means which are not followed by the same letters are significantly different.

Table 23. **Effect of time of feeding of the two-spotted mite on D'Anjou fruit finish**

Plot	Period kept mite-free as possible	Fruiit finish (U.S. No. 1)
		%
4	March—July 1	46 bc[1]
3	March—July 15	44 c
2	March—August 15	50 abc
1	March—harvest (September)	53 ab
5	July—harvest	54 ab
7	August 15—harvest	53 ab
6	July 15—harvest	59 a
	Significance level	1%

[1] Means which are not followed by the same letters are significantly different.

Table 24. **Effect of time of feeding of the two-spotted mite on fruit set and yield of D'Anjou pear**

Plot	Time kept mite free (1965)	Fruit set 1966	1966 yield (40-lb. lugs)
		%	*No.*
2	March—August 15	23.8 ab[1]	18.6 a
1	March—harvest (September)	23.7 ab	18.5 ab
3	March—July 15	22.1 ab	16.0 ab
5	July—harvest	25.3 a	16.0 ab
6	July 15-harvest	21.5 bc	15.3 abc
4	March—July 1	18.7 c	13.6 bc
7	August 15—harvest	18.4 c	11.5 c
	Significance level	5%	5%

[1] Means which are not followed by the same letters are significantly different. Read vertically.

The number of trees sampled depends upon intra-tree mite density variation and upon the accuracy required. Between-tree variation in mite density appears to be dependent upon population density and upon the mite species involved. Studies in 1970 showed the coefficients of variation (C.V. = standard deviation/mean x 100) were inversely related to population density of the two-spotted and the European red mite, and as well for the important predator mite *Metasiulus occidentalis* (Table 25). Table 25 also shows greater variation occurred with the European red mite than with the two-spotted or predaceous species.

The C.V. values obtained in the above study

Table 25. Relationship of coefficient of variation (C.V.) to density of eggs (E) and post-embryonic (E) stages of spider mite

Species	Orchard	Number mites per leaf		C.V. percent	
		E	PE	E	PE
P. ulmi	2	0.62	0.11	264	656
		10.03	5.40	128	185
		26.00	14.30	63	72
T. urticae	1	1.20	1.10	297	380
		7.20	4.90	244	272
		10.10	3.70	189	194
M. occidentalis	1	0.04	0.16	323	182
		0.18	0.17	218	161

were used to calculate the number of trees to be sampled to achieve the desired accuracy. These estimates of sample size (number of trees) are given in Table 26. As can be seen, the number of trees to be sampled may be very great if a high C.V. is expected or if a high degree of accuracy is demanded.

The accuracy required of spider mite density estimates is dictated by the population level capable of causing economic injury to the pear crop. From the section on damage (pages 12 to 13) we assumed populations of the two-spotted mite much greater than 5 per leaf may cause significant damage. We then can use this figure for an estimate of an economic threshold for this species, at least on the D'Anjou variety. Sample size must be great enough, however, to accurately distinguish mite density at or below this density.

Even though a great deal of intra-tree variation is associated with low spider mite levels, the needed precision of density estimates also can be very low. For example, even though the C.V. for the two-spotted mite is about 300 for the 1 mite per leaf density (Table 25) the confidence level chosen could be as high as ± 60 percent without undue concern of actual mite density exceeding the economic injury level.

Table 26. Sample size required to estimate mite density on pear trees with specified precision

Confidence level	Confidence interval (± %)	Number of trees to sample, with coefficient of variation (percent)		
		C.V. 100	C.V. 200	C.V. 300
90%	10	272	1089	2450
	20	68	272	613
	40	17	68	153
	60	8	30	68
95%	10	384	1537	3457
	20	96	384	864
	40	24	96	216
	60	11	43	96

In actual practices, estimates of mite density have been based on weekly sampling of 40 to 50 trees (5 leaves per tree) per 20 acres of orchard. The results have been satisfactory in the case of the yellow and two-spotted species, but have been less satisfying with the European red mite. Further studies on spider mite sampling methodology are certainly warranted to provide growers and pest control consultants with a confidence in predicting results now lacking in most sampling schemes.

Control Tactics

Biological Control

In the absence of chemicals applied during the summer for control of other pear pests, spider mites seldom reach damaging levels. Studies in an unsprayed orchard showed that over an eight-year period (1964-71) spider mite levels never exceeded a monthly average of 0.04 per leaf and did not cause significant leaf injury during this period (Table 27). Spider mite levels in commercial orchards which abandon standard pesticide programs usually are brought under biological control within a period of 1 to 2 years (Figure 8).

Though several known predators of spider mites may be found on pear trees in southern Oregon, the predaceous mite *Metasiulus occidentalis* Nesbit is thought primarily responsible for providing economic control.

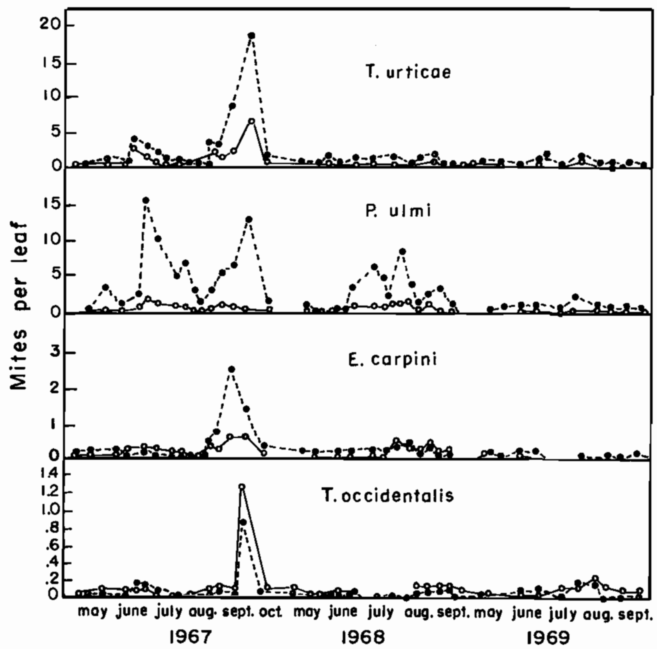

Figure 8. Population trends for spider mites and predaceous mites, 1967-1969, in a commercial orchard. Dashed lines indicate post-embryonic stages and solid lines egg stages.

Table 27. Population levels of spider mites in an unsprayed orchard

Year	Average number mites/leaf				
	May	June	July	Aug.	Sept.
1964	0.00	0.002	0.000	0.003	0.006
1965	.00	.000	.000	.000	.006
1966	.00	.000	.000	.002	.000
1967	.00	.000	.002	.000	.002
1968	.00	.000	.002	.004	.007
1969	.02	.010	.003	.040	.026
1970	.00	.005	.010	.000	......
1971	.00	.000	.000	.010	......

Despite the high potential for achieving biological control of the spider mite species, several factors complicate this program.

First, the control of other pest species requires insecticidal treatments during the summer for their control. These chemicals generally have been destructive to predator mites. This has been especially true since the appearance of resistance to organophosphates by the pear psylla and substitution of these materials with chemicals more toxic to the predator mites (see sections on codling moth and pear psylla chemical control).

A second complicating factor is the serious economic effects of spider mite injury in the transition period between the discontinuance in use of synthetic acaricides for control and the time required to achieve control with predaceous mites. Examination of Figure 8 will show that during the 1967 transition period, populations of spider mites exceeded 5 to 10 mites per leaf on several occasions. In this orchard, both fruit size and fruit set were affected because of 1967 mite damage (Table 28) Our experience shows some use of of acaricide also would be necessary in years when predators failed for one reason or another to give control. As reported earlier, the two-spotted mite caused severe injury in some years prior to the introduction of synthetic organic pesticides.

Ideally, when an acaricide is found to be needed it should (1) give control of the target mite, but (2) not cause resurgence in target mite species, and (3) be minimally disruptive to the predaceous mite, *M. occidentalis*. Tests conducted in 1969-70 rated several acaricides for these characteristics. Table 29 gives the results of these tests which indicated several materials were available that met the above criteria. As can be seen, not only did materials differ, but rates of the same acaricide gave somewhat different results.

Table 28. Effect of spider mite feeding on fruit size and fruit set of D'Anjou pears

Summer pesticide program	Fruit size Average number fruit per carton class 1967	Percent fruit set 1968
Miticide	146 a	29.1 a
No miticide	156 b	15.9 b

Despite the difficulties discussed above, a program of biological control of spider mites was utilized by many Rogue Valley growers between 1968 and 1972. This program relied heavily upon chemical pre-bloom programs for control of the pear rust mite, San Jose scale, and pear psylla and upon azinphosmethyl (Guthion) and oil for codling moth and psylla control during the summer. It is hoped problems associated with the use of disruptive chemicals can be resolved and an integrated program for spider mite control can be re-established.

Table 29. Rating of some registered acaricides for their suitability in an integrated control program for the two-spotted spider mite, Medford, 1969-70

Material and rate A.I. per 100 gal. water	Rating[1] (1 = best, 11 = worst)
Ethion 0.50	1
Plictran 0.13	2
Supreme oil 1 gal.	3
Ethion 0.13	4
Plictran 0.25	5
Phosalone 0.75	6
Dicofol 0.17	7
Acaralate 0.13	8
Acralate 0.25	9
Phosalone 0.13	10
Dicofol 0.70	11

[1] Rating based on (1) degree of direct control, (2) lack of resurgence in two-spot density, and (3) survival of predator mite, *M. occidentalis*.

Chemical Control

The spider mites attacking pears, for the most part, appear to have been induced to pest status by the use of synthetic pesticides introduced after World War II. However, evidence indicates that prior to this time, the pear growers did suffer periodically from losses attributed to the two-spotted species. Reports from the area Extension horticulturist in 1926 and 1930 indicated the species was a major problem. In fact, the first synthetic pesticide used (DN111) was available on a commercial basis in 1942, three years before the use of DDT in the area.

Chemicals Used

Subsequent to 1942, about 14 synthetic pesticides had been introduced and used for spider mite control, but primarily because of resistance only one miticide is currently available that has widespread use (Table 30).

Table 30. Chronology of use pattern for synthetic acaricides used during foliar period on pears in southern Oregon

Material	Year first used	Year dis-con-tinued	Reason discontinued
DN111	1942–43	1946	Phytotoxic
EPN	1946	1954	Lack of control
TEPP	1947	1969	Loss of registration
Aramite	1947	1960	Loss of registration
Parathion	1948	1953	Lack of control
Ovatran	1949	1955	Lack of control
Chlorobenzilate	1952	1968	Lack of control
Kelthane	1955	1972	Lack of control
Tedion	1956	1962	Lack of control
Trithion	1955	1968	Lack of control
Morocide	1968	1972	Phytotoxicity
Chlordimiform	1970	1976	Withdrawn by manufacturers
Plictran	1972	Still in use	
Ethion	1963	1970	Lack of control
Vendex	1976	Still in use	

With the exception of most of the organophosphates and chlordimiform, many chemicals used for mite control have been highly specific in activity and have not been observed to cause major disruption to non-target species except to predaceous mites. Even with the important predaceous mite *M. occidentalis*, some acaracides can be used selectively to minimize the mortality to this species (see Table 29).

Pre-bloom Timing

The European red mite is the only spider mite species receiving pre-bloom or post-harvest chemical treatment for control. In this species, the overwintering eggs are in an exposed situation and can be contacted with spray materials. Petroleum oils have been used for this application since the European red mite appeared in 1952, and at present no indication of a decrease in effectiveness has been seen. In general, control with the pre-bloom oil sprays is improved by delaying the treatment as long as possible into the late-delayed dormant or pre-pink period. Treatment at this later time also may give a small degree of control of the other spider mites beginning to immigrate from overwintering sites beneath the bark scales to the opening fruit buds (Table 31).

Table 31. Effect of pre-bloom oil treatments on population density of the two-spotted mite

Oil and rate per 100 gal. water	Percent infested fruit buds at petal fall (April 18): Delayed dormant application	Pre-pink application
Volck Supreme 1 gal.	25	13
Niagra light-med. 1 gal.	24	15
Untreated	31	40

Occasionally, synthetic chemicals with residue or phytotoxicity problems are registered for use only during the pre-bloom or post-harvest period. One such material, *oxythioquinox* (Morestan), is used by growers primarily for control of pear psylla but also has been shown to suppress spider mite levels when used during the pre-bloom stage or at the post-harvest period. Table 32 gives the results obtained with this material as it affects the two-spotted mite population.

Table 32. Comparison of pre-bloom and post-harvest morestan application for control of the two-spotted, mite, Medford, Oregon, 1963 and 1964

Material and rate per 100 gals. water	Time of appli-cation[1]	Two-spotted mites: Sept. 18, 1963	Sept. 24, 1963	April 1, 1964	April 21, 1964
		No./leaf	*No./leaf*	*No./bud*	*No./leaf*
Oxythioquinox 25% W.P. 1 lb.	P.H.	17.0	0.4	2.6	0.40
Oxythioquinox 25% W.P. 1 lb.	D.D.	16.9	16.9	2.4	0.38
Oxythioquinox 25% W.P. 1 lb.	P.H. & D.D.	24.1	0.5	0.6	0.14
Check		22.4	20.9	22.8	1.62

[1] P.H. = Post-harvest application applied September 19, 1963; D.D. = Delayed dormant application applied March 17, 1964.

Despite the apparent effectiveness of the pre-bloom or post-harvest treatments in lowering spider mite density, these treatments generally have been discouraged in southern Oregon except when their use has been shown to be vital in the suppression of other pest species. These treatments have been excluded because they have not been shown to produce economic benefits by deleting one or more summer acaricide treatments. In other words, the pre-bloom or post-harvest use of acaricides for the two-spotted mite can be viewed only as preventive applications without regard to the IPM concept of economic thresholds or economic injury levels.

Foliar Sprays

Foliar applications traditionally have been accepted by growers as the proper period for use of acaricides in the control of spider mites on pears. This foliar period extends from post-bloom (petal fall) until close to harvest (mid-August for the early Bartlett variety and late September for the winter pears). However, within this time frame, growers' decisions regarding the need for acaricide treatment are limited by other, non-entomological factors such as irrigation schedules, thinning, etc.

In practice, growers make every attempt to include acaricide treatment along with sprays to control other pests such as the codling moth. These summer treatments are applied about one month apart and begin in mid-May. To delete an acaricide from one or more of these summer "cover sprays," growers must be certain that spider mite levels will not reach economically damaging densities for a 3- to 4-week period or until ground conditions again allow passage of spraying equipment.

In view of this limitation, most growers routinely include synthetic acaricides in their cover sprays regardless of mite density (see section on mite damage). This practice certainly has increased the rate of spider mite resistance to the synthetic acaricides.

Cultural Control

Orchard Sanitation

Some evidence indicates weed species on the orchard floor harbor populations of the two-spotted spider mite and that the pests are capable of moving into the tree canopy. Table 15 presents data showing this source contributed to eventual mite density on the tree. Before recommending a program of clean cultivation, however, it should be remembered that not all orchard floor plant species will support pear-feeding spider mites and that spider mite weed hosts also may be important reservoirs for predaceous mite species. A more thorough study of this relationship is necessary before any definite conclusion on weed management can be reached.

Overtree Irrigation

Significant reductions in spider mite levels have been reported following overtree irrigation from several Northwest fruit growing areas. In southern Oregon pear orchards, no dramatic population reductions have been measured. Table 33 gives an example of the density change in populations of the two-spotted mite resulting from a 12-hour period of tree washing by over-tree irrigation. Some observational data are available, however, indicating that while spider mite density is not affected, the damage caused by these levels perhaps may be reduced by minimizing the effect of water loss associated with mite feeding.

Host Plant Resistance

No data have been developed in southern Oregon quantifying the differences of various pear cultivars in susceptibility to spider mite attack. Based on observation during the last 15 years, we would rank the major pear varieties as to the frequency of having sustained severe mite injury in the following order (from highest to lowest): D'Anjou, > Bosc > Bartlett > Comice. The explanation for these differences is yet to be investigated.

Table 33. Effect of over-tree irrigation on densities of the two-spotted spider mite, 1977

	Number mites/leaf	
Method of irrigation	Pre-sprinkled July 6	Post sprinkled July 7
Overtree sprinkled	16.2	17.1
Undertree sprinkled	17.3	20.4

Pear Psylla

The pear psylla, *Psylla pyricola* Förster first was reported in the United States in Connecticut in 1832. It was detected in Washington state in 1939; in Hood River, Oregon, in 1949; and in southern Oregon's Rogue River Valley in 1950. Though the initial appearance of this pest was greeted with apprehension by local growers and those responsible for pest control in the area, the destructive potential of the species was not realized immediately. In 1957, however, pear trees in the area began to show symptoms of poor growth, lower tree vigor, and outright collapse. For a 4- or 5-year period this malady referred to as pear decline was not related to pear psylla, but it since has been defined as being induced by a virus-like mycoplasma organism carried by this pest. Between 1957 and 1963, nearly 2,000 acres of pear trees in southern Oregon were either killed outright or their production capabilities severely crippled by pear decline.

Though the period of pear decline ravages has subsided, the pear psylla still remains an important pest of pears and is the most expensive (ca. $120/acre annually) pest to control in commercial orchards.

Life History

Developmental Stages

The pear psylla (Figure 9) overwinters in the adult stage, which is somewhat larger and darker than the summer adult. Both males and females overwinter and mating does not occur until prior to egg laying in January or early February. Most of the first eggs laid by overwintering females are deposited on fruit spurs, but as the fruit buds open, eggs are laid on exposed leaf or fruit tissue. The interval between oviposition and appearance of the first nymphal stage averages about 5 weeks in southern Oregon (Table 34).

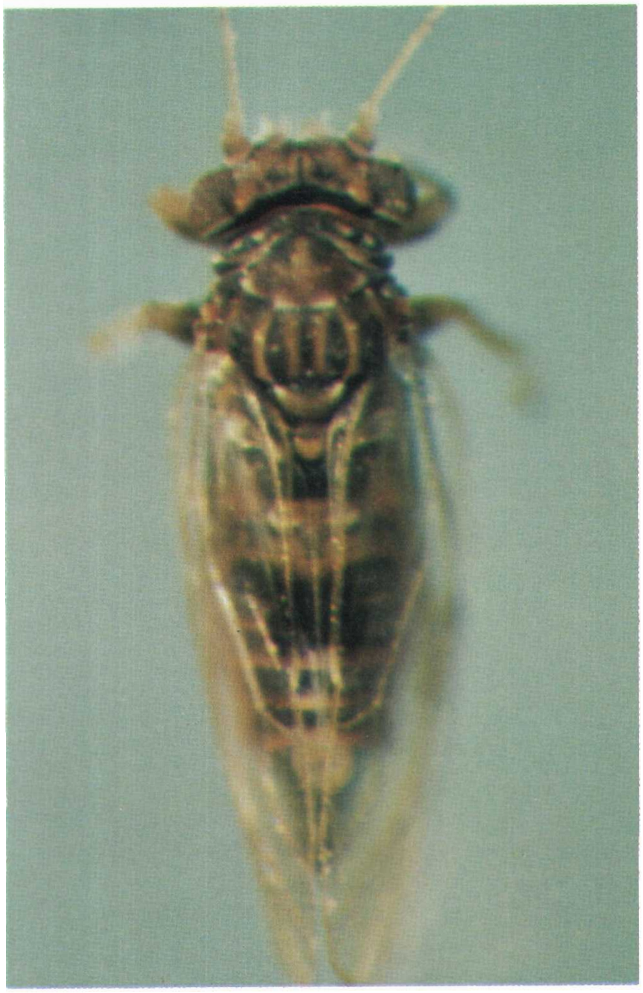

Figure 9. Adult Pear Psylla

The pear psylla passes through five nymphal instars prior to reaching the adult stage. All nymphal stages feed on green leaf tissue and, as they feed, secrete a sticky "honeydew" liquid around their bodies. The fifth instar is referred to as the "hardshell" stage and is dark brown to black in color and bears prominent wing pads. This stage

Table 34. Variation in the developmental time of the first generation of pear psylla in southern Oregon

Year	Date of first egg	Date of first nymph	Eclosion time	Date of first summer adult	Total days (egg to adult)
			days		
1961	Jan. 28	March 15	47	May 3	96
1959	Feb. 12	March 30	46	April 28	75
1957	Feb. 18	March 20	31	April 30	72
1955	March 3	April 4	32	May 9	67
1952	Feb. 14	March 25	40	May 5	78
		Average	39		

can move about actively and often is found at the base of leaf petioles.

In southern Oregon, four complete generations of this species appear annually. The approximate time of occurence for these is given in Table 35.

Table 35. Approximate time periods of the various pear psylla generations in southern Oregon

Generation	Stage	Time of approximate occurrence
1	Egg	Jan. 10-April 20
	Nymph	March 10-May 20
	Adult	April 20-June 20
2	Egg	May 10-June 25
	Nymph	May 25-July 15
	Adult	June 20-Aug. 10
3	Egg	July 5-Aug. 20
	Nymph	July 10-Aug. 25
	Adult	July 20-Sept. 15
4	Egg	Aug. 10-Sept. 15
	Nymph	Sept. 1-Nov. 15
	Adult	Sept. 15-May 5

Migration

As mentioned above, there are morphological differences between the overwintering and summer adult forms. The larger, overwintering adults also exhibit a greater tendency for dispersal and are capable of moving substantial distances. In southern Oregon, it is typical for adults to disperse outward from pear orchards in early fall and into surrounding vegetation. By late winter, this behavior is reversed and migration back into pear orchards occurs. What proportion of the population emigrates and what percent remain in the orchard to overwinter is not known.

Both the fall and winter dispersal patterns are important to the management of the pear psylla. For example, late winter movements back into pear orchards begin in early January but may continue through March or later. Chemical treatments against overwintering adults, normally applied in early February, may be highly effective against psylla present in the orchard but will not have the persistance necessary to control late-arriving immigrants (Table 36). Thus, multiple pre-bloom pesticide treatments sometimes are used to achieve economic reduction (see section on host plant modification).

Temperatures

Studies of the effect of temperature on pear psylla have not been conducted in southern Oregon. However, data from California, Washington, and British Columbia, Canada, show temperatures

Table 36. Effect of immigration by overwintering pear psylla on control with Perthane applied at the dormant period, 1975

Material and rate a.i./100 gal. water	Average number pear psylla adults per limb tap		
	Pre-treatment	Post treatment	
	Feb. 14	March 12	April 16
Perthane® 1.0 lb.	0.6	0	4.7
Untreated	2.4	45.0	38.2

in excess of 90° F cause reduction in egg laying and over 100° F cause some nymphal mortality. Observations in the Rogue Valley would indicate that while some mortality to young instar nymphs can be attributed to temperatures over 95°-100° F, this factor does not play an important role in natural control of this pest.

Host Plant Conditions

The amount of young succulent pear foliage available appears to be an important factor in determining pear psylla densities. Generally, the actively growing points on the pear tree are preferred for oviposition. This is evident especially in the late winter when the vast majority of eggs from overwintering females are found around swelling buds. Also, during the summer months, eggs are most commonly laid on the terminal leaves of actively growing pear shoots. The sampling methods developed have utilized this relationship to measure pear psylla egg and nymph densities through the year.

Host Range

Although the adult pear psylla and occasionally the egg stage can be found on other hosts, the insect can complete its development only on pears. Even within the genus *Pyrus* some species appear not able to support the completion of psylla development. This monophagous habit of the pear psylla offers some promise in its management (see section on host plant resistance).

Damage

The pear psylla causes at least three types of pear damage. Each of these damage types is associated with different psylla densities and has different economic injury levels. In addition, each damage type has control tactics best suited to its prevention.

Pear Decline

As previously described, the cause of this disease has been attributed to a microplasma-like organism and the pear psylla is the vector. Symptoms vary, but may be expressed by lowered tree vigor, poor fruit set, small fruit size, or tree death. The symptoms are caused by sieve-tube necrosis at or below the graft union and their severity is related to the origin of the rootstock material. Cultivars grafted onto *Pyrus pyrifolia* or *P. ussuriensis* are more susceptible than those on *P. communis*. Since the rootstocks themselves usually are propagated from seeds rather than clonal root cuttings, a natural variation in pear decline susceptibility exists even within the resistant or susceptible understocks. With disease-carrying insects, the pest density necessary to cause economic damage is generally very low and in the case of pear psylla-pear decline relationship, was presumed to be near zero. In this situation, the most appropriate control tactic was the introduction of resistant rootstock material. Horticultural research showed several rootstocks such as 'Old Home,' were not affected by the microplasma organism. These have been used in many of the new pear plantings in the southern Oregon area (Westwood et al., 1971).

Psylla Toxin

A second type of injury attributable to pear psylla is caused by the injection of a toxicogenic substance by nymphal stages. Symptoms of this disorder are similar to those of slow decline, including poor tree vigor and lowered productivity. However, the effects of the toxin generally are related to very high psylla densities, perhaps over a several-year period, and are found on cultivars grafted onto both decline-tolerant as well as susceptible rootstocks. Damage from psylla toxin has not been observed under conditions of low to moderate psylla infestation and it is believed the economic injury level for this damage is reached only during years when psylla numbers go relatively unchecked by chemical or biological controls.

Psylla Honeydew

In the process of feeding, psylla nymphs secrete a sticky substance called honeydew. This material may drip onto fruit, causing a dark russeting on the surface. If the marking is excessive, downgrading of fruit will occur, and crop value will be reduced (see page 37). The presence of copious amounts of honeydew at harvest time have resulted in picker complaints and increased harvesting costs.

In contrast to pear decline and the effects of psylla toxin, injury from psylla honeydew represents direct fruit damage and is of utmost concern to growers. Current spray costs of more than $100 per acre per year for psylla control are directed at avoiding this type of damage. Unfortunately, we have conducted no critical studies to relate psylla density to potential fruit damage and without this information, the implementation of IPM for this pest has been curtailed. Based on experience, a tentative treatment threshold to avoid honeydew damage to fruit is given in Table 37.

Sampling

The sampling methodology for pear psylla has been developed to measure densities of various stages of this pest at various times of the year. While these sampling procedures have not been related to a known economic injury level, they can be used in a generalized sense based on experience to indicate the presence of potential damaging populations (Table 37). Under the current situation, the economic threshold is highest in the early season and lowers toward harvest.

Table 37. Tentative treatment thresholds to avoid pear psylla honeydew damage to fruit, Bartlett variety

Treatment period	Sample for	Approximate treatment threshold
Dormant—prior to application of dormant spray	Adults	< 1 per 10 taps
Prior to Delayed Dormant spray	Adults	< 1 per 10 taps
Prior to pink stage spray	Eggs	1 egg per spur
Prior to 1st summer spray (Mid-May)	Adults	1 per tap
	Eggs, Nymphs	< 1-2 per fruit cluster
Prior to 2nd summer spray (Mid-June)	Adults	1 per tap
	Eggs, Nymphs	0.1 per leaf
Prior to 3rd summer spray (Mid-July)	Adults	2 per tap
	Eggs, Nymphs	0.2 per leaf

Adults

Sampling adult pear psylla is carried out by jarring limbs with a rubber covered piece of wood dowling and recording the number of adults falling onto a 18 by 18 inch cloth-covered catching frame. This procedure is followed from the pre-bloom period through the summer months. The information is used to determine (1) degree of control obtained following chemical treatment, and (2) population structure which, in conjunction with counts of immature stages, is used to determine control strategy. Limb jarring also will yield data on the density of several important psylla predators to determine the potential for biological control.

The sample size (number of limb units to be tapped) necessary to provide a reliable estimate of actual population numbers appears to be inversely related to the psylla density present. That is, the higher the density, the fewer samples required.

Immatures

As previously mentioned, the pear psylla adults deposit eggs on actively growing points of the pear tree. Thus, the sampling unit changes through time. Table 38 gives the sample units used during these seasonal changes.

Table 38. Sampling units for evaluating pear psylla density

Period	Psylla stage	Unit
Dormant to bud swelling (January to March)	eggs	unopened fruit spurs
Prepink to petal fall (March 15 to May)	eggs & nymphs	leaves and fruit from fruit spurs
Summer (May to September)	eggs & nymphs	terminal and basal leaves on growing pear shoots

Control Tactics

Biological Control

In southern Oregon, the role of predators appears to play a significant role in the natural control of the pear psylla, at least under certain conditions. In an eight-year study (1964-1971) conducted in an unsprayed Bartlett pear orchard, populations of *P. pyricola* did not reach levels to cause commercial downgrading of fruit due to psylla honeydew. The population trends of psylla egg and nymph densities recorded in this study are given in Figure 10.

More than 30 predators and parasites from North America reportedly feed on pear psylla. In southern Oregon, the most important of these appears to be several coccinellid species as well as the lacewing *Chrysopa carnea* Steph. and the mirid *Deraeocoris brevis piceatus* Knight. This latter predator was shown to consume an average

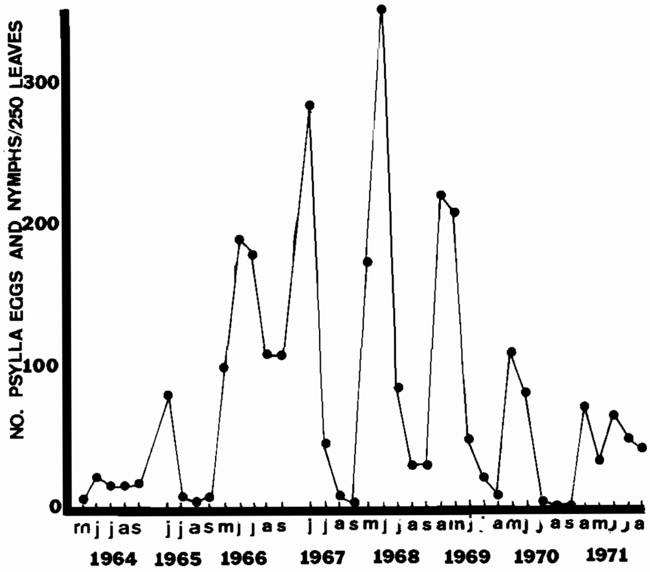

Figure 10. Population trends of the pear psylla in an unsprayed orchard, Medford, Oregon.

of about 400 psylla eggs and nymphs during its development period (Table 39).

In unsprayed orchards, the predator complex generally begins to appear in mid- to late May.

Table 39. Average daily consumption of pear psylla eggs and nymphs by *Deraeocoris brevis piceatus* under laboratory conditions

Average pear psylla consumed per day	*D. brevis* nymphal instar 1	2	3	4	5	Adults
Eggs	1.3	3.4	6.7	5.0	3.6	3.3
Nymphs	0.6	2.3	7.3	22.0	22.9	15.3
Total	1.9	5.7	14.0	27.7	26.5	18.6
No. feeding days observed	3	29	23	7	20	6

Table 40. Effect of predators on abundance of pear psylla eggs and nymphs on Bartlett pear, July, 1966

Limb no.	Stage	Number pear psylla at indicated weeks after initial count: 0	1	2	3
1	Eggs	119	60	8	0
	Nymphs		14	6	3
2	Eggs	70	52	5	0
	Nymphs		3	13	7
3	Eggs	52	4	0	0
	Nymphs		2	1	2
4	Eggs	34	12	0	0
	Nymphs		9	1	0
5	Eggs	73	46	0	0
	Nymphs		0	4	0
	Total	348	192	38	12
	% reduction		45	88	97

Their numbers peak in late June or July. Typically, pear psylla densities are economically suppressed during this period (Figures 10, 11, and 12 and Table 40). Cool temperatures in early summer appear to delay the influx and buildup of predaceous species, and, under these conditions, commercial psylla suppression may not be achieved.

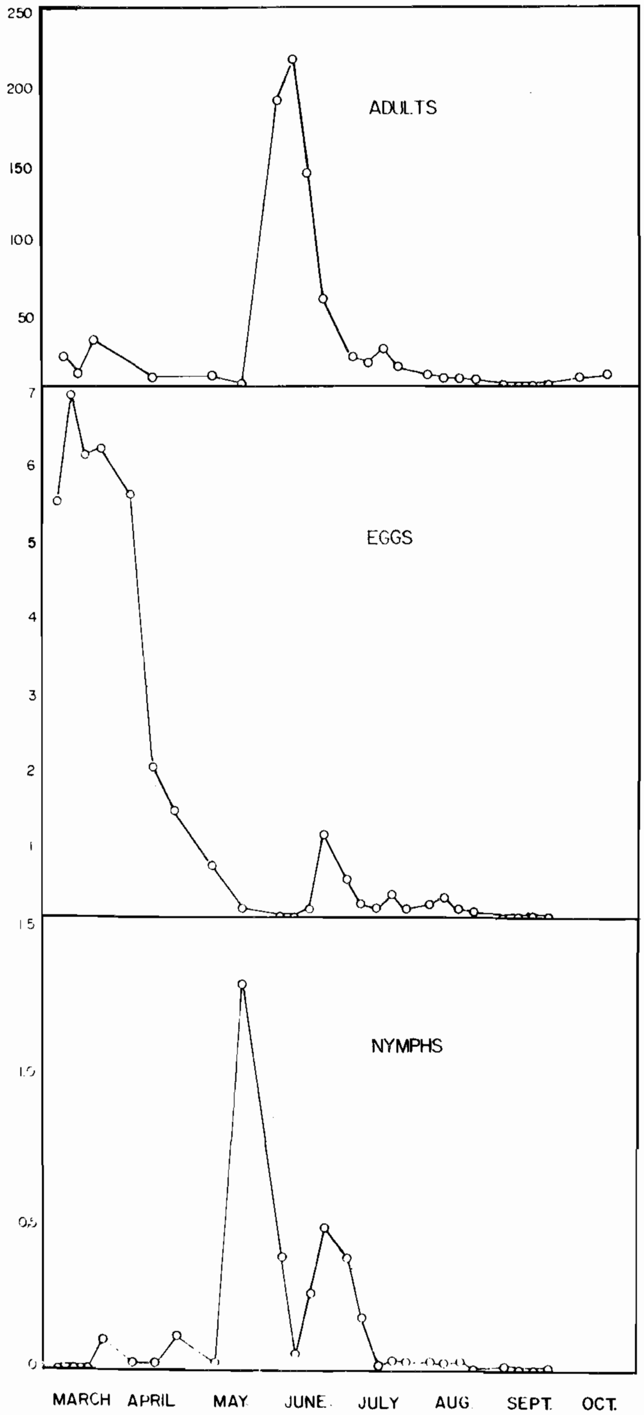

Figure 11. Population trends of pear psylla in an unsprayed Bartlett pear orchard (Medford, Oregon). Number of nymphs and eggs per leaf. Number adults per 10 limb taps.

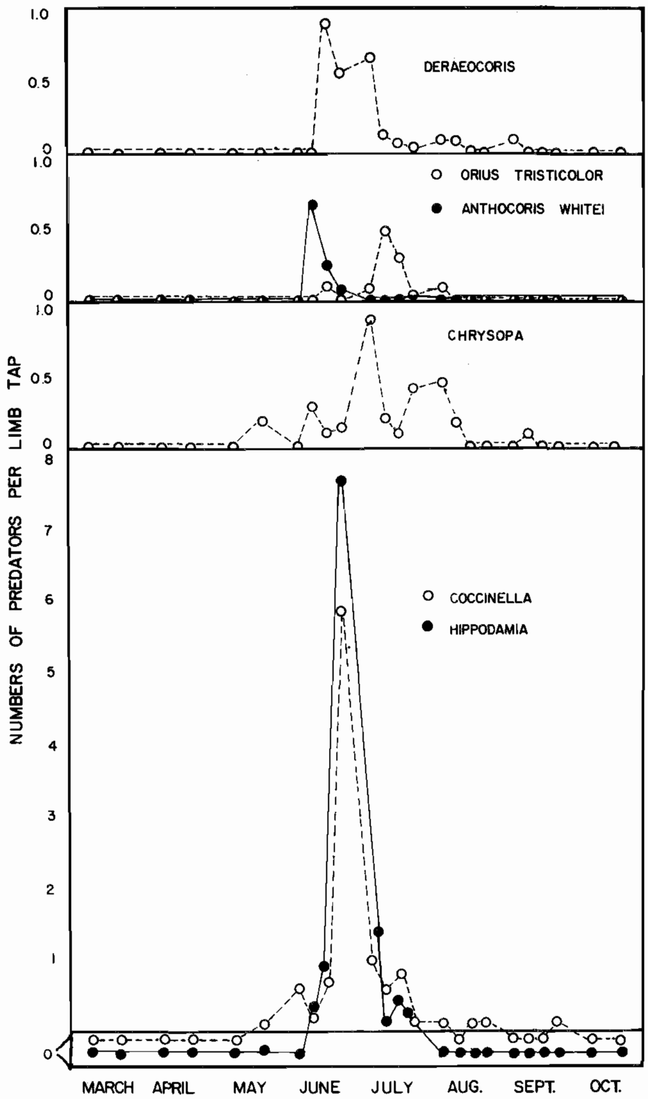

Figure 12. Population trends for psylla predators in an unsprayed Bartlett pear orchard (Medford, Oregon). Number per limb tap.

As mentioned in the section on codling moth, most organophosphate pesticides used for codling moth control will reduce substantially the density of psylla predators. An example of the effects of these pesticides on *D. b. piceatus* is given in Table 41. As seen, the 24-hour mortality to the nymphal stage of this mirid ranged from 89 to 100 percent when exposed to direct chemical application.

Chemical Control

Due primarily to the disruptions caused to potentially active biological control agents by the use of pesticides, growers have relied upon synthetic chemicals to achieve commercial suppression of the pear psylla.

Table 41. Effects of direct application of pesticides on *D. brevis piceatus* nymphs

Material	Pound a.i. per 100 gallons water	Number treated	Percent mortality 24 h
Azinphosmethyl	0.13	15	100
	.50	17	100
Phosmet	.50	18	100
	1.00	18	100
Phosalone	.37	18	89
	.75	17	94
Check	......	25	0

1.) Resistance

When the pear psylla first made its appearance in the Rogue Valley in 1950, the organophosphate chemicals already being used in the area during the summer period also were effective on *P. pyricola.* About 1961, the registered organophosphates no longer were effective and growers substituted chlorinated hydrocarbons such as Dieldrin. These compounds lasted only about four years until resistance made them non-commercial. In 1962, azinphosmethyl, an organophosphate effective against psylla, was introduced and gave commercial control until 1965 when it, too, was lost due to resistance. At present, amatraz (BAAM) is the only effective chemical available for summer use.

2.) Timing

a) Dormant treatment. In 1965, a dormant spray treatment directed exclusively at overwintering pear psylla adults prior to oviposition first was used by southern Oregon growers. This treatment, developed by Burts (1968) in Washington state, was introduced to compensate for the absence of effective summer pesticides lost to resistance by *P. pyricola.* Perthane®, the chemical initially used in 1965 at this timing, still remained effective in 1978. However, because Perthane exhibits a relatively short residual period of activity, the degree of control obtained with this compound depends upon its being used at an appropriate time. Two techniques have been used to determine the appropriate timing for this dormant treatment. These include the dissection of overwintering female psylla and their examination for the presence of mature eggs, and the use of temperature accumulation to predict egg development. This latter method, suggested by Burts in Washington state, accumulates maximum temperatures over a base of 43° F beginning January 1. In southern Oregon, it has been found egg laying begins when these totals reach about 200 to 250 degree days (Table 42). Recent development in host plant masking (see page 27) and the probable registration of more persistant adulticides (see page 25) for pre-bloom treatment may cause a relaxation in the critical timing now required to obtain commercial control with the dormant treatment.

Table 42. Egg deposition by overwintering psylla in relation to accumulated degree days over 43° F from January 1

Year	Date of first psylla egg	Date, number degree days over 43° F = 250
1970	January 27	January 25
1969	February 14	February 26
1968	February 10	February 7
1967	February 8	February 15
1966	February 10	February 19
1964	February 14	February 18
1963	February 11	February 8
1960	January 24	February 6
1959	February 5	February 1
1958	February 9	February 7
1957	February 18	February 18

b) Pink bud timing. In recent years, use of this timing to obtain additional reduction in psylla numbers has increased. As was the case for the dormant spray, this timing was brought about because of resistance to organophosphates used during the summer months. The advantage of the pink spray is that pear psylla populations are predominately in the early nymphal instars at this time and are more susceptible to several insecticides.

c) Post-bloom timing. The history of summer insecticide use patterns for psylla control has been discussed. These chemicals generally are added to the codling moth sprays and are applied 3 to 4 times per season. With less effective compounds available for psylla control, the summer sprays are timed for the period when the majority of the pear psylla are in the younger nymphal instars.

3.) Experimental Compounds

Two very different types of chemicals recently have become available on an experimental basis. These are the synthetic pyrethroids and those referred to as insect growth regulators (IGR's).

The synthetic pyrethroids (Tables 43 and 44), including Ambush and Pydrin, are broad spectrum materials and appear to be highly effective on pear psylla as well as on the codling moth. In tests, these materials suppressed density of overwintering psylla adults when applied in the dormant timing at rates as low as 0.2 pound a.i. per acre.

Table 43. Control of pear psylla with prebloom permethrin application to Bartlett pears in 1975 and 1976, Medford, Oregon

Material and rate AI/100		Average number of psylla post treatment[a]			
		1975[b]		1976[c]	
		Adults/tray	Eggs and nymphs/spur	Adults/tray	Eggs and nymphs/spur
Permethrin	0.025	0.86 a	0.56 a	....	....
	0.050	0.22 a	0.71 a	0.68 c	8.78 b
	0.075	....	....	0.40 abc	3.54 a
	0.125	....	....	0.24 ab	0.74 a
	0.250	....	....	0.16 ab	0.40 a
	0.375	....	....	0.07 a	1.60 a
Perthane	1.0	0.12 a	1.35 a	0.52 b	11.10 b
Untreated	....	8.71 b	23.02 b	6.00 d	34.70 c

[a] Means followed by the same letter are not significant at the 5% level. Read vertically.
[b] Treated Feb. 11. 4 4-tree replicates. Post treatment adult counts February 18-April 3. Six post treatment egg and nymph counts March 5-April 16.
[c] Treated February 25, 3 4-tree replicates. Five post treatment adult counts February 17-April 21. Five post treatment egg and nymph count February 25-April 20.

Table 44. Summer control of pear psylla with permethrin applications to Bartlett pears in 1975 and 1976, Medford, Oregon

Material and rate AI/100		Average number pear psylla post treatment[a]			
		1975[b]		1976[c]	
		Adults/tray	Eggs and nymphs/leaf	Adults/tray	Eggs and nymphs/leaf
Permethrin	0.008	16.3 bc	1.14 abc	....	....
	0.016	16.6 bc	1.06 abc	....	....
	0.025	12.3 abc	1.44 bc	....	....
	0.032	6.78 ab	0.76 ab	....	....
	0.050	6.92 ab	0.56 a	....	....
	0.125	....	....	0.40 a	0.03 a
	0.250	....	....	0.30 a	0.06 a
	0.375	....	....	0.20 a	0.04 a
Chlordimiform	0.50	4.23 a	0.86 ab	2.00 b	0.22 a
Untreated	....	22.19 c	1.66 c	3.97 c	1.45 b

[a] Means followed by the same letter are not significant at the 5% level. Read vertically.
[b] Treated May 31, July 8, August 4. Three 4-tree replicates, nine post treatment counts June 11-September 9.
[c] Treated May 13, June 22, July 27. Three 4-tree replicates. Six post treatment counts May 21-August 5.

Not all side effects of these compounds have been evaluated, but it is clear that their use in the summer months will result in substantial reduction in predator numbers and has been shown to cause severe outbreaks in spider mite levels (see codling moth section, page 7).

As opposed to the synthetic pyrethroids, the IGR's such as Zoecon's 515 (isopropyl 11-methoxy-3,7,11-trimethyldodeca-2, 4-dienoate) appear to be highly selective compounds. In our tests with pear psylla, the primary effect of the IGR's was thought to be the prevention of ecdysis by interfering with normal embryonic development (Tables 45 and 46). In addition, no dramatic reduction in predators of pear psylla or of spider mites was measured (Table 47). Because of their selectivity, the IGR's appear to be excellent candidates for use in an integrated pest management program for pear psylla control.

Table 45. Effects of insect growth regulator residues on development of pear psylla nymphs transferred to treated pear trees; treated March 22, 1973

Material (lbs. A.I./ 100 gal.)	Number nymphs transferred[a]	Percent nymphs surviving to adult[b]	Number eggs from new adults[b]	Percent eggs hatched[c]
ZR-512 0.4	84	16.7	428	37.6
ZR-515 0.4	67	11.9	155	0
Biofilm 6 oz.	93	8.6	347	31.7
Untreated	50	28.0	329	50.5

[a] 22 March
[b] 21 April
[c] 28 April

Table 46. The development of pear psylla eggs and nymphs from adults exposed to residues of insect growth regulators, Treated March 22, 1972

Material (lbs. A.I./100 gal water)[a]	Percent pear psylla in various stages: April 12						April 19					
		Instars						Instars				
	Egg	1	2	3	4	5	Egg	1	2	3	4	5
ZR-512 0.4	94	3	2	1	0	0	94	2	0	2	2	0
ZR-515 0.4	100	0	0	0	0	0	100	0	0	0	0	0
Biofilm 6 oz.	54	15	7	18	5	1	55	28	0	3	3	10
Untreated	77	12	1	3	6	1	69	5	0	0	12	14

a Biofilm® is a spreader-sticker added at the rate of 6 oz./100 gal. water to both ZR-512 and ZR-515.

Table 47. Effects of insect growth regulators and standard pesticides on various pest and beneficial species in Medford pear orchards, 1972

Material and rate A.I./ 100 gal.	Post-treatment levels of nontarget species: Codling moth % infested fruit[b]	Number mites/leaf: European red[b]	2-spot[b]	Pear rust mite[c]	*Metaseiulus occidentalis*[b]	Number predators/ limb tap: *Chrysopa larvae*[b]	*Deraeocoris brevis*[b]
ZR-512 0.4	11.7	1.88	4.32	20.73	0.16	1.3	1.69
ZR-515 0.2[a]	13.3	3.04	6.13	25.68	0.32	0.8	2.11
Phosalone 1.15	0.0	....	......	....	0.04	....	......
Untreated	18.0	16.67	7.14	90.84	0.53	1.5	1.22
Plictran 0.5	......	....	......	0.40	......	....	......
Chlordimeform 0.5	......	0.4	1.22	....	......	0.1	......

a ZR-515 used at 0.4 lb. AI pear rust mite and in *Deraeocoris brevis* plots.
b Treated 12 May and 15 June, air-carrier spray equipment; 2 & 1/4 acre replicates.
c Treated 21 July, handgun equipment; 3 single-tree replicates.
d Treated 26 July, handgun equipment; 1/5-acre plots.

Host Plant Resistance and Host Plant Modification

1.) Host Resistance

The pear psylla is a monophagous insect and can complete its development only on pear. The genus *Pyrus* contains 20 to 25 species of pear. Only three commonly are cultivated for their fruit, and several others used for root stocks or understocks. The common European pear, *P. communis L.*, is of ancient origin from which hundreds of cultivars have been derived. A 1969-70 study in southern Oregon revealed pear psylla did not prefer to lay eggs or would not complete their development on several of these *Pyrus* species. For the most part, the commercially grown varieties of *P. communis* were highly preferred while those species from Asia (except for *P. pyrifolia*) were the least suitable hosts (Tables 48 and 49). Unfortunately, no significant degree of host resistance was found in *Pyrus* cultivars which bear fruit of commercially acceptable quality.

Table 48. Infestation level of pear psylla on *Pyrus* species, Medford, Oregon

Test 1. Infestation on caged *Pyrus*

Geographic area	Average number psylla per 100 sq. in.: Eggs	Nymphs reaching maturity
Asia	17	4
Asia Minor	63	30
North Africa	128	81
Europe	99	61

Test 2. Natural infestation on *Pyrus* species collection

Geographic area	Average number psylla per 25 leaves: Eggs	Nymphs
Asia	27	8.8
Asia Minor	86	48.0
North Africa	44	9.0
Europe	95	49.0

Test 3. Infestation on individually caged *Pyrus*

Geographic area	Number psylla x 10 per sq. in.: Eggs	Nymphs
Asia	17	4
Asia Minor	23	10
Europe	19	8

Table 49. Infestation levels of pear psylla on individually caged *Pyrus* species and varieties, 1968

Geographic area and species	Cultivars	Code[a]	Source[b]	Eggs 10 per in.^{2}	X	Nymphs x 10 per in.^{2}	Nymph: Egg ratio x 100
Asia:							
P.dimorphophylla			OSU-M	11		3	27
P.fauriei		Kor.	OSU-C	8		0	0
P.fauriei		Minn.	OSU-C	12		4	33
P.hondoensis			OSU-M	9		4	44
P.pashia		052	OSU-C	8		3	37
P.pashia		Pak.	OSU-C	32		9	28
P.ussuriensis			OSU-M	8		4	50
P.ussuriensis		Harb.	OSU-C	9		3	33
P.kawakamii		UCLA	OSU-C	54		4	7
P.calleryana x P.pashia		D-6	OSU-C	16		3	17
Average				17		4	28
Asia Minor:							
P.amygdaliformis			OSU-M	35		16	46
P.elaeagrifolia		WB	OSU-C	4		3	75
P.elaeagrifolia		Olez II	OSU-C	13		19	146
P.syrica		1	OSU-C	14		1	7
P.syrica		2	OSU-C	49		12	24
Average				23		10	59
Europe:							
P.pryster		G.D.	OSU-C	15		6	40
P.communis	Buerre d'Angleterre		OSU-M	37		3	8
	Anjou	OP-2	OSU-M	20		5	25
	Maxine		OSU-M	14		7	50
	Winter Bartlett		OSU-M	20		7	35
	Winter Nelis		OSU-M	23		7	30
	Rogue Red	5-235	OSU-M	9		8	89
	Doyenne Gris		OSU-M	21		8	38
	Bosc	OP-5	OSU-M	30		8	27
	Louis Pasteur		OSU-M	21		9	43
	Fox		OSU-M	23		10	43
	Marie Louise		OSU-M	18		10	55
	Bergomote d'Ete		OSU-M	24		10	42
	Conference		OSU-M	11		10	97
	Packham's Triumph		OSU-M	21		11	52
	Seckel		OSU-M	27		12	44
	Hardy	Prosser	OSU-M	22		13	59
	Le Brun		OSU-M	20		13	65
	Red Clapp's Favoriet		OSU-M	41		16	39
	Forelle		OSU-M	24		17	75
	Dana Hovey		OSU-M	31		18	58
Average				19		8	48
L.S (.05 level)				32		15	

a Code refers to particular individual selections of species chosen for testing.

b Source refers to Southern Oregon Experiment Station, Medford (OSU-M) regional collection plot and Department of Horticulture Lewis-Brown Farm collection, Oregon State University, Corvallis (OSU-C).

2.) Host Modification

a) Tree growth modification. Pear psylla seemingly prefer young succulent foliage for ovipositional sites, and sampling techniques for this pest are based on selecting activity growing buds or shoots as the sample unit. A chemically induced lowering in overall shoot growth has been found to cause a related reduction in pear psylla numbers. Using the tree growth regulator Alar® (2,2-dimethylhydrazide) at 2,000 parts per million applied in May and June, overall population levels of pear psylla eggs and nymphs were reduced by 50 percent and honeydew damage to fruit by 75 percent (Table 50).

Though these studies are not yet completed, it would seem the use of tree growth controlling chemicals may be an important control tactic in regulation of pear psylla density.

b) Host masking. As described above, the pear psylla is highly selective in its choice of host and

Table 50. Effect of the tree growth regulator Alar on pear shoot growth and upon pear psylla density and damage

Treatment	Average number psylla May 17-Aug. 12		Mean length terminal growth cm
	Eggs + nymphs/leaf	Adults/tap	
Alar 2000 ppm May 10 & June 7	0.41	4.05	19.33
Untreated	1.21	7.43	25.88

in its selection of suitable ovipositional sites. This would infer the species must receive the correct chemical clues or stimuli from its host before egg laying is triggered. In studies conducted both in the Rogue Valley and elsewhere, treatments with petroleum oils in the dormant period prevent egg laying by the pear psylla for a period of up to six weeks (Figure 13). We believe these treatments may inhibit the production or reception of chemical stimuli produced by the pear host necessary to evoke oviposition.

The use of oil sprays as ovipositional deterrents has been useful in management of pear psylla. These treatments, applied in early to mid-January, allow growers greater flexibility in timing the dormant adulticide treatment by extending the pre-ovipositional period and allowing for a more complete return of adult psylla from sources outside the orchard.

Table 51. Effect of over-tree irrigation on pear psylla density and honeydew damage to Bartlett fruit

Sprinkler irrigation	Percent change in psylla 24 hours after irrigation	Percent honeydew damaged fruit at harvest[1]
Overtree	+ 16	4.2
Undertree	+ 18	14.7

[1] Percent damage following 6 biweekly irrigations during summer of ca. 3″ water at each irrigation.

Cultural Control

Cultural practices to increase the vigor or lengthen the period of new shoot growth will increase the severity of pear psylla attack. These practices include pruning, fertilizer use, and irrigation. Careful management of these horticultural aspects to avoid excess tree stimulation should be practiced.

Over-tree Irrigation

One cultural practice, over-tree irrigation, can be used advantageously to reduce psylla injury by washing potentially damaging honeydew from trees. This method of irrigation can reduce the incidence of honeydew injured fruit by 50 to 60 percent. This practice, however, did not result in substantially lowered psylla densities (Table 51).

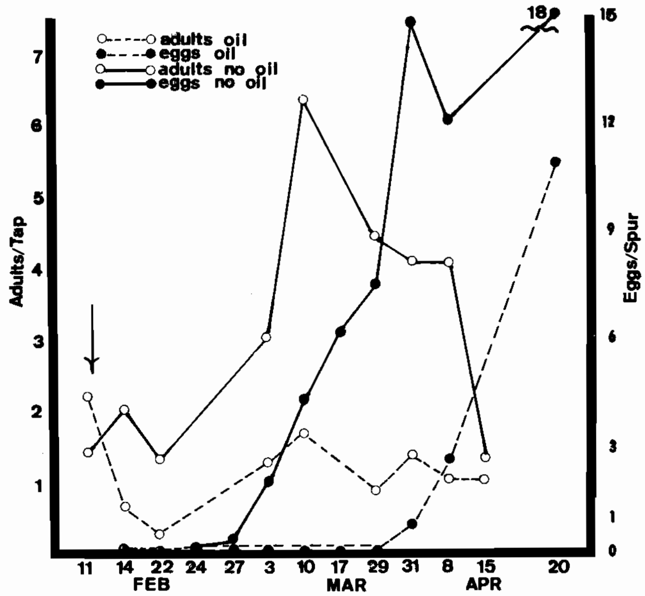

Figure 13. Effect of oil sprays on delay of egg laying by the pear psylla.

San Jose Scale

San Jose scale, *Quadraspidiotus perniciosus* (Comstock), along with the codling moth, was one of the earliest recognized pests of pears in southern Oregon (Cordy, 1977). As early as 1890, growers were concerned about tree and fruit losses caused by this scale. While the San Jose scale is usually controlled to the point where little tree damage results, it still causes severe fruit downgrading in many Rogue Valley orchards.

Life History

Developmental Stages

In southern Oregon, as in most temperate climates, San Jose scale overwinters in the first nymphal instar stage referred to as the "blackcap" stage. Both male and females overwinter. These stages are diapausing forms and resume growth in late winter when diapause ends and warmer temperatures begin. Immature male scale will pass through two molts into a pupal stage from which the fragile 2-winged adult male emerges. Females pass through three molts before reaching maturity and, after mating, give birth to live offspring called crawlers. These young are (except for the mature males) the only motile forms exhibited by this scale. Generally, crawlers move only a short distance from the mother and may settle on woody tissue or on leaves and fruit. In southern Oregon San Jose scale completes two generations per year. Generally, the first generation crawlers are found in early June and continue to appear through late July (Figure 14). Later-appearing crawlers of the first generation overlap with the appearance of crawlers of the second generation. Crawlers of the last generation appear in August and may continue until severe fall frosts occur sometimes as late as early December.

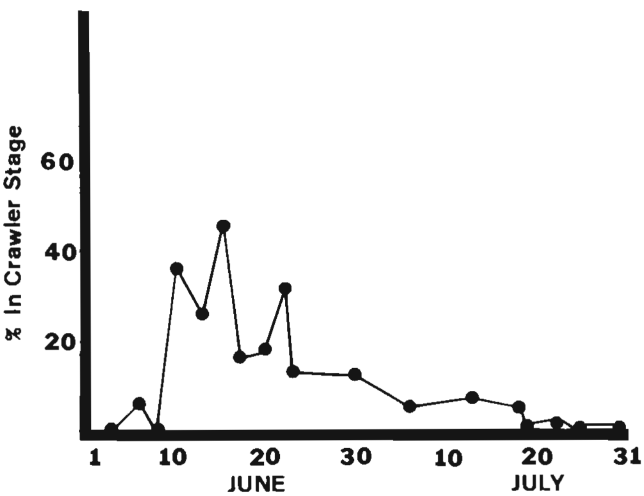

Figure 14. Duration of the appearance of first generation San Jose scale crawlers on pear, 1977.

Damage

Under conditions of relatively high population densities, San Jose scale may cause limb dieback, reduced tree vigor, or even death of the tree. However, even in untreated orchards, attacks of this severity are infrequent. Another type of damage, caused by crawler settlement and feeding on the pear fruit (Figure 15), is very common in southern Oregon, and because of the strict grades and standards set on fruit quality, this type of injury often results in severe crop losses. The presence of one live scale or the feeding mark caused by one scale will prohibit the fresh shipment of pears to most European markets, and more than two scale per fruit will drop fruit grade from the U.S. No. 1 to the Fancy category. The cost of such grade changes are discussed in the section dealing with economics of pear pest management.

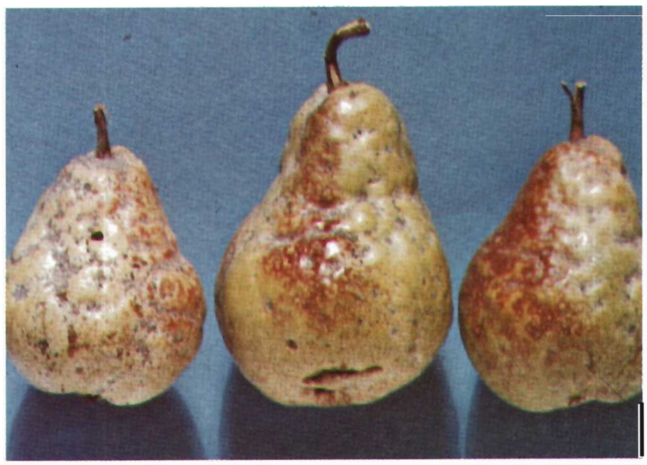

Figure 15. Pear damage caused by San Jose scale.

Scale Density and Damage

The allowable scale damage that would offset the cost of control practices depends upon the value of the various pear varieties. Using the Bosc variety as an example and pesticide costs of approximately $30 per acre, the allowable fruit loss to San Jose scale in the absence of any costs for control would be in the range of a 2 percent fruit infestation. The scale population necessary to cause this 2 percent loss would be an economic injury level. Using the scale infestations of fruit spur wood (see section on sampling) as an indicator of the economic threshold for fruit damage (economic injury), it is estimated an infestation of fruit spurs exceeding 1 to 4 percent will result in economic losses at harvest (Figure 16).

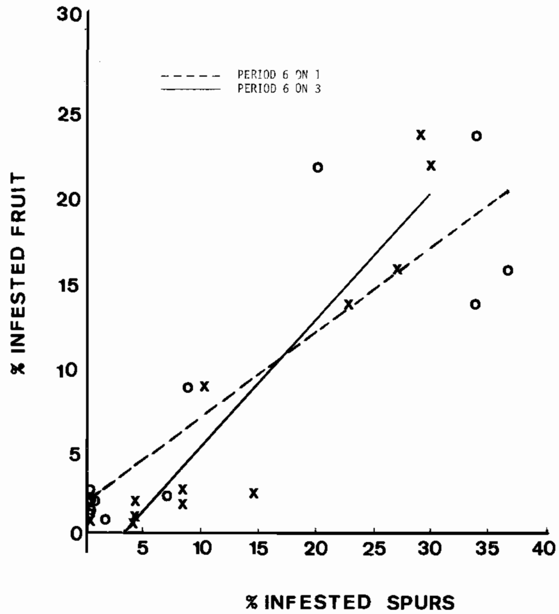

Figure 16. Relationship between the percent infested spurs in period 1 and 3 to percent infested fruit in period 6 following delayed dormant application of pesticides for control of San Jose scale. Data points (x and o) represent the average percent of infested spurs and infested fruit from 4 single-tree replications for each of 10 chemical treatments and an untreated check (see text for designation of periods).

Sampling

Several sampling methods have been used for San Jose scale. These include taking of twig and shoot, bark, or fruit samples. In general, these have been used to evaluate the efficiency of various control tactics, especially pesticides. In the practice of integrated pest management, it is helpful to select as the sample unit one with predictive value in forecasting the potential for economic loss. In southern Oregon, the pear fruit is considered to be the plant part most sensitive to injury and the sample unit most predictive of losses to the fruit is believed to be the woody portion of fruit spurs. The choice of this unit was based on the low vagility of crawlers and the fact that this unit, with its attached leaves and fruit, also could be used in the density determination of other pear pests (for example, see sampling section for pear psylla). Samples taken from the upper one-half of the tree generally support higher-scale numbers and were better predictive units of damage potential.

In the case of San Jose scale, the total number of scale on fruit spurs need not be counted. Rather, the percent of infested spurs was a better predictor of percent infested fruit at harvest (Table 52). In addition, samples taken in April, June, or early August were more reliable than those taken in May or late August (Table 52).

Table 52. Correlation coefficients between percent San Jose scale infested Bosc pears in period 3 or period 6 and total number of scale or percent infested spurs found in previous sample periods, Medford, Oregon, 1973[a]

Period infestation sampled	Period fruit sampled	Regression coefficient	
		Total no. scale	Percent infested spurs
1	6	0.567**	0.708**
2	6	0.341**	0.591**
3	6	0.554**	0.803**
4	6	0.497**	0.838**
5	6	0.661**	0.694**
1	3	0.541**	0.634**
2	3	0.307*	0.531**

* Significantly different from zero at P = 0.05.

** Significantly different from zero at P = 0.01.

[a] Period 1—late April; 2—late May; 3—late June-early July; 4—early August; 5—late August; and 6—mid-late September.

Control Tactics

Biological Control

Data from 1964 to 1971 from unsprayed Barlett orchards showed the San Jose scale infestation of fruit at harvest ranged from 1 percent in 1964 to 92 percent in 1967 (Table 53). Based on tolerable injury levels for the various varieties (page 38), the infestation level recorded surpassed tolerable economic levels in 5 years of the 7-year study period (Table 53). Thus, it seems the native parasite and predator complex cannot be relied upon to give economic pest suppression to meet tolerable fruit injury levels. On the other hand, several natural agents attack the San Jose scale and these, if left undisturbed by pesticide treatments, appear to be able to hold scale below the level when reduction in tree vigor occurs. These natural enemies include several coccinillid species, an anystid mite (cover photograph), and the parasite *Prospaltella perniciosi* (Tower). This latter species was found in 1970 to have attacked more than 80 percent of the scale in an untreated Bartlett orchard.

Table 53. San Jose scale damage to Bartlett pears in an unsprayed orchard over a 7-year period

Year	Percent infested fruit
1964	1.0
1965	2.0
1966	6.0
1967	92.1
1969	3.8
1970	5.5
1971	11.9

For the San Jose scale, as well as other pear pests, the potential for biological control would be quite promising except for the high standards of fruit quality demanded either by law or by the general public.

Chemical Control

1.) Timing

a) Pre-bloom. San Jose scale overwinters as a young nymph primarily on exposed sites on pear limbs or shoots, so a chemical treatment applied in the dormant period usually gives commercially acceptable control. This treatment timing has been used effectively by Rogue Valley growers since at least the early 1920s. The spray, usually containing oil plus either sulphur or an organophosphate insecticide, is applied prior to bud separation. After that time, the compounds can be quite injurious to pear buds. Tests in 1974 indicated oils used alone were usually sufficient to obtain control; however, combination sprays may add to scale mortality as well as prove effective against other pest species (Table 54).

The dormant or the delayed dormant treatment timings generally provide better control than post-bloom treatments. This probably is due to the improved tree coverage offered at this time and attributed to the absence of foliage. In addition, the pre-bloom timing is less disruptive to non-target beneficial species than the sprays used during the foliar period.

Table 54. Evaluation of commonly used pesticides for pre-bloom control of the San Jose scale

Material and rate a.i./100	Percent mortality
Volck Supreme oil 2 gals.	96.3
Orchex 796 2 gals.	100.0
Ethion 0.38 lb.	87.9
Ethion 0.38 lb. + Volck oil 1 gal.	100.0
Volck oil 1 gal. Orchex 796 1 gal.	64.9 94.8

b) Post-bloom. The summer treatment for San Jose scale control usually is timed to coincide with the appearance of the crawler stage. As discussed in the section dealing with life history, the crawlers of the first generation usually appear in early June and those of the second generation appear in mid-August. Treatments during these periods may reduce population numbers but cannot be relied upon to give commercial control in the absence of pre-bloom sprays.

In addition to the poorer spray coverage obtained during the summer, there are two other reasons why the crawler-directed sprays do not result in commercial scale reduction. First, the emergence of crawlers spans a period of at least two months (see Figure 14) and the residual activity of the registered pesticides is not nearly of this duration. Tests in 1969 showed that while some materials killed crawlers for a 14-day period, their effectiveness was dissipated at least by the end of a 4-week period (Tables 55-56). While summer treatments timed at 14-day intervals may be effective, they rarely are used in southern Oregon because of the growers' preoccupation with other necessary horticultural practices.

Another possible time to achieve scale control during the foliar period is directed at males just

Table 55. Effect of pesticide residue on degree of San Jose scale control

Material and rate a.i./100	Percent mortality of crawlers at days after application	
	14	28
Ethion 0.25	32.	0.
0.50	82.	58.
Parathion 0.50	94.	22.
Phosalone 1.0	99.	68.

Table 56. San Jose scale crawlers killed by pesticide treatment following settlement on fruit

Material and rate a.i./100	Percent of scale crawlers found dead but settled 14 days after pesticide treatment
Parathion 0.5	78.
Phosalone 1.0	52.
Diazinon 0.4	80.
Ethion 0.25	92.

prior to adult emergence (Downing, 1977). Since these forms appear over a shorter period and because of their greater vagility, it was presumed they would be more susceptible than at the crawler stage to summer chemical suppression. The testing of this timing, in fact, did reduce scale infestation somewhat over that produced by crawler-directed sprays (Table 57). However, these data also point out the poor control of San Jose scale to be expected from treatments during the foliar period.

Table 57. Control of San Jose scale obtained by treatments directed at male or crawler stages

Timing[1] and date	Percent infested fruit at harvest
1st male – April 19	18.0
1st male + 7 days – April 27	35.0
1st male + 14 days – May 6	25.5
1st crawler + 7 days – June 13	35.5
Untreated	71.3

[1] Diazinon at 0.5 lbs. a.i./100 were used in these studies.

Pear Rust Mite

The pear rust mite *Epitremerus pyri* (Nalepa) (Figure 17) first was identified in southern Oregon pear orchards in 1931. Since then reports of sporatic but severe damage have surfaced, due to this eriophyid mite. While the species attacks both pear fruit and foliage, it can be considered a direct pest because leaf injury is seldom of economic importance.

Figure 17. Pear Rust Mite

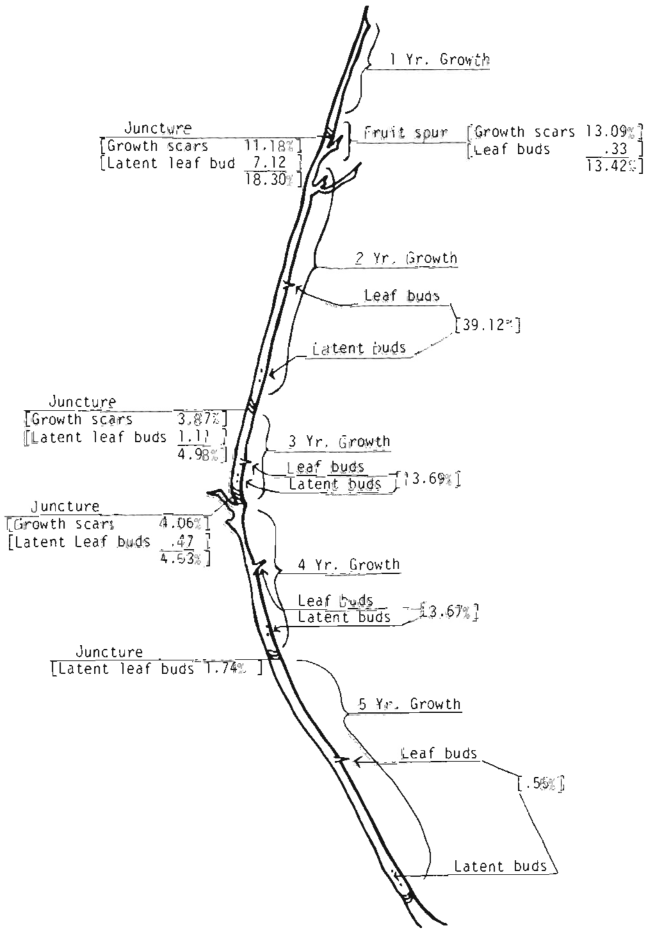

Figure 18. Overwintering distribution of the pear rust mite on 5-year wood sections of pear limbs, December 1972.

Life History

Very little is known about the biology of *E. pyri*, but some information is available regarding the seasonal intra-tree distribution of this species, an aspect of the life history of importance to IPM as it affects sampling procedures. The pear rust mite overwinters in bark crevices or behind loose bud scales, predominately on 2- to 3-year-old wood (Figure 18). Emergence from these overwintering sites coincides with the separation of fruit buds. These developing clusters become the initial feeding sites for the rust mite. A period of time is spent within the fruit cluster when damage to fruit may occur. As the clusters open and leaves expand, the rust mite moves to leaf tissue, though a residual population may be found on the fruit through most of the summer. The seasonal dispersion pattern of the rust mite on Bartlett pear is given in Table 58.

During this period, the rust mite passes through several generations but the exact number is unknown. Also uninvestigated is the fecundity and longevity of the mite. Observations indicate there are several generations per year and these may be favorably influenced by the availability of young succulent tissue.

Damage

The pear rust mite feeds on the surface of fruit and foliage causing a bronzing of the tissue. Bartlett fruit injured by the rust mite usually is acceptable for cannery use, but for fresh market a heavy russett covering more than 5 to 10 percent of the surface results in downgrading or perhaps culling (see acceptable standards, page 37). Other clear-skinned pear varieties such as Comice or D'Anjou, sold almost exclusively on the fresh markets, however are, particularly susceptible to the economic effects of rust mite damage. On the other hand, the normally russetted Bosc variety seldom is downgraded due to rust mite feeding.

Mite Density and Damage

In 1974, the relationship between seasonal rust mite density and russett damage was evaluated. For these tests, an acceptable level of injury was based on control costs and the type and degree of rust mite damage. Based on a spray cost of $10 per acre per year (see page 38) and a return to the grower of approximately $1,000 per acre for fruit value, a loss more than 1 percent of the fruit would exceed the cost of control. The population density responsible for a loss of this magnitude would then be an economic injury level. The results obtained indicated pear rust mite densities exceeding an average of five per fruit on one or more sample dates resulted in excess of 1 percent fruit damage, i.e. fruit with more than 5 percent of the surface russetted (Figure 19). In these studies,

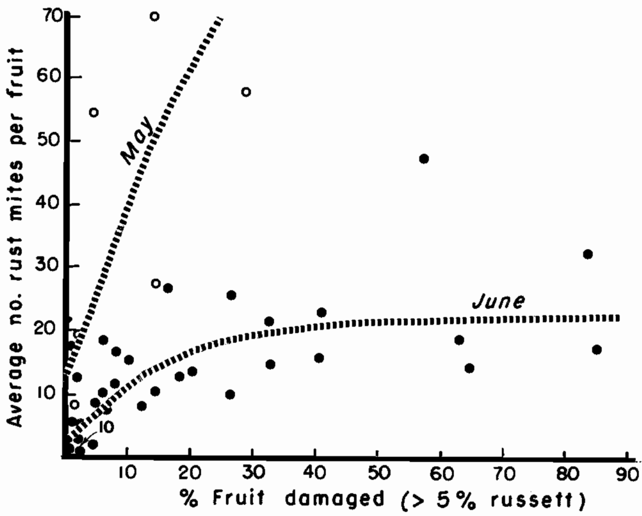

Figure 19. Relationship between rust mite density in May and June and fruit injury at harvest (August 2) on Bartlett pears, 1974.

indications of economic injury level may be higher in the early part of the season (May) than in June or July (Figure 19). The economic injury levels, however, would be lower on more valuable varieties such as Comice.

Sampling

The pear rust mite may be sampled to detect its presence, to evaluate control tactics, or to determine the potential for economic injury. The first two sampling objectives probably are best accomplished by fruit buds (early season) or leaves (summer) serving as the sample units (see page 32 on rust mite distribution). However, as suggested by the dispersion pattern exhibited by the rust mite, these sample units may not be indicative of potential fruit injury. In the studies on rust mite injury cited above, the sample selected was the pear fruit because this represented the basic economic unit influenced by mite feeding. In addition, fruit samples in the upper portion of the pear

Table 58. Seasonal dispersion pattern of the pear rust mite on various fruit cluster sites 1973

	Percent of population													
Fruit cluster site	3/25	4/8	4/16	4/23	4/29	5/6	5/18	5/28	6/9	6/16	7/2	7/13	7/27	8/10
Fruit bud scale	28.4	11.5	0.6	0.9	0	0	0.2	0	0	0	0	0	0	0
New spur wood	9.5	13.3	11.5	6.4	1.8	7.0	0.3	0.8	0.2	0.4	0.2	0	0	0
Leaves	26.5	24.1	21.3	26.5	53.3	55.5	75.7	86.4	87.9	93.9	56.8	94.3	100	83.8
Fruit	0	10.7	17.2	22.7	15.8	22.1	22.2	12.7	11.9	5.6	42.9	5.7	0	16.2
Fruit stem	35.6	40.3	49.5	43.4	29.1	15.5	1.7	0.1	0	0	0	0	0	0
	Total population													
No. mites per fruit cluster	110	171	178	401	246	516	813	1118	1665	555	516	287	25	

tree consistently supported higher rust mite densities (Figure 20) and, therefore, were used in the sampling system developed. This system, using five fruit from the upper one-half of each tree, was used in estimating the sample size (number of trees) required to obtain a reliable estimate of mean population density.

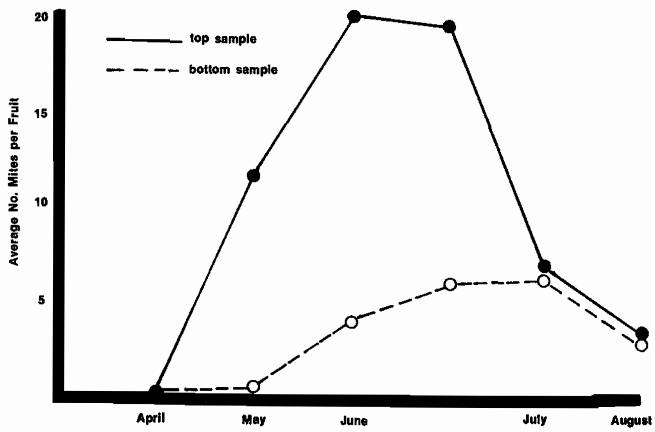

Figure 20. Rust mite density on fruit from top and lower areas of untreated Bartlett pear trees, 1973.

Based on density data taken from untreated Bartlett trees, the required sample size was calculated for various sample periods (Table 59). As can be seen, the sample size decreased with time, indicating decreasing variation between sample means. From a cost standpoint, using the confidence interval of ± 10 percent would result in a sample size so large as to be impractical. In most cases, it would seem a confidence interval of ± 30 percent or even higher could be used.

Control Tactics

Biological Control

In pear orchards not receiving pesticide treatments, the pear rust mite, like the codling moth, is a persistently destructive pest. Between 1965 and 1971, nearly 50 percent of unsprayed Bartlett fruit was downgraded or culled because of rust mite damage (Table 60). Thus, the potential for commercially acceptable levels of the biological control of *E. pyri* seems poor, at least with the indigenous predator complex existing in southern Oregon.

Table 59. Sample size required to estimate rust mite density

Confidence interval (± %)	Number of trees to sample with coefficient of variation (%) — Confidence level 95 percent			
	May	June 6	June 20	July
	CV 185%	CV 107%	CV 82%	CV 69%
10	1314	440	258	183
30	146	49	29	20

Table 60. Damage to Bartlett pears caused by rust mite feeding

Year	Percent fruit russetted	Percent average area of surface russetted
1965	76	43
1966	61	14
1967	83	16
1968	39	12
1970	30	36
1971	1	12

Chemical Control

1. *Chemicals used.* Many pesticides are available for rust mite suppression and the choice of a particular compound usually depends upon its effectiveness on other pear pests in addition to *E. pyri.* Table 61 summarizes the most commonly used pesticides for various stages of tree development.

2. *Timing.* The pear rust mite historically has been controlled in the pre-bloom or post-harvest period. Treatments primarily directed toward the San Jose scale generally also have been effective on *E. pyri.* Occasionally, because of wet ground conditions, the pre-bloom treatments are not applied and severe rust mite damage may occur. In 1968, a study was conducted to evaluate timing of application in relationship to control and fruit injury. These studies showed pre-bloom treatments were necessary to minimize damage. The later the rust mite control was applied, the more severe the fruit russett (Table 62).

Table 61. List of chemicals commonly used for pear rust mite control at various stages of tree development

Timing	Material	Other target pests
Delayed dormant	a) Lime sulfur	San Jose scale
	b) Diazinon	San Jose scale
Pink bud	a) Oxythioquinox	Spider mites Pear psylla
	b) Endosulfan	Pear psylla
Summer	a) Plictran	Spider mites
	b) Amatraz	Pear psylla

Table 62. Timing of pesticide application for control of *E. pyri* in relatiionship to injury to Bartlett fruit, Medford, Oregon, 1966

Time of application[b]	Number *E. pyri*					Fruit injury[a]	
	Apr. 22[c]	May 6[d]	May 24	June 8	June 27	Percent fruit surface marked	Percent fruit with russett
Delayed dormant (Mar. 12)	9	0.4	1.2	0.3	0.5	5.0	2.0
Pink bud (Mar. 31)	3	.9	1.3	.5	.5	5.8	6.0
1st cover (May 15)	409	15.1	0.6	.5	.8	9.3	64.0
2nd cover (June 15)	559	20.3	48.3	14.1	.0	21.0	94.0
Untreated	1234	16.1	18.6	10.4	6.8	29.5	86.0

a At harvest July 29.
b Treatment of 1 lb. endosulfan applied to four 4-tree replicates.
c Total *E. pyri*/25 leaf punches, 3/4 in. diam.
d Avg. number *E. pyri* per leaf; sample size of 80 leaves.

Economic Aspects of Integrated Pest Management

As referred to in the introduction, one of the important aspects of integrated pest management deals with crop economics as they relate to pest control. The IPM system requires pest density be related to damage potential and that damage be shown to be of real economic impact.

Components of Crop Value

Two facets of pear culture economics bear on IPM. First, a potential crop value exists aside from pest damage considerations. Secondly, pest levels affect this potential value. The first aspect deals with dollar value per unit in the absence of pest damage and varies from year to year, variety to variety, and from orchard to orchard. This potential crop value may be reduced by certain pest densities.

Actual crop value, that is, the amount returned to the grower before his operating expenses, is determined by many factors outside the scope of this report. But from a production standpoint, the value is strongly influenced by (1) yield per land unit (usually per acre), (2) fruit quality, and (3) fruit size. In the following section we will discuss each of these variables and the influence of pest damage on these value determinants.

Yield

Yield in the Absence of Pest Damage

Table 63 presents the variation in yield of Bartlett pears over a nine-year period. This variation is more or less typical of all pear varieties grown in southern Oregon. In this table, the yield was quite variable, ranging from 14.2 tons per acre in 1969 to only 5.6 tons per acre in 1970, and a mean yield of 10.7 tons per acre. Most of the variation was not pest-induced, but rather the effect of poor pollination or of spring frosts.

Pest Influence on Yield

The yield of pears generally is given in tons per acre with this measurement of productivity taken at harvest time. Insects and mites that affect bloom density, fruit set, or which cause any preharvest loss of fruit also affect yield. In this category are found the effects of spider mite and pear psylla feeding as well as early season damage by codling moth which may cause pre-harvest fruit drop. The damage type induced by individual pest species are discussed in their respective sections.

Yield and Economic Injury

As seen in Table 63, total yield will vary enormously from year to year. When pest control decisions are made relative to this variable, the potential yield will have to be estimated based on past history of particular orchards. This estimate will require constant updating as seasonal events raise or lower the yield estimates.

Other factors of fruit quality and fruit size being constant, an increase in the yield of fruit per

Table 63. Variation in yield[1]/acre of the Bartlett variety, 1964-70

Year	Tons/acre
1964	11.8
1965	10.8
1966	8.0
1967	12.3
1968	12.3
1969	14.2
1970	5.6

[1] Yield from Southern Oregon Experiment Station mature Bartlett pear orchard.

acre generally will lower the economic injury level of a particular pest known to influence yield. This is due to the fact that control measures such as pesticides are applied on a per-acre basis with associated costs related to acreage treated not to yield per acre. Thus, a miticide may cost $20 per acre per application. Based on a yield of 10 tons per acre, this amounts to $2 per ton. However, if yield were estimated at 20 tons per acre the cost is reduced to $1 per ton. If mite density to be treated would have caused a $1.50 per ton per acre reduction in crop yield, the treatment would have been justified in the higher, but not the lower, producing situation.

Fruit Quality

Fruit Quality in the Absence of Pest Injury and Grower Returns

Table 64 summarizes the monetary return to growers over a six-year period for various grades of winter pears. In this table, only returns for the U.S. No. 1 and Fancy grades are given because they represent the most common packs of fresh shipped pears from the Rogue River area. When returns for all varieties over a six-year period (Table 65) were lumped, the higher grade U.S. No. 1 averaged nearly 50 percent greater returns than the 'Fancy' (U.S. No. 2) grade.

Pest Influence on Fruit Quality

Over the years, improvements in fruit quality have been an important competitive market force in maximizing grower profits and have resulted in preferential prices being given for fruit nearly blemish free. Many quality standards cause downgrading or culling of pears with no more than minor surface marking. These requirements have reduced the economic injury levels of pest species known to cause surface damage. Pear pests in southern Oregon important in determining fruit quality include the codling moth, pear psylla, San Jose scale, and the pear rust mite. Table 66 gives the acceptable level of damage for these pests for the various fruit grades.

Table 64. Effect of fruit grade on average dollar return to grower[1] for winter pear varieties, 1971-77

Return 1971-77	Variety and dollar return per packed box for 2 grades[1]					
	Bosc		Comice		D'Anjou	
	U.S. 1	Fancy	U.S. 1	Fancy	U.S. 1	Fancy
Average	4.30	2.68	4.80	1.61	2.70	2.02
Low	3.28	1.28	2.68	0.92	1.96	1.06
High	6.02	4.35	8.34	2.15	3.50	3.15

[1] Southern Oregon Experiment Station return.

Table 65. Average pear crop value (1971-77) of winter varieties from all sizes and grades

Variety and dollar value[1] per acre		
Bosc	Comice	D'Anjou
$1,700.	$1,850.	$1,100.

[1] Return to Southern Oregon Experiment Station, based on estimated average yield of 10 tons/acre.

Fruit Quality and Economic Injury

The potential value of various fruit grades can be used in conjunction with potential pest control costs to set approximate levels of tolerable damage. Because of the high differential in dollar returns for the higher grades, the losses due to fruit marking often outweigh the cost of added control measures. For instance, using the average returns from Table 65, if pear psylla density on the Comice variety were to reach levels that caused a 5 percent decrease in grade from U.S. No. 1 to U.S. No. 2, and if the yield were 10 tons per acre, the net loss would be about $70 per acre. Under current conditions, this situation would justify at least two additional pesticide treatments. However, on the Anjou variety a similar decrease of 5 percent would lower crop value by only $15 per acre, currently not sufficient to offset additional pesticide treatment.

Fruit Size

Fruit Size in the Absence of Pest Injury

There is a definite tendency for the public to prefer pears of certain sizes. These normally will return premium prices. Table 67 presents the effect of fruit size on the value of four pear varieties over a six-year period. As is evident, substantial differences in dollar return are given for various sizes. In the case of Bosc and D'Anjou varieties, a trend for lower value for the very largest and smaller sizes has begun. With Bartlett and Comice, a direct relationship exists between larger fruit and greater value.

Pest Influence on Fruit Size

The shifts in fruit size caused by insect or mite feeding are the result of indirect damage, especially to leaf tissue that reduces the total amount of photosynthate. The feeding injury of several pests, including the pear psylla, San Jose scale, and the two-spotted spider mite, appear to affect fruit size.

Table 66. Acceptable damage for various winter pear fruit grades due to major pest species

Pest	Fruit grade	Damage permitted
Codling moth	U.S. Extra fancy	2 healed slight stings.
	U.S. No. 1	2 healed stings.
	Fancy	3 healed stings.
Pear psylla	U.S. Extra fancy	Less than 10% surface with thinly scattered spotting. Less than ½ inch diameter with moderately scattered spotting. Less than ⅜ inch diameter with heavily concentrated spotting.
	U.S. No. 1	Less than 25% surface with thinly scattered spotting. Less than ¾ inch diameter with moderately scattered spotting. Less than ½ inch diameter with heavily concentrated spotting.
	Fancy	Less than ½ inch of surface with thinly scattered spotting. Less than 1&¼ inch diameter with moderately scattered spotting. Less than ¾ inch diameter with heavily concentrated spotting.
San Jose scale	U.S. Extra fancy	1 scale or scale mark.
	U.S. No. 1	2 scale or scale marks.
	Fancy	6 scale or scale marks.
	Export all grades	No more than 2% of lot with scale.
Pear rust mite on smooth skinned varieties	All U.S. grades	Smooth russett permitted on portion of calyx end not visible for more than ½ inch along the contour of pear when placed calyx end down on a flat surface.

However, except for the last pest species, studies have not been made on pears relating pest density to changes in fruit size.

Fruit Size and Economic Pest Injury

Severe leaf damage may cause a shift to smaller fruit sizes and, at times, this will have important economic impacts. In the case of the Bosc variety, a difference in return of $1.25 per packed box between the 135 fruit per box and the 150 fruit per box sizes may result (Table 67). Based again on 10 tons of fruit per acre yield (ca. 450 packed boxes) an increase in 10 boxes per acre from the 135 to the 150 size would reduce returns by about $12.50 per acre or about the cost of one acaricide treatment.

Total Crop Value

It is apparent from the above discussion that the three aspects of crop value (yield, quality, and size) are highly variable even in the absence of pest damage effects. Since a known value is necessary to set economic injury levels for the various pest species, the question arises as to just what dollar figure should be placed on a particular pear crop in a particular orchard to enable the appropriate decisions regarding control tactics. As an example, a study of Table 64 will reveal that for any of the three winter varieties tested, the value varied as much as $5 per packed box between years with the high and low returns. To complicate the matter even more, the final value is not exactly known until months after harvest and comes belatedly after all pest control decisions have been made for that particular year.

Though growers are apt to disagree, it probably is advisable to use average crop value rather than high or low average values in assessing the damage potential of pest species. Using the maximum crop value received in the past as a standard will lower economic injury thresholds to a point where unnecessary control measures become routine. On the other hand, using the low return as an economic base, will result most often in a higher incidence of unacceptable pest damage.

Average crop value usually can be calculated based on packing house printouts for varieties within these orchards. As mentioned previously, the estimate of crop value will have to be updated

Table 67. Effect of fruit size on dollar return to grower for winter pear varieties, 1971-77, U.S. No. 1 grade

Variety	60	70	80	90	100	110	120	135	150	165	180
Bosc	$3.30	4.24	4.98	5.42	5.34	5.42	5.35	5.24	3.99	3.01	2.03
D'Anjou	2.59	2.78	3.07	3.08	3.06	3.05	3.00	2.88	2.42	2.21	1.41
Comice				6.02	5.64		4.24		0.93		

with seasonal events that influence yield, quality or fruit size.

Total average crop value per acre for the winter pear varieties is given in Table 65. These figures are based on a 10 ton per acre yield with U.S. No. 1, Fancy and cull fruit making up 85 percent, 10 percent, and 5 percent of the packout, respectively. Cull fruit is given a value of $10 per ton.

Table 68. 1977 spray program for pear pests in southern Oregon

Timing of application	Material and approximate cost ($) per acre		Pests at which treatment directed
Dormant	Oil	8.00	Pear psylla
Late Dormant	Perthane +	24.00	Pear psylla
	Diazinon +	16.00	San Jose scale
	Oil	5.00	Pear psylla, San Jose scale, mite eggs
Pink	Morestan	20.00	Pear psylla, rust mite
1st Summer	Thiodan	18.00	Pear psylla
	Guthion	6.00	Codling moth
2nd Summer	BAAM	30.00	Pear psylla
	Guthion	6.00	Codling moth
	Plictran	20.00	Spider mites
	Diazinon	16.00	San Jose scale
3rd Summer	BAAM	30.00	Pear psylla
	Guthion	6.00	Codling moth
	Plictran	20.00	Spider mites
	Total	$217.00	
Cost for individual pests			
Pear psylla	$120.		
Pear rust mite	10.		
Spider mites	42.		
San Jose scale	32.		
Codling moth	18.		

Crop Value and Current Costs for Pest Control

Costs for pest control (Table 68) can be compared to potential crop value to arrive at a very general level of permissible damage by particular pests (Table 69). If, for example, pear psylla control costing $120 per acre is compared to the average value of the three winter varieties, it amounts to 7 percent, 6 percent, and 11 percent of the average value for Bosc, Comice, and D'Anjou, respectfully. Thus, depending upon the pear variety, if no chemical control program was used for this pest, the grower could afford from 6 to 11 percent crop loss and not have incurred economic loss. An increase in crop value or a decrease in control costs will lower the tolerable damage level.

The work of IPM is to relate potential damage by various pest densities to the fluctuating crop values described above and to develop control tactics realistic for the grower in the economic paradigm.

Table 69. Cost of control for various pear pests as expressed by percent of crop value for winter pear varieties[1]

Pest species	Variety: Bosc	Comice	D'Anjou
Codling moth	1.1%	1.0%	1.6%
Pear psylla	7.1	6.4	10.9
San Jose scale	1.9	1.7	2.9
Pear rust mite	0.6	0.5	0.9
Spider mites	2.5	2.3	3.8

[1] See Table 65.

Horticultural Aspects of Integrated Pest Management

Since horticultural practices influence crop value, pest density, or pest damage expression, they influence the practice of integrated pest management. The horticultural aspects most pertinent to IPM include (1) the selection of appropriate cultivars (varieties) and understocks and (2) the development of horticultural practices that maximize or stabilize production of high-quality pears or those implemented to reduce production costs.

Pear Varieties

Of the 300 to 400 pear varieties described, only 4 or 5 are of commercial significance in southern Oregon. Each of these has its own characteristics including variations in susceptibility to pest attack. Variations in value also occur between varieties. Crop value determines the economic impact of pest damage and has been covered in the first part of this section.

Variation of the pear varieties to injury has been shown with several pear pests, including the codling moth and the pear psylla, and is probably present with most other pear pests. There are several reasons why certain varieties of pear are able to tolerate higher pest densities than others. One example deals with the difference in damage caused by pear psylla honeydew which is more noticeable on the clear skinned varieties, such as D'Anjou or Comice, than on the normally dark russetted Bosc variety. This allows for a somewhat higher tolerance to psylla densities on the latter variety. Also, a pear variety may be more tolerant of pest attack due to various morphological or physiological attributes such as thicker leaf cuticle (spider mites) or the presence of stone cells in the fruit (codling moth).

Finally, variation in tree vigor differs between cultivars and may influence population density of so-called flesh feeders such as pear psylla and the pear rust mite.

Pear Rootstocks

All pear cultivars are grafted onto understocks of other *Pyrus* (occasionally quince) varieties or species. These stocks are selected for several purposes including resistance to root insects or disease, to promote precocious bearing, for tree growth control, or to maximize yields. The influence of rootstocks on yield can be dramatic. Work in southern Oregon (Lombard and Westwood, 1976) showed there may be as much as a 3- to 4-fold increase in pear tree productivity depending upon the rootstock used. Orchards planted using the more efficient rootstocks will have increased yields and will tend to have lower economic injury levels for many pest species. The rootstock also may influence pest levels on the most common varieties. Though few studies have been conducted to quantify these effects, a significant difference was measured between population densities of the pear rust mite on Bartlett pears top worked to various rootstocks (Table 70).

Horticultural Practices

In addition to the choice of rootstock and cultivar, a number of horticultural practices either enhance or decrease the potential for IPM implementation. A few of these practices are given in Table 71 along with their apparent effects on IPM.

It is also apparent that some of the newer developments in horticulture will alter the crop economics which, in turn, will influence management of pear pests. One of the recent trends in orchard management is to replace the older orchards with high-density plantings of more than 500 trees per acre. Yields from these plantings are expected to be 2 to 3 times that from the older standard planted orchards and will have the effect of reducing economic injury levels and treatment threshholds accordingly.

Table 70. Influence of understocks on population density of the bear rust mite on the Bartlett cultivar

Understocks	Rust mites/leaf
Old Home clonal	81.8 a
Old Home/Quince A	82.5 a
Nivalis	82.5 a
Old Home/Bartlett seedling	83.4 ab
Old Home/Nelis	90.1 abc
Calleryana	100.5 bc
Nelis seedling	105.6 c
Bartlett seedling	106.2 c

Table 71. A partial list of various horticultural practices and their effects on integrated pest management of pear pests

Practice	Effect on IPM
Irrigation (furrow or under tree sprinkler)	Due to slow drying conditions on heavy soils, prevents curative spray practices and leads to preventive pesticide applications.
Irrigation (over-tree)	a) Removes pesticide deposits and may cause increases in frequency of chemical treatments (see codling moth). b) Reduces injury and/or population density of pest species (see pear psylla, pear rust mite and spider mites).
Pruning (mechanical tree topping)	Promotes new shoot growth which may cause increases in pest levels (see pear psylla).
Post harvest defoliation	To allow early pruning. May decrease overwintering populations of some pest levels (see spider mites).
Fertilizer treatment	No studies available from southern Oregon, but excess nitrogen application have been reported to result in increases in densities of several orchard pest species (see Burts and Hoyt, 1974).

Bibliography

Barnes, M. M. 1959. Deciduous fruit insects and their control. Ann. Rev. Entomol. 4:343-362.

Batiste, W. C., W. H. Olsen and A. Berlowitz. 1973. Codling moth: influence of temperature and daylight intensity on periodicity of daily flight in the field. Jour. Econ. Entomol. 66:883-892.

Burts, Everett C. 1968. An area control program for the pear psylla. J. Econ. Entomol. 61:261-263.

Cordy, C. B. 1977. History of the Rogue Valley fruit industry. mimeo. 30 p.

Downing, R. S. and D. M. Logan. 1977. A new approach to San Jose scale control. (Hemiptera: Diaspididue). Canad. Entomol. 109:1249-1252.

Glass, Edward H. Coordinator, Integrated Pest Management: Rationale, Potential, Needs and Improvement. 1975. Entomol. Soc. America Special Publication. 75-2. 141 p.

Hoyt, S. C. and E. C. Burts. 1974. Integrated control of fruit pests. Ann. Rev. Entomol. 19:231-252.

Lombard, P. B., P. H. Westigard and Dunbar Carpenter. 1966. Over-head sprinkler system for environmental control and pesticide application in pear orchards. HortSci. 1(3&4):95-96.

Lombard, P. B. and M. N. Westwood. 1976. Performance of six poor cultivars on clonal Old Home, double rooted and seedling rootstocks. J. Amer. Soc. Hort. Sci. 101: 214-216.

Madsen, H. F. and C. V. G. Morgan. 1970. Pome fruit pests and their control. Ann. Rev. Entomol. 15:295-320.

Madsen, H. F. and J. M. Vakenti. 1973. Codling moth: use of codlemone baited traps and visual detection of entries to determine needs of sprays. Environ. Ent. (2): 677-679.

Madsen, H. F., P. H. Westigard and R. L. Sisson. 1963. Observations on the natural control of the pear psylla, *Psylla pyricola* Forster, in California. Canad. Entomol. 95(8):837-844.

Nickel, John L. 1960. Temperature and humidity relationships of *Tetranychus desertorum* Banks with special reference to distribution. Hilgardia. 30(2).

Pickel, C. 1976. Computerized forecasting as an aid for timing codling moth control. MS thesis, U. of C. Berkeley. 37 p.

Riedl, Helmut, B. A. Croft and A. J. Howitt. 1976. Forecasting codling moth phenology based on pheromone trap catches and physiological-time models. Canad. Entomol. 108:449-460.

Stern, Vernon M., Ray F. Smith, Robert van den Bosch, Kenneth S. Hagen. 1959. The integration of chemical and biological control of the spotted alfalfa aphid. Hilgardia. 29(2): 81-154.

Terriere, L. C., Ulo Kiigemagi, R. W. Zwick and P. H. Westigard. 1966. Persistence of pesticides in orchards and orchard soils. Adv. Chem. Ser. 60:263-270.

Westigard, P. H. 1969. Timing and evaluation of pesticides for control of the pear rust mite. J. Econ. Ent. 62(5): 1158-1160.

Westigard, Peter H. 1971. Integrated control of spider mites on pear. J. Econ. Ent. 64(2):496-501.

Westigard, P. H. 1973. Pest status of insects and mites on pear in southern Oregon. Journ. Econ. Ent. 66(1):227-232.

Westigard, Peter H. 1973. The biology of and effect of pesticides on *Deraeocoris Brevis Piceatus* (Heteroptera: Miridae). Can. Ent. 105:1105-1111.

Westigard, Peter H. 1974. Control of the pear psylla with insect growth regulators and preliminary effects on some non-target species. Environ. Ent. 3(2):256-258.

Westigard, P. H. 1975. Population injury levels and sampling of the pear rust mite on pears in southern Oregon. J. Econ. Ent. 68(6):786-790.

Westigard, P. H. and D. W. Berry. 1964. Control of the pear rust mite, *Epitrimerus pyri*. J. Econ. Ent. 57(6):953-955.

Westigard, P. H. and D. W. Berry. 1970. Life history and control of the yellow spider mite on pear in southern Oregon. J. Econ. Ent. 63(5):1433-1437.

Westigard, P. H. and D. W. Berry. 1975. Pear psylla control in southern Oregon. Proc. Ore. Hort. Soc. 66:131-136.

Westigard, P. H. and L. D. Calvin. 1971. Estimating mite populations in southern Oregon pear orchards. Can. Ent. 103:67-71.

Westigard, P. H. and L. D. Calvin. 1976. Sampling San Jose Scale in a Pest Management Program on Pear in southern Oregon. Jour. of Econ. Ent. 70:138-140.

Westigard, P. H., L. G. Gentner and D. W. Berry. 1968. Present status of biological control of the pear psylla in southern Oregon. J. Econ. Ent. 61(3):740-743.

Westigard, P. H., Louis Gentner and B. A. Butt. 1975. Codling Moth: Egg and first instar mortality on pear with special reference to varietal susceptibility. Environmental Entomology. 5:51-54.

Westigard, P. H. and K. L. Graves. 1976. Evaluation of pheromone baited traps in a pest management program on pears for codling moth control. The Can. Ent. 108: 379-382.

Westigard, P. H., Ulo Kiigemagi and P. B. Lombard. 1974. Reduction of pesticide deposits on pear following overtree irrigation. HortSci. 9(1):34-35.

Westigard, P. H., P. B. Lombard and D. W. Berry. 1967. Bionomics and control of the two-spotted spider mite on pear in southern Oregon. Ore. Agr. Exp. Sta. Tech. Bull. 101, 32 pp.

Westigard, P. H., P. B. Lombard and J. H. Grim. 1966. Preliminary investigations of the effect of feeding of various levels of the two-spotted mite on its Anjou pear host. Proc. Amer. Hort. Soc. 89:117-122.

Westigard, P. H., L. E. Medinger and O. E. Kellogg. 1972. Field evaluation of pesticides for their suitability in an integrated program for spider mites on pear. Jour. Econ. Ent. 65(1):191-192.

Westigard, P. H., M. N. Westwood and P. B. Lombard. 1970. Host preference and resistance of *Pyrus* species to the pear psylla, *Psylla pyricola* Foerster. J. Am. Soc. Hort. Sci. 95:34-36.

Westigard, P. H. and R. W. Zwick. 1972. The pear psyla in Oregon. Agr. Exp. Sta. Tech. Bull. 122, 22 pp.

Westwood, M. N., H. R. Cameron, P. B. Lombard and C. B. Cordy. 1971. Effects of truck and rootstock on decline, growth and performance of pear. J. Amer. Soc. Hort. Sci. 96:147-150.

Yothers, M. A. and E. R. Van Leeuwen. 1931. Life history of the codling moth in the Rogue River Valley of Oregon. U.S.D.A. Tech. Bul. 255. 35 p.

Zwick, R. W. and P. H. Westigard. 1978. Prebloom petroleum oil applications for delaying pear psylla (Homoptera: Psyllidae) oviposition. Can. Ent. 110:225-236.

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