New Insecticides and Miticides for Apple and Pear IPM

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I. Chloronicotinyls

A. **Provado** (imidacloprid) – Provado was the first registered compound of the relatively new class of synthetic analogs of nicotine, chloronicotinyls. Provado, and other chloronicotinyls, act in the nerve synapse like nicotine acetylcholine. In tree fruits it is generally used as a systemic insecticide and stomach poison. It does have contact insecticidal properties, however the residue is relatively short-lived in the environment. Instead, it is absorbed into leaves, where is can have a long effective residue. Provado is relatively safe for mammals.

1. Lepidopteran pests
   Codling moth – Provado has only low to moderate toxicity to *codling moth* in laboratory studies and provided very little suppression of fruit injury in a field trial.

   Leafrollers – We have conducted only one field trial with Provado against pandemis *leafroller* and it provided very little suppression of larval densities.

   Lacanobia fruitworm – We have conducted one test with Provado against *Lacanobia* and it provided no suppression of the larval population.

2. Indirect/secondary pests
   Provado is primarily used as an *aphicide* in Washington, but also will provide adequate suppression of *leafminers* and *white apple leafhopper*. Provado is somewhat toxic to *campylomma*, but cannot be used during the critical period for prevention of damage (bloom). There is no apparent direct effect on *mites*.

3. Pear pests
   The use of Provado is an important control tactic for control of both *pear psylla* and *grape mealybug* in pear and mealybug in apple. Provado is effective against the early instars of both of these pests (first and second instars of *pear psylla*, 'soft-shell', and second and third instars of *grape mealybu*g, 'crawlers'). Effectiveness against older instars of these pests is greatly reduced, and there is relatively little activity against adults. Using oil as an adjuvant to Provado has been demonstrated to increase mortality of *pear psylla* and *grape mealybug*.

   Provado is only registered for post-bloom use in both pear and apple. Thus, in order to use it effectively early in the season for both *pear psylla* and *grape*

mealybug control, applications should be applied as soon after petal fall as possible (once bees are out of the orchard). This petal fall timing has proven to be particularly effective during growing seasons with relatively mild winters, when bloom comes relatively early. In more 'normal' years, an application of Provado at petal fall can be too late to have maximum effectiveness against *grape mealybug*; observations of 'crawlers' should be made before the spray is applied.

The summer generation of *grape mealybug*, as well as summer generations of *pear psylla*, can be controlled using Provado as well. However, the effectiveness of the material is reduced relative to the early season applications. Additionally, Provado has a negative effect on the beneficial mirid bug *campylomma* (an early season pest in apple). *Campylomma* is an important *pear psylla* predator.

4. Beneficial arthropods
   Provado, like other chloronicotinyls, has been associated with an increase in *mite* populations, possibly by hormoligosis. Provado has low toxicity against *predatory mites* and the effect of *mite* flare-ups is not consistent so the risk is considered low to moderate. Provado is considered moderately toxic to *Colpoclypeus florus*, *lacewings* and *coccinellids*.

B. **Actara** (thiamethoxam) – Actara is a closely related compound to Provado. Its activity and use is much the same as Provado, with the same target pests and 'transtemic' activity. Do not use Actara 5 days prior to placing *bees* in orchard and while bees are in the orchard, and exercise caution when bees are in neighboring blocks, especially if there are blooming weeds in the orchard. As of 2004, Actara was no longer available for use in apple.

1. Lepidopteran pests
   Codling moth – We have not tested Actara against *codling moth*. It is not expected to have activity against any Lepidoptera.

   Leafrollers – See comments under *codling moth*.

   Lacanobia fruitworm – See comments under *codling moth*.

2. Indirect/secondary pests
   Note that Actara is no longer available in Apple (2004). Two year's tests on *campylomma* have demonstrated good efficacy against this pest, even though it cannot be used during bloom (pink would be the preferred timing). Actara is effective against the *green aphid* complex, and offers some suppression of *woolly apple aphid* and *rosy apple aphid* (limited data). There is no evidence of useful activity against *leafminer*. Actara is also a good *leafhopper* material.

3. Pear pests

Actara has much the same activity against *pear psylla* and *grape mealybug* as Provado. Like Provado, Actara is effective against the early instars of both of these pests (first and second instars of *pear psylla*, 'soft-shell', and second and third instars of *grape mealybug*, 'crawlers'). Effectiveness against older instars of these pests is greatly reduced, and there is relatively little activity against adults. Using oil as an adjuvant to Actara has been demonstrated to increase mortality of *pear psylla* and *grape mealybug*.

Actara, unlike Provado, is registered for prebloom use in pear. It should not be applied later than clusterbud when used prebloom, to avoid any potential for effects on bees. The clusterbud timing is very effective in controlling both *pear psylla* and *grape mealybug*. In typical years, this period is when peak *pear psylla* egg hatch is occurring, and the age distribution is limited to first and second instar nymphs, as well as adults and eggs. Actara applications will cause mortality to the nymphs, and residual activity will continue to control hatching eggs. This period is also when *grape mealybug* have peak emergence from egg masses. Actara is very effective against the second instar crawlers that become exposed at this time.

Actara can also be effective in petal fall applications, as with Provado, provided the *pear psylla* and *grape mealybug* are of the appropriate stage. Actara is at least equal in efficacy to Provado when used against summer generations of both *pear psylla* and *grape mealybug*. Oil is an effective adjuvant for Actara. Summer applications of Actara have negative effects on the biocontrol agent *campylomma*; care should be taken to avoid impacting populations of this important beneficial.

4. Beneficial arthropods
   Actara does not appear to be directly toxicity to *predatory mites*, thus the overall risk of *mite* disruption is currently rated low. Do not use Actara where *bee* exposure is possible.

C. **Assail** (acetamiprid) – Assail is the first chloronicotinyl registered on apples and pears that has a high degree of lepidopteran activity, although it is primarily limited to *codling moth*. A short worker reentry interval (12 hrs), relatively short preharvest interval (7 days) and relatively low toxicity rating (Category III) allow more flexibility with Assail than the organophosphate insecticides that it will replace. Practical resistance management would suggest that growers should limit the number of chloronicotinyl applications in a season, so care must be taken when adding Assail to a program that is already using Provado or Actara.

1. Lepidopteran pests
   Codling moth – Initial tests with Assail indicated this product was very active against *codling moth*. In fact, Assail performed more like Imidan (and to some extent Guthion) than any new insecticide we have researched in many years. Assail can be applied at the same timing as Guthion and Imidan, with 2

applications per generation starting at egg hatch providing control of *codling moth* larvae similar to the industry standards. New evidence shows that when Assail is applied topically it is also highly toxic to *codling moth* eggs. A good resistance management strategy would be to limit Assail applications to one generation/year.

Leafrollers – We have not tested Assail in the field against *leafrollers*. However, laboratory bioassays indicate that Assail has only low toxicity to neonate larvae.

Lacanobia fruitworm – We have not tested Assail in the field against *Lacanobia*. However, laboratory bioassays indicate that Assail has only low toxicity to neonate larvae.

2. Indirect/secondary pests
   Assail has good activity against *leafhopper* and the *green aphid* complex, with lesser activity against *rosy apple aphid* and *woolly apple aphid*. Assail also is a good *campylomma* material (and possibly *thrips*) and since it only has a bee toxicity rating of III it can be used at bloom when bees are not active. *Leafminers* are on the label but we do not have any experience with Assail against this pest; we would expect suppression like other chloronicotinyls.

3. Pear pests
   Assail has much the same activity as Actara and Provado for *pear psylla* and *grape mealybug*. It is relatively safe for bees, and can be used before bloom at the optimal timing for controlling both *pear psylla* and *grape mealybug*. The relative efficacy of Assail against *pear psylla* is reduced with late summer applications, so Actara may be a better option at that time. Assail is similar to Actara and Provado with regards to the same positive effects of adding oil as an adjuvant, and the same negative effects on *campylomma*.

   Assail appears to have potential to become a viable alternative to Guthion for *codling moth* control in pear. However, because of resistance management concerns, it should be viewed primarily as a control for *pear psylla* and *grape mealybug*. With the current alternatives available for *codling moth* control (mating disruption, insect growth regulators), chloronicotinyls such as Assail should be used carefully against *codling moth* as they would be selecting for resistance in *pear psylla*.

4. Beneficial arthropods
   Given the efficacy against *codling moth*, the tendency may be to use multiple applications in a season, however both a 2- and 4-spray program have caused detectable *mite* flareups, some quite severe. At least some of this effect is attributable to a deleterious effect on *predatory mites*. This effect has been quite consistent in orchards with previous history of mite problems, thus risk of *mite* disruption is rated high in such areas. However, risk is mitigated if

only a single application is made to an orchard with a stable *mite* situation. The addition of 1% oil to an Assail spray (the oil itself is miticidal) may help to reduce mite flare-ups in some, but not all, situations. The cumulative effect of multiple chloronicotinyl applications for multiple years is unknown, but elevated risk is probable.

D. **Calpyso** (thiacloprid)- Calypso is next in the line of chloronicotinyls registered on apples and pears that has lepidopteran activity, also primarily limited to *codling moth*. Calypso and Assail are very similar products, with regards to toxicity and efficacy against most pests. Practical resistance management would suggest that growers should limit the number of chloronicotinyl applications in a season, so care must be taken when adding Calypso to a program that is already using Provado, Actara or Assail. Calypso also has a more restrictive label than Assail. For example, Calypso has a 30 day PHI, applications are not allowed between pink and petal fall in both pears and apples, 100 ft buffer for aerial applications near rivers and streams, and several endangered species restrictions (see label).

1. Lepidopteran pests

   Codling moth – Calypso appears to have a high degree of activity against *codling moth*, with expected results very similar to Assail. Calypso also has the same ovicidal properties as Assail. Our data suggest that growers should be able to replace a Guthion spray with a Calypso spray and not notice a significant decrease in control. Both Assail and Calypso will allow growers more flexibility with worker reentry intervals than Guthion. Rotating Calypso with Assail cannot be considered resistance management as these products belong to the same class of chemistry and have the same mode of action.

   Leafrollers – We have not tested Calypso in the field against *leafrollers*. However, laboratory bioassays indicate that Calypso has only low toxicity to neonate larvae.

   Lacanobia fruitworm – We have not tested Calypso in the field against *Lacanobia*. However, laboratory bioassays indicate that Calypso has only low toxicity to neonate larvae.

2. Indirect/secondary pests

   Calypso is a good *leafhopper* material and definitely has *campylomma* activity, but perhaps not as strong as Assail. However, a preliminary Calypso label restricts use between pink and petal fall. Make sure to follow label restrictions when applying Calypso during this time period. Calypso has the same activity as Assail against the *green aphid* complex and *rosy apple aphids*. The earlier it can be applied against *rosy apple aphids* the better. Calypso does not have activity against *woolly apple aphids*.

3. Pear pests

Calypso is effective against *pear psylla* and *grape mealybug*, like Actara, Provado, and Assail, and also can be used for *codling moth* control, like Assail. Calypso has been shown in field tests to control high densities of *pear psylla* in prebloom, petal fall, and summer applications, much the same as the other chloronicotinyls. In field tests against *grape mealybug*, at all appropriate timings, Calypso also significantly reduced the populations, but not to the same degree as the other three chloronicotinyls. Pest mortality was increased when oil was added to Calypso applications, and Calypso appears to have the same negative effects against *campylomma* as the other chloronicotinyls.

In field trials against *codling moth*, Calypso successfully controlled high populations of *codling moth*, comparable to both Guthion and Assail. However, use of this material against *codling moth* in pear comes with the same caveats as with Assail; it may be more important to direct this class of insecticides at *pear psylla* rather than *codling moth*, where there are other effective alternatives.

4. Beneficial arthropods
   Given the efficacy against *codling moth*, the tendency may be to use multiple applications in a season, however both a 2- and 4-spray program have caused detectable *mite* flareups, some quite severe. At least some of this effect is attributable to a deleterious effect on *predatory mites*. This effect has been quite consistent in orchards with previous history of mite problems, thus risk of *mite* disruption is rated high in such areas. However, risk is mitigated if only a single application is made to an orchard with a stable *mite* situation. The addition of 1% oil to an Assail spray (the oil itself is miticidal) may help to reduce mite flare-ups in some, but not all, situations. The cumulative effect of multiple chloronicotinyl applications for multiple years is unknown, but elevated risk is probable.

E. **Clutch** (chlothianidin)- Clutch is another chloronicotinyl with lepidopteran activity. Clutch will be registered with very little field efficacy data, so implementing this new insecticide into an IPM program should be done carefully.

1. Lepidopteran pests
   Codling moth – Laboratory bioassays of Clutch against neonate larvae indicate that although it has a fairly low LC_{50}, it does not appear to have the same acute toxicity as Calypso or Assail. Field trials in 2003 were disappointing with Clutch, but we are still experimenting with optimizing the rate. If the label rate is high enough, Clutch could have the same potential to control *codling moth* as Assail or Calypso.

   Leafrollers – We have not tested Clutch in the field against *leafrollers*. However, laboratory bioassays indicate that Clutch has only low toxicity to neonate larvae.

Lacanobia fruitworm – We have not tested Clutch in the laboratory or in the field against *Lacanobia*.

2. Indirect/secondary pests
   We have no tests evaluating Clutch against any of the secondary pests. Claims about efficacy would just be speculation at this point.

3. Pear pests
   Clutch appears to have the same activity against *pear psylla* and *grape mealybug* as the other chloronicotinyls. Trials with other chloronicotinyls suggest that the addition of oil appears to increase efficacy. The same negative effects against *campylomma* as with the other chloronicotinyls should also be expected.

   Use of this material against *codling moth* in pear comes with the same caveats as with Assail; it may be more important to direct this class of insecticides at *pear psylla* rather than *codling moth*, where there are other effective alternatives.

4. Beneficial arthropods
   Given the efficacy against *codling moth*, the tendency may be to use multiple applications in a season, however both a 2- and 4-spray program have caused detectable *mite* flareups, some quite severe. At least some of this effect is attributable to a deleterious effect on *predatory mites*. This effect has been quite consistent in orchards with previous history of mite problems, thus risk of *mite* disruption is rated high in such areas. However, risk is mitigated if only a single application is made to an orchard with a stable *mite* situation. The addition of 1% oil to an Assail spray (the oil itself is miticidal) may help to reduce mite flare-ups in some, but not all, situations. The cumulative effect of multiple chloronicotinyl applications for multiple years is unknown, but elevated risk is probable.

II. Insect Growth Regulators (IGRs)

A. **Intrepid** (methoxyfenozide) - Intrepid (and Confirm) acts to initiate a premature lethal molt in caterpillars. It is lethal because the insect is not able to complete the molt and dies within the old skin that it cannot shed. In some cases Intrepid will not kill the larva but the subsequent adult will not be able to reproduce. Intrepid has little or no contact activity and must be ingested by larvae to have a toxic effect. Intrepid has strong ovicidal activity whether applied topically or if eggs are laid on residues. Intrepid is very specific to lepidopteran pests and has the advantage over some older insecticides in having a short REI (4 hours) and PHI (14 days).

   1. Lepidopteran pests

Codling moth – Intrepid controls *codling moth* in two ways, first as an ovicide and then as a larvicide. This product cannot be considered a simple replacement for Guthion. Intrepid is highly toxic to both eggs and larvae in laboratory studies, but does not provide the same amount of crop protection as Guthion or Imidan under the same use pattern. The reduced efficacy in field applications relative to organophosphates is probably due to reduced residual control. We expect only about 14 days of activity against susceptible populations. Our data also suggests that an earlier ovicide timing (100DD) is at least equivalent to the traditional larvicide timing (250DD). If the ovicidal timing of Intrepid is as good or better than the egg hatch timing it opens a new strategy for using this product. Because Intrepid also has good activity against *leafrollers* its use in the petal fall period could simultaneously control *codling moth* and *leafroller*. Intrepid should not be considered a "stand alone" control for *codling moth* except where very low pressures are present. It has its best fit as a component of a pheromone-based IPM program where it is integrated with the use of *codling moth* mating disruption. There is concern that *codling moth* populations resistant to organophosphates may also be tolerant or resistant to Intrepid due to OP mediated cross-resistance.

Leafrollers – Intrepid has good efficacy against *leafrollers*. Intrepid has primarily been evaluated at its full field rate against *leafrollers*; however, it is likely that reduced rates will also be effective. Intrepid is effective against *leafrollers* in the spring from bloom to about 14 days after petal fall. One application of Intrepid can be effective against low *leafroller* densities but a second application might prove necessary against high populations. In the spring Intrepid should be used when weather forecasts predict warm conditions, 65°F or better for at least 3 days, in order to ensure active feeding by larvae. Intrepid has a longer residual activity against *leafrollers* so it should not be subject to the vagaries of weather on efficacy as are Bt products. Intrepid is also effective against *leafroller* larvae in the summer and the best timing is when larvae are young. When applied at 20% egg hatch of *leafroller* Intrepid provided excellent control, comparable to Success in most tests. Intrepid has a long residual activity but has no contact activity. Therefore, Intrepid must be applied with good coverage but it is not necessary to use dilute sprays. We have some concern that *leafroller* populations show a highly variability degree of susceptibility to Intrepid, and this variability seems directly related to the OP resistance in the same populations. This could mean that the genetic basis for resistance to Intrepid exists in some *leafroller* populations in WA. Good product stewardship should be used including switching between products with different modes-of-action as part of a resistance management program.

Lacanobia fruitworm – Intrepid is very effective against *Lacanobia*. The best timing of Intrepid against this insect is when about 80% of eggs have hatched, prior to the presence of large larvae (700DD). A single application seems adequate to control this pest and it is very likely that reduced rates will be as

effective as the full field rate. Experience in the Areawide II project showed that *Lacanobia* densities were suppressed in orchards that used Intrepid in multiple applications against *codling moth*. These timings overlapped with the optimal timing for *Lacanobia* providing control of both pests at the same time.

2. Indirect/secondary pests
   Intrepid has no known effects on *campylomma, leafhoppers, aphids, mites* (either phytophagous or predatory). Suppression of *leafminer* depends on timing; better success has been achieved where it has been used in *codling moth* programs than in single-application *leafminer* timings (although suppression may be sufficient in some cases).

3. Pear pests
   Intrepid has been tested against *codling moth* in pear, and appears to work effectively against low to moderate populations. At low densities, Intrepid was comparable with Guthion treatments. However, when challenged with very high *codling moth* populations, Intrepid treatments sustained significant damage. Intrepid does not affect *pear psylla* or *grape mealybug*.

4. Beneficial arthropods
   Intrepid has no known negative impacts on beneficial arthropods.

B. **Confirm** (tebufenozide) – Confirm has the same mode of action as Intrepid against lepidopteran larvae, however it has a much poorer ovicidal activity compared to Intrepid.

1. Lepidopteran pests
   Codling moth – We have had several years of experience with Confirm as a *codling moth* control. Confirm does not provide nearly the same level of crop protection as Guthion or Imidan, even when applied at more frequent intervals. Our experience has shown little difference in efficacy in the timing or even rates of Confirm used against *codling moth*.

   Leafrollers – Conifrm has efficacy against *leafrollers* but not as good as Intrepid. Confirm is effective against *leafrollers* in the spring from bloom to about 14 days after petal fall. One application of Confirm can be effective against low *leafroller* densities but two applications are necessary against moderate to high populations. Like Intrepid, Confirm has a long residual activity but has no contact activity.

   Lacanobia fruitworm – Confirm is moderately toxic to *Lacanobia* in laboratory studies, but seemed to provide reasonable control in field trials.

2. Indirect/secondary pests

Confirm has no known effect on *campylomma, leafhoppers, aphids, mites* (either phytophagous or predatory). We expect probable suppression of *leafminer* similar to Intrepid but not as strong.

3. Pear pests
   Confirm has been tested against *codling moth* in pear, and appears to work effectively only against low populations. However, even at low *codling moth* densities Confirm treatments sustained significant injury. Confirm may provide acceptable control of low to moderate *codling moth* densities in pear when used in conjunction with other control tactics, such as mating disruption. Confirm does not effect *pear psylla* or *grape mealybug*.

4. Beneficial arthropods
   Confirm has no known negative impacts on beneficial arthropods.

C. **Esteem** (pyriproxyfen) - This insect growth regulator functions as a juvenile hormone mimic. It can be a highly selective insecticide providing control of *leafroller* and *codling moth* (not *Lacanobia fruitworm*) without disrupting activities of biological control agents. Esteem has low toxicity to mammals and has a short worker reentry period (12 hours), but a long pre-harvest period (45 days).

1. Lepidopteran pests
   Codling moth – Esteem has activity against the *codling moth* egg, acting as an ovicide. In order to be effective, the *codling moth* must deposit eggs on top of Esteem residues. Therefore, Esteem should be applied prior to the onset of oviposition (100 DD). In high pressure situations, especially if reduced activity from organophosphates is expected, a second Esteem application would likely be necessary at 14-21 days. This approach keeps active Esteem residues during most of the egg laying period. Esteem can only be considered a moderately effective *codling moth* tool, and can make the difference in successfully implementing a "soft" pest management program.

   Leafrollers – Esteem seems to work equally well against the *pandemis* or *obliquebanded leafroller*. Esteem is thought to act primarily against the last larval stage of *leafrollers*. Esteem must be consumed by the *leafroller* larva to have any effect, therefore good coverage is very important. Once consumed by the *leafroller* larvae Esteem acts to disrupt the normal transition from larva to pupa or, in some cases, pupa to adult. Esteem may also have activity against *leafroller* eggs. Both *leafroller* species reach the last larval stage shortly after petal fall, which makes the 100DD timing for *codling moth* an ideal time to target *leafrollers* as well. Esteem efficacy against *leafrollers* is difficult to assess because the larvae do not immediately die and deformed larval-pupal intermediates or pupae that do not produce adults are difficult to locate. It is necessary to monitor the *leafroller* generation following the one treated to see the effect of the Esteem treatment.

Lacanobia fruitworm – We have no information on the efficacy of Esteem against *Lacanobia*. Because use of this product is probably going to be limited to the early season it probably does not have a fit for *Lacanobia*.

2. Indirect/secondary pests
   Delayed dormant applications, and to a lesser extent early summer applications, of Esteem have good activity against *San Jose scale*. Prelimary data indicate Esteem may be active against *rosy apple aphids*. We have not tested Esteem against other indirect pests.

3. Pear pests
   In addition to being an effective management tool for control of *codling moth* in pear, Esteem works well against *pear psylla*. Its juvenile hormone mimic activity affects the insect much the same as Comply (fenoxycarb). Esteem has been shown to act on eggs and first through third instar nymphs, and may have sublethal effects on later instars ('hardshells') and adults as well. The first generation of *pear psylla* is the best target for Esteem applications, as the life stage distribution is the most synchronized at this time. The use of delayed dormant oils, sulfurs, Thiodan, and Surround greatly enhance this synchrony, further increasing the effectiveness of Esteem. Applications against the first generation can be made from delayed dormant (targeting early eggs) through 2 weeks post-petal fall (targeting third instar nymphs). The optimal timing, however, is from clusterbud to petal fall, when there is peak egg hatch. Results with Esteem have been variable, in some cases being able to control high populations while in others not controlling low populations. This may be a result of a predisposition of some orchards to resistance. Orchards with some degree of developing resistance to Comply may have reduced control effectiveness with Esteem. Esteem does not appear to have significant effects against *grape mealybug*.

3. Beneficial insects
   Esteem has no known negative impacts on beneficial arthropods.

D. **Dimilin** (diflubenzuron) – It is unlikely that Dimilin will ever have a label for use on apple, however our experiences on apple may help develop use patterns for the same pests on pear. Dimilin is another selective insect growth regulator. Dimilin inhibits chitin synthesis, which makes its mode of action unique compared to Intrepid or Esteem.

1. Lepidopteran pests
   Codling moth – Dimilin does have activity against the *codling moth* egg. When Dimilin is applied at the beginning of the egg-laying period (100DD) it will disrupt normal egg development. To obtain adequate control two applications of Dimilin will be required. In apple Dimilin has not provided the same degree of control as products like Guthion or Imidan.

Leafrollers – Dimilin has not been evaluated as a possible control for *leafrollers*.

Lacanobia fruitworm – We have not tested Dimilin against *Lacanobia*.

2. Indirect/secondary pests
   Dimilin has no known effect on *mites, aphids, campylomma, scale, or leafhopper*. When originally tested it was quite effective on *leafminer*, but this diminished over the course of a few years (not really an issue on pears, and no projected registration on apple).

3. Pear pests
   Dimilin has been tested extensively in pear for *pear psylla* and *codling moth* control for over two decades. Dimilin has been shown to have moderate activity against *pear psylla*; it will control a low to moderate population. Like Esteem, Dimilin affects the eggs and early instars of *pear psylla*, although there are likely sublethal effects on later instars and adults. Dimilin has been found to be most effective when applied to the first generation of *pear psylla*, from delayed dormant through petal fall. The optimal timing to target *pear psylla* is at clusterbud, where maximum effects against eggs and early nymphs would occur. When using Dimilin in a *pear psylla* program it is important that Thiodan, sulfurs, and oil are used at delayed dormant to help reduce the pest pressure and better synchronize the generation. Applications in the summer also can provide some degree of control; however, the level of effectiveness is decreased as more and larger instars become present in the developing populations.

   Codling moth is another target pest for Dimilin applications in pear. Dimilin has been shown to be effective against *codling moth*, but the level of control is lower than other available products. Dimilin should be used only against low populations of *codling moth*, except in situations where other control tactics such as mating disruption are being used. There is concern that *codling moth* populations resistant to organophosphates may also be tolerant or resistant to Dimilin due to OP mediated cross-resistance. This may lead to variable results in observed efficacy.

4. Beneficial arthropods
   Dimilin is not acutely toxic to beneficial arthropods. However, we found in one study that *Colpoclypeus florus* females directly exposed to Dimilin laid eggs that were not viable. Dimilin apparently sterilized the female or had some other sublethal effect on normal egg development.

E. **Diamond** (Novaluron/difluorobenzamide)-
   Diamond is the next generation of benzoyl urea growth regulators, in the same class as Dimilin. Although similar to Dimilin in its targets and mode of action, we believe that Diamond is more active than Dimilin against those same pests. Diamond inhibits

chitin synthesis and embryogenesis, which makes its mode of action unique compared to Intrepid or Esteem. Diamond's primary target is the egg stage, however it is also effective against early instar *pear psylla*.

1. Lepidopteran pests
   Codling moth- We believe the primary target of Diamond is against the *codling* moth egg. Evaluations of field-aged residues indicated Diamond was causing more than 90% suppression of egg hatch 35 days after application. Field trials indicated that a season-long Diamond program (3 applications/generation) reduced *codling moth* fruit injury 85-95% relative to the untreated control. In these trials, Diamond was applied prior to the onset of oviposition (75 DD) with repeat applications at 14-day intervals. Second generation applications began at 1000 DD. Diamond is probably the best ovicidal alternative currently available for summer use.

   Leafroller- We have not evaluated Diamond against *leafrollers* in field trials. Laboratory bioassays indicated that Diamond had very little activity against *leafroller* neonates. These results were corroborated with field-aged residue tests, which indicated little or no activity of even 1-day-old residues. We believe the primary activity of Diamond against *codling moth* is ovicidal, however we have not evaluated the ovicidal activity against *leafroller*.

   Lacanobia fruitworm- We have not evaluated Diamond against *Lacanobia* in field trials. However, laboratory bioassays indicated that Diamond is highly toxic to *Lacanobia* neonates. Field-aged residue tests indicate a breakdown in efficacy after 21 days from application.

2. Indirect/secondary pests
   Diamond has no known effect on *mites, aphids, campylomma, scale, or leafhopper*. It is possible that there would be effects against *leafminer*, however we have not verified this with field trials.

3. Pear pests
   Diamond has the same spectrum of activity against pear pests as Dimilin, but at a higher level. Diamond is active against *pear psylla*, acting primarily against the eggs and early instars. Diamond has been found effective when applied against the first generation of *pear psylla*. The clusterbud timing optimizes the efficacy of Diamond as the population is made up of eggs and newly hatched nymphs at that time. When using Diamond in a *pear psylla* program it is helpful to use products such as Surround, Thiodan, sulfurs, and oil, which when used at delayed dormant help to reduce the pest pressure and better synchronize the generation. Diamond is also effective shen used during the summer; however, the level of effectiveness is decreased as more and larger instars become present in the developing populations.

Codling moth is another target pest for Diamond applications in pear. Diamond should control low-moderate populations of *codling moth*, with results similar to chloronicotinyls. If other control tactics are being used (e.g mating disruption or larvicidal insecticides) Diamond will be an effective tool in high pressure situations as well. There is concern that *codling moth* populations resistant to organophosphates may also be tolerant or resistant to Diamond due to OP mediated cross-resistance. This may lead to variability in observed efficacy.

4. Beneficial arthropods
   Since Diamond is a relatively new insecticide, we have little experience against beneficial arthropods. Our experience with growth regulators is that they are not acutely toxic to beneficial arthropods, however there is concern about sublethal effects, especially on fertility of adults exposed to residues.

III. Miticides

A. **Acramite** (bifenazate)- Acramite is a hydrazine compound from a relatively new class of chemistries, carboxylic acid ester. Its mode of action is a GABA (gamma-aminobutryric acid) agonist in insects, but has not been confirmed in mites. Acramite was recently registered for use on tree fruits, including apple, pear, peach, nectarine, plums, prunes. Acramite is primarily used against motile stages, but may have some ovicidal activity.

   1. Apple - Acramite appears to be a specific, selective miticide, with good activity against *spider mites*. No *rust mite* activity.

   2. Pear - Acramite has proven to be a very effective miticide in pear. Acramite can control low to moderate populations of *twospotted spider mites*, and will suppress heavy infestations. Heavy infestations, where leaf damage has occurred and defoliation has already begun, will require another miticide to be used with Acramite. This material is limited to one application per year in pear. This limitation will hopefully slow the first development of resistance to this compound, and maintain its usefulness in pear for the future.

B. **Zeal** (also known as **Secure**) (extoxazole) – Zeal comes from a new class of chemistry, diphenyloxazoline, with a unique mode of action. Zeal acts primarily as an ovicide, but has molt inhibiting activity against immature mites as well. Zeal works on contact and has translaminar movement.

   1. Apple - Preliminary tests suggests that Zeal has good *mite* activity in apple. Zeal performs much like Acramite against twospotted spider mites, but may be more effective on *European red mite*.

   2. Pear - Zeal has proven in field tests to be a very effective material in controlling *twospotted spider mites* on pear. Its activity is primarily ovicidal

(like Savey and Apollo, though with a different mode of action). As such its effects in controlling *mite* populations are relatively slower than other compounds, and it likely will not prove to be a 'rescue' material.

C. **Envidor** (spirodiclofen)- Envidor is from a new class of chemistry, tetronic acid, which disrupts the endocrine system, affecting energy production. Envidor is an IGR-type insecticide, so expect slow activity (vs. quick knock down). Envidor is not acutely toxic to adults. Envidor may affect some insect pests as well as *mites*, but has not been well studied in tree fruits. There is evidence on other crops that oil may be antagonistic to Envidor, thus current recommendations caution against the use of oil as an adjuvant.

1. Apple - Results to date have shown that Envidor has promising activity against *mites*. One example of a trial conducted on a rising population showed the typical slow activity expected of an IGR insecticide. After five days, a population of 10-15 *mites*/leaf was still present, but sufficient control for the rest of the season was noted.

2. Pear - Envidor has been demonstrated in field tests to be an effective miticide. Its activity is much like that of Acramite and Secure, in that they all work well to control moderate populations and suppress high populations. These products will likely not be adequate 'rescue' treatments due to their relatively slow activity. Envidor will fit well with Acramite and Zeal in an acaricide resistance management program as all three miticides effectively employ different modes of action.

D. **Mesa** (milbemectin) - Mesa is similar to abamectin (Agri-Mek), with a similar spectrum of activity (*mites, leafminer*). Residual activity appears shorter than Agri-Mek's and cross-resistance must be a consideration. The motile forms of *mites* are the primary target.

1. Apple - Tests to date have shown reasonable *mite* activity.

2. Pear - Mesa's similarity in mode of action to Agri-Mek provides it with activity against both *spider mites* and *pear psylla*. However, Mesa is only effective against *spider mites* at the labeled rates, and *pear psylla* control should not be attempted with Mesa at these rates. Mesa provides effective *spider mite* control. However, *spider mite* populations with developing resistance to Agri-Mek may not be controlled by applications of Mesa. Fortunately, Agri-Mek resistance in pear orchards is fairly limited in distribution in Washington.

E. **Nexter** (formerly known as Pyramite) (pyridaben)- Nexter belongs to the pyridazinone class of miticides. Nexter's mode of action is as a mitochondrial electron transport inhibitor (METI), blocking cellular respiration (similar to Fujimite

and Kanemite). Practical resistance management would suggest that the use of METI miticides (either Nexter, Fujimite or Kanemite) be limited to one application/year.

1. Apple- Nexter has been shown to be an effective miticides in apple, possibly being more active against *European red mites* than *twospotted spider mites*. Nexter is also toxic to *apple rust mites*. Although *apple rust mite* can be considered a pest in very high densities, its presence is generally believed to be useful in maintaining populations of *predatory mites*.

2. Pear- Nexter has been shown to be an effective miticide in pear, with the highest activity against *European red mites*. Nexter provides good control of *pear rust mite*s in most situations and generally acceptable, yet variable, control of *twospotted spider mite*s. Nexter will also provide control of *pear psylla* in low to moderate pressure situations when applied at clusterbud. *Pear psylla* control is rate dependent, so rates may need to be increased as *pear psylla* densities increase.

F. Fujimite (fenpyroximate)- Fujimite belongs to the phenoxypyrazole class of insecticides. Its mode of action is as a mitochondrial electron transport inhibitor (METI), blocking cellular respiration (similar to Nexter and Kanemite). Practical resistance management would suggest that the use of METI miticides (either Nexter, Fujimite or Kanemite) be limited to one application/year.

1. Apple- Fujimite appears to be a good miticide alternative for the control of *European red mites* and *twospotted spider mites* in apple.

2. Pear- Fujimite appears to be a more active METI miticide than Nexter. Fujimite has a level of activity against both *European red mite* and *twospotted spider mites*. We do not have sufficient experience with the use of Fujimite against *pear rust mite* to comment on the potential to control this pest. Fujimite can be expected to control low to moderate populations of *pear psylla*.

G. Kanemite (acequinocyl)- Kanemite belongs to the quinoline class of insecticides. Its mode of action is as a mitochondrial electron transport inhibitor (METI), blocking cellular respiration (similar to Nexter and Fujimite). Practical resistance management would suggest that the use of METI miticides (either Nexter, Fujimite or Kanemite) be limited to one application/year.

1. Apple- Only limited data exists on Kanemite's potential in apple.

2. Pear- Kanemite appears to be a good miticide alternative for the control of *twospotted spider mites* in pear. Kanemite probably has activity against *European red mite* as well, however we have only limited and inconclusive data. Kanemite's affect on *pear rust mite* is unknown.

IV. Other Pesticides

A. **Success/Entrust** (spinosad)- The active ingredients of Success and its organic formulation Entrust are spinosyns produced through a fermentation process of a microorganism, *Actinomycetes spinosa*. Spinosyns are active in the nerve synapse, binding at the nicotine receptor site. As with many new insecticides Success has little contact activity and must be ingested before expressing it toxicity. Spinosad is active against many important lepidopteran pests and the potential exists to use this product many times during the growing season. Resistance management must be a concern for maintaining its use for as long as possible.

1. Lepidopteran pests

Codling moth – Laboratory bioassays with spinosad (Success and Entrust) indicated it was only moderately toxic to *codling moth*. Results from initial field trials showed that spinosad would provide suppression of *codling moth*, but never in the range that would provide commercially acceptable control. Recent trials have shown that combining spinosad with 1% oil v:v significantly increases the observed efficacy. It is believed that this tank mix utilizes two modes of action, oil suppressing egg hatch and spinosad killing hatching larvae. If retreatment intervals are frequent enough (10-14 days), spinosad plus oil can provide effective *codling moth* control. This combination makes Entrust a potentially valuable tool for organic growers. However, season long control is probably not an option as the frequency of application required may be cost prohibitive and a seasons allotment of active ingredient would be surpassed in the first generation. Therefore, an organic management program must still use all tools available to control *codling moth*. If possible, we would suggest the use other *codling moth* alternatives for two reasons. First, there are products that work better with fewer numbers of applications and would therefore be less expensive. Second, and more important, spinosad is a very good insecticide for *leafroller* control and we want to conserve its use in apple primarily for this purpose. Good product stewardship is important in reducing the risk of resistance development in all lepidopteran pests.

Leafrollers – Spinosad is a very effective insecticide for the control of *leafrollers*. It works well as a single spray in the spring at petal fall to control the overwintering larvae. It also works well as a summer treatment timed to coincide with the presence of early stage larvae. If populations are high it might require two applications in summer to suppress *leafroller* densities below damaging levels. We conducted a resistance monitoring study with spinosad in 2001 and the good news was there was no change in the susceptibility of the populations that had been exposed to spinosad for up to three years. However, recent anecdotal reports suggested that the observed efficacy of spinosad applications has not met expected efficacy levels. It is important to adopt a good resistance management program and use other

leafroller control products in rotation with spinosad as a way to retain its efficacy as long as possible.

Lacanobia fruitworm – Spinosad is effective against *Lacanobia* larvae but only against the young larvae (first through third instar). If the timing is late control will not be as good as could be achieved with other products. In high populations two applications are required to achieve adequate control.

2. Indirect/secondary pests
   Spinosad is a good *leafminer* material. Use spinosad at a slightly earlier timing than the standard one (10% tissue feeders) for the best control. Control is improved by the use of an adjuvant (oil or organosilicone). Spinosad also has *thrips* activity. Although we have only limited data on *thrips*, it appears that a higher volume (200 gal/acre) is needed for this use. We have not tested spinosad on *leafhopper*, *campylomma*, *scale*, *aphids* or *mites*, and have no reason to suspect activity.

3. Pear pests
   There has been some limited work with spinosad against *leafrollers* in pear, and while the studies were not conclusive, they suggested that spinosad would provide control. *Codling moth* trials on pear gave results similar to apple. *Codling moth* control could be achieved with frequent applications in combination with oil, especially in low to moderate pressure orchards. Spinosad was tested against *pear psylla* in the field, and a low level of activity was observed.

4. Beneficial arthropods
   Spinosad has no direct effect on predatory mites. However, laboratory bioassays indicated that spinosad was acutely toxic to *Colpoclypeus florus* and *Pnigalio flavipes*. Field-aged residue trials indicated the negative effect on these parasitoids was seen for up to 14 days.

B. **Avaunt** (indoxacarb) - Avaunt belongs to the oxadiazine class of insecticides. It has a novel mode of action, acting as a voltage dependent sodium channel blocker on the nerve axon.

1. Lepidopteran pests
   Codling moth – Laboratory bioassays with Avaunt against *codling moth* suggest that it has only low to moderate toxicity against neonate larvae and eggs when applied topically. In field trials, control did not hold up through the second generation with three applications per generation and only suppression of damage was noted at harvest. If Avaunt is going to be effective against *codling moth*, it would need to be mixed with 1% oil. This tank mix utilizes two modes of action, oil suppressing egg hatch and Avaunt acting on hatching larvae. Avaunt does not appear to be a good *codling moth*

control alternative as there are many other products available with a higher level of activity.

Leafrollers – Laboratory bioassays suggested that Avaunt would be active against *pandemis* and *obliquebanded leafrollers*. However, when we tested Avaunt against field collected populations it appeared that one population of *obliquebanded leafroller* larvae showed high levels of resistance to Avaunt while the two field populations of *pandemis leafroller* were only slightly less susceptible than our laboratory colony. Additional research is needed to test the mechanism of this observed difference in susceptibility between the two species, but for now Avaunt appears to be best suited for *pandemis leafroller*.

Lacanobia fruitworm – Avaunt is very effective against the *Lacanobia*. In several field tests Avaunt has controlled larvae of the *Lacanobia* with only a single, well-timed application. Even when Avaunt was used at reduced rates there has been little difference in the efficacy of this product against *Lacanobia*.

2. Indirect/secondary pests
   Avaunt has provided reasonable control of *leafhopper*, and has some effect on *leafminer* and *thrips*. Avaunt has no *campylomma* activity.

3. Pear pests
   We do not have any data for the effectiveness of Avaunt on pests of pear.

4. Beneficial arthropods
   Avaunt is not acutely toxic to *predatory mites*.

C. **Surround** (kaolin) - Surround is a particle film technology developed by USDA researchers. The active ingredient is kaolin clay that is specially processed to maximize its pesticidal and horticultural activity. Three years of research on Surround in WA has shown that it has a fit in IPM programs but carries some potential negative impacts on natural enemies.

   1. Lepidopteran pests
      Codling moth – Surround does have an impact on *codling moth* larvae. The main effect of Surround appears to be as a barrier to oviposition and/or prevent larvae from entering the fruit. The exact mechanism of action is not completely understood but *codling moth* larvae have been shown to avoid Surround treated areas on apple, making excellent coverage essential. In several tests we have shown that 3 applications of Surround per generation (50 pound per acre rate) will suppress *codling moth* damage 50-60%. It is possible that lower rates of Surround would be equally effective but those studies have not been conducted.

Leafrollers – Leafroller larvae tend to avoid Surround residues on leaves. The impact is greatest on young larvae so residues (applications) should be in place prior to egg hatch. It is possible that Surround would interfere with oviposition as well. Spring applications of Surround suppress *leafrollers* evidently by interfering with their ability to move from overwintering hibernacula and establish feeding sites in opening buds. Summer applications of Surround have been shown to suppress *leafroller* densities. The suppressive activity of Surround is probably not enough to eliminate the need for other *leafroller* treatments in moderate to high pressure areas.

Lacanobia fruitworm – Surround has a strong negative effect on *Lacanobia* populations. In laboratory studies, newly hatched *Lacanobia* larvae suffer high mortality if they are provided only Surround treated foliage and show a very strong preference to colonize untreated foliage in a choice test. In the field, Surround has been effective in reducing *Lacanobia* densities. Two applications prior to egg hatch may reduce most *Lacanobia* populations below economically important levels.

2. Indirect/secondary pests

   Surround has some effect on a broad range of species. There is no apparent (direct) effect on *aphids* or *campylomma*, but some suppressive effect on *mites*. However, Surround has also been associated with causing *mite* flare-ups, possibly through predator repellency. Surround suppresses *leafminers* but has a deleterious effect on the *leafminer* parasitoid *Pnigalio flavipes,* which may outweigh any benefit. One particular study indicated *scale* and *leafminer* outbreaks occurred in half or full season kaolin programs. Further, generalist predators were reduced, possibly provoking an increase in aphid populations. *White apple leafhopper* is suppressed by one or two applications/generation targeting nymphs.

3. Pear pests

   The use of Surround is becoming a standard part of the pear pest management program. Surround is effective for *pear psylla* control, likely through a combination of repellency or host masking rather than direct mortality. It appears that Surround is most effective when targeted against adult *pear psylla*, applied to limit oviposition. The optimal time for this tactic is the prebloom period. Two to three applications of Surround, applied from dormant or delayed dormant through bloom, has been demonstrated to be the most effective way to reduce *pear psylla* adult densities in orchards, and consequently reduce their oviposition. Surround has been used in combination with oil and sulfur during the prebloom period to improve pear psylla and pear rust mite control without significant detrimental effects.

   Postbloom applications of Surround are also effective for *pear psylla* control, but diligence is required in maintaining coverage and residue. Surround needs to entirely coat the foliage, as the material is not intoxicating the *psylla*; tree

growth produces new foliage that needs to be covered by repeated Surround applications. Once *psylla* have survived into later instars, Surround does not appear to be effective and other tactics must be applied. Additionally, Surround can be disruptive to biological control; applications in the prebloom period minimize this effect, while summer applications directly impact predator populations. Thus, summer use of Surround is often not reliable and can be costly. Postharvest applications, made after the trees defoliate, can provide residue that deters *pear psylla* immigration into treated orchards through the beginning of the following season. This tactic may prove useful for *psylla* management in orchards that have difficulty making applications early in the season because of snow, mud, etc.

Grape mealybug is not effectively managed by Surround. *Twospotted spider mites* are also not managed by Surround. However, damage from *spider mites* appears to be mitigated in Surround treated orchard by some unknown mechanism. Pear leaves treated with Surround can tolerate much higher than normal densities of *spider mites* without suffering from 'transpiration burn'. While there is potential to use Surround to thus increase the damage threshold of *spider mites*, the negative impacts on natural enemies prevents biological control from becoming established, as in apple.

4. Beneficial arthropods
   Surround is a safe insecticide that is generally not acutely toxic to insects, but rather acts through host masking or repellency. Surround has a broad-spectrum of activity and can disrupt some stable and important biological control systems. Of particular concern are its negative effects on *predatory mites*, the *leafminer* parasitoid *Pnigalio flavipes* and generalist *pear psylla* and *aphid* predators. Using Surround earlier in the season will limit its impact on beneficial arthropods.

D. **Horticultural Mineral Oil**- Horticultural mineral oils were among the first insecticides used in orchard pest management. Products have in recent years become more refined and quality controls tightened to reduce the potential for phytotoxicity. Pre-bloom use of oil is an important component of an apple IPM program. This use provides control of *San Jose scale* and *European red mite* (eggs) as well as suppression of aphids, all without negative impact on natural enemies. Summer use of horticultural mineral oils has increased as they have become safer. Typical concentrations of oil for summer use are 0.25-1%. Higher concentrations of oil have a greater risk of phytoxicity. There remain questions about the long-term negative impact of summer oil use on fruit tree vigor and fruit size. This is probably more of a concern for pear than apple but careful observation of any decline in tree vigor should be a part of any program using summer oil treatments. Season-long use of oil, especially for codling moth control in organic orchards, has been implicated in increased sunburn, poor fruit finish and poor wax deposition. Care must be exercised when using sulfur in orchards implementing an oil program to prevent phytotoxicity.

1. Lepidopteran pests

   Codling moth – Horticultural mineral oils act against *codling moth* by suffocating the egg. The best timing strategy is to allow oviposition to occur and just prior to egg hatch make an oil application. Since oil works only if applied topically to the egg, there is not residual control of subsequent eggs. Thus, repeat applications must be made as more eggs are deposited. A suggested protocol would be to apply the first application at 200DD from biofix, with repeat applications at 400 and 600DD (approximately every 14 days). This should cover about 80% of the first generation oviposition period. Second generation applications should begin at 1200DD, with repeat applications at 1400 and 1600DD. In orchards with high *codling moth* populations the re-treatment interval should be shortened to 100-150DD intervals (or every 7 days). Organic orchards that rely heavily on oil to control *codling moth* should use this strategy in conjunction with mating disruption. If *codling moth* pressure is moderate to high, then all available organic tools must be used (including Entrust and granulosis virus).

   Leafrollers – Oil used in combination with Lorsban in the delayed-dormant period is effective against *leafrollers* but it is the Lorsban that provides control. In one particular study, we used season-long oil applications to control codling moth and observed that *leafroller* densities were also suppressed. However, we have not been able to describe the exact mechanism for this action or even which life stage was affected. Oil can result in mortality of *leafroller* eggs and may deter oviposition by females. Oil is also a good adjuvant, improving uniformity of coverage and insecticide penetration through the leaf surface.

   Lacanobia fruitworm – We have no information on the effect of oil on this insect.

2. Indirect/secondary pests

   Oil is a toxicant to a broad range of secondary and indirect pests, and often has an effect on soft-bodied insects. It suppresses *mites* fairly effectively, although repeat applications may be necessary. One to two applications per generation applied against *white apple leafhopper* nymphs are effective in reducing populations. Oil is also an ovipositional repellent to adult *leafhopper* females, but the effect is temporary. *Woolly apple aphids* are also suppressed by oil applications. Oil at the delayed dormant timing has been a standard recommendation for eight decades or more, and is still effective in long-term control of the overwintering stages of *European red mite* and *San Jose scale*.

3. Pear pests

   Horticultural mineral oils are important tools in pear pest management. At the very least they should be used for delayed dormant applications and as adjuvants, and in some cases they can be useful as stand-alone applications. Application of oil early in the season, in the dormant and delayed dormant

periods, is important in starting the *pear psylla* control program. Additionally, these applications help control *San Jose scale* and *European red mites*, if present. The early oil sprays inhibit *pear psylla* oviposition; the mechanism of this activity is not known. Nevertheless, this inhibition helps push peak oviposition back by one to two weeks and helps synchronize the population development (there is also some degree of ovicidal activity).

Using oils as adjuvants helps increase the level of control obtained from virtually every psyllicide it has been tested with. In some cases this is simply from the mortality induced by the oil, while in others there is synergism in activity. In our tests, we include 0.25% oil and find that it helps the chloronicotinyls, Agri-Mek, Neem compounds, and Applaud. This is also true of the new miticides. Caution should be taken when using oils with some materials, particularly emulsifiable concentrates, to reduce the possibility of fruit marking and other phytotoxic effects.

We have tested using oils alone for control of *pear psylla, spider mites*, and *codling moth*, and these studies have met with some success. It appears that repeated applications are capable of suppressing the pests; however, if damaging levels are present, the oils do not reduce the populations below eonomic thresholds. There are anecdotal concerns in the industry regarding the long-term use of frequent oil applications. Some have hypothesized that there could be significant reductions in yield and/or fruit size following several years of 'intensive' oil use. A preliminary two-year study in Bartlett did not find any negative effects; however future long-term studies need to be conducted to properly address this issue.

4. Beneficial arthropods
   Oil can cause a reduction in *predatory mite* populations, but the effect is fairly subtle, and has not provoked mite flare-ups.

E. **Bt** (*Bacillus thuringiensis*) - There are several products that contain the active ingredients produced by the bacteria *Bacillus thuringiensis* (Bt). All Bt products must be consumed to have activity against insects. This is why Bt products do not affect most natural enemies of insect pests. Once consumed, Bt products are activated in the alkaline gut of insects, thus making them very safe to mammals. Bt products have short residual activity and are degraded by sunlight and high temperatures.

1. Lepidopteran pests
   Codling moth – We have evaluated Bt products against *codling moth* and they have very little activity. The main problem is associated with the short residual activity and the inability to uniformly cover the surface of the fruit, thus allowing *codling moth* larvae to enter without becoming intoxicated.

Leafrollers – Bt products have their best fit in apple IPM as *leafroller* controls. Several Bt products have been tested over the last decade and few differences have been detected in their relative efficacy assuming that appropriate rates are used. In the spring Bt products are best used between bloom and 10-14 days after petal fall. Because the *leafroller* larva must consume the Bt it is important to have good coverage of foliage and to apply sprays when temperatures are predicted to be 65°F or higher for 3 or more days. *Leafroller* larvae are not active feeders when temperatures are below 65°F and long periods of cool wet weather following a Bt application will greatly reduce the efficacy of the treatment. It is usually necessary to apply more than one Bt treatment to obtain adequate *leafroller* suppression. We have consistently observed 50-60% control with one application and 80-95% control with two applications 7 to 10 days apart. In the summer Bt treatments last only 5 to 7 days; however, with good coverage, it is possible to obtain good control. When dealing with a high *leafroller* population three applications may be necessary to achieve adequate control. *Leafroller* larvae that consume a sublethal dose of Bt will continue to develop at a normal rate after a 7-10 day recovery period. This delayed development has consequences in implementing a *leafroller* degree-day model. In orchards that have received a Bt application, model predictions may be delayed by more than 100DD.

Lacanobia fruitworm- Bt products have been evaluated against *Lacanobia* but have not proven effective.

2. Indirect/secondary pests- no activity against secondary pests.

3. Pear pests- Bt is used in pears for *leafrollers* as described for apples.

4. Beneficial arthropds- No known negative effects against beneficial arthropods.

F. **Azadirachtin** (neem products) - There are several neem-based insecticides available for tree fruit, and nearly all have azadirachtin as the active ingredient. Azadirachtin is derived from many parts of the Indian neem tree. The insecticidal activity is rather complex; azadirachtin may act as an ovipositional deterrent, feeding deterrent, and insect growth regulator. The IGR activity itself is complex relative to other IGRs, in that azadirachtin interferes with neuroendocrinal control of metamorphosis, affecting both ecdosteroidal and juvenile hormone titers. Neem products in general are very safe to applicators.

1. Lepidopteran pests
   Codling moth – We have evaluated azadirachtin against *codling moth* and even when multiple applications were made at different rates control was not achieved.

Leafrollers – We have tested products containing azadirachtin against *leafrollers*. In general they have not been active in laboratory bioassays even when development was followed through most of the larval stages. Azadirachtin can act slowly, similar to IGRs. If azadirachtin has any potential efficacy against *leafrollers* it is likely that multiple applications will be required to provide adequate suppression of populations.

Lacanobia fruitworm- Initial studies indicated that azadirachtin was moderately active against *Lacanobia*, but mortality took more than two weeks even under laboratory conditions. Field tests have been conducted, but the data collected were inconclusive.

2. Indirect/secondary pests
   Although *green aphids* are often listed as a target, there does not appear to be much mortality. Using M-Pede (insecticidal soap), oil or multiple azadirachtin applications can increase activity against *green aphids*. There does appear to be a useful level of activity against *leafminer*, but this has been variable depending on material and timing. Activity is slow in comparison to other products. There is some suppression of *woolly apple aphid* (Ecozin). Some suppression has been observed of *leafhopper* and *campylomma* (Neemix).

3. Pear pests
   There has been limited testing of the neem products against *grape mealybug* and *codling moth* in pear, and extensive testing against *pear psylla*. Azadirachtin has complex modes of action against the pests, but the primary method of activity is as an insect growth regulator. There appears to be little activity against *grape mealybug*. *Codling moth* is also not controlled by the neem compounds, although there appears to be some activity. *Pear psylla*, on the other hand, can be managed using neem products. However, because of the IGR activity, the population response to azadirachtin is slow. This, combined with the short residual activity, makes frequent reapplications necessary. Additionally, it is difficult to control high populations of *pear psylla* with these materials. Applications beginning at clusterbud or petal fall, and followed with four to six applications every seven to ten days, have been successful in managing *pear psylla*. Using oil as an adjuvant has also been shown to increase the mortality in *pear psylla*.

4. Beneficial arthropods
   We have only limited data on the effect of azadirachtin on beneficial arthropods. Initial laboratory screenings suggested that azadirachtin was not acutely toxic to the important parasitoids, *Colpoclypeus florus* or *Pnigalio flavipes*.

G. **CM granulosis virus**- The *codling moth* granulosis virus has been known for many years and different companies have attempted to formulate it as a biological pesticide.

Most formulations have not provided consistent control. The virus is subject to rapid degradation by UV light and high temperatures. The virus has the potential if effective to cause mortality of *codling moth* larva but this usually does not occur fast enough to prevent its entry into the fruit. Granulosis viruses are species specific, and have been identified for many lepidopteran pests. The advantages of the *codling moth* granulosis virus is that it only affects *codling moth* (will not affect any other lepidopteran pests) and thus does not interfere with activities of natural enemies.

1. Lepidopteran pests
   Codling moth – There are currently three active formulations of *codling moth* granulosis virus available to Washington growers (Cyd-X, Carpovirusine, and Virosoft CM). We have only one year's experience with these formulations, but our data suggests that they all are highly virulent. There was no apparent difference in activity between the products if used at equivalent rates of virus particles/acre. Bioassays of field-aged residues indicated residual control of these products broke down after 7 days in the field. A retreatment interval of 10-14 days seemed appropriate.

   Field trials indicated that little suppression of fruit injury could be expected in high pressure orchards after one generation of use. Delayed mortality is common and after 14 days many larvae exposed to virus were still alive and actively feeding. The full effect of the virus treatments was not noted until the subsequent generation, when the population did not develop to expected levels. After the first generation there was no significant reduction in fruit damage relative to the untreated control in any virus treatment. However, a greater than 90% reduction of second generation adults was noted in all virus treatments. It was not clear whether the larvae were dying prior to exiting the fruit, as fully mature larvae or pupae. Granulosis virus could be a valuable tool for organic growers as well as conventional growers under the right circumstances. We suggest that virus treatments be part of a management program that utilizes as many tools as possible, including mating disruption, oil, and a fast acting larvicide.

   Leafrollers – A *pandemis* granulosis virus has been identified, but it has never been formulated into an insecticide. *Codling moth* granulosis virus has no activity against *leafrollers*.

   Lacanobia fruitworm – Codling moth granulosis virus has as no activity against *Lacanobia*.

2. Indirect/secondary pests - no data, no reason to suspect activity

3. Pear pests – same as for apple pests

4. Beneficial arthropods- No reason to suspect activity.

H. **Applaud** (buprofezin) - Buprofezin is a unique chemistry, belonging to the thiadiazine class of insecticide. Its mode of action is also unique, in that it can be used as a contact insecticide, stomach poison, or insect growth regulator (chitin synthesis inhibitor). Applaud is likely to only have registration on pear.

1. Lepidopteran pests
   Codling moth – We have not tested Applaud against *codling moth*.

   Leafrollers – We have not tested Applaud against *leafroller*.

   Lacanobia fruitworm – We have not tested Applaud against *Lacanobia*.

2. Indirect/secondary pests –
   No Washington data

3. Pear pests
   Applaud is very active against *grape mealybug* and *pear psylla*, and could become an important component of pear IPM programs. Because of its activity against the same primary pests as the chloronicotinyls, Applaud could be an excellent rotation candidate in a resistance management program.

   Field tests of Applaud against *pear psylla* have been conducted at numerous timings, all with good success. Applaud has activity that is comparable to the chloronicotinyls against pear psylla, although the residual activity appears shorter (less than 2 weeks). Nevertheless, it appears to be the most active compound available against *grape mealybug*, particularly in summer applications.

4. Beneficial arthropods
   No known adverse affects on beneficial arthropods.

I. **Proclaim** (emamectin benzoate)- Proclaim is a similar chemistry as Agri-Mek and even Mesa. The active ingredient in Proclaim is avermectin B1, whereas Agri-Mek is a mixture of avermectin B1a and B1b. Avermectins belong to the glycoside class of insecticides. The mode of action of Proclaim is probably as a chloride channel agonist in GABA mediated neurotransmission.

1. Lepidopteran pests
   Codling moth- Laboratory bioassays indicated that Proclaim was highly toxic to *codling moth* neonate larvae. However, it does not appear to be fast acting and larvae are able to enter the fruit and feed for a short time before dying. Field-aged residue tests showed moderate to high level of activity through 21 days. Field trials (3 applications at 14 day intervals) further illustrated the impact of delayed mortality. Proclaim offered only a moderate suppression of fruit injury, but upon closer inspection most of the larvae that entered the fruit

later died. The result was ultimately a very high level of activity on *codling moth* larvae (95% reduction in live larvae).

Leafrollers- Laboratory bioassays indicated that Proclaim was extremely toxic to both *obliquebanded* and *pandemis leafroller* larvae (LC_{50}= 0.0006 and 0.0008 ppm, respectively). However, field-aged bioassays showed that Proclaim residues were short lived in the field with a decrease in activity noted at 14 days. Proclaim provided excellent control of pandemis leafroller in field trials. Two applications will probably be needed against high populations, especially during the summer generation.

Lacanobia fruitworm- Laboratory tests of Proclaim against *Lacanobia* were confounding. Initial screenings showed Proclaim was highly toxic to *Lacanobia* neonate larvae. However, field-aged residues tests showed only moderate activity for less than 7 days. We have no field trial experience with Proclaim.

2. Indirect/secondary pests
   We have no data on Proclaim's efficacy against indirect or secondary pests of apple.

3. Pear pests
   We have no data on Proclaim's efficacy against *pear psylla*, *grape mealybug* or *mites*.

4. Beneficial arthropods
   We have no data on Proclaim's affects against beneficial arthropods, but primary activity is believed to be through ingestion with low to moderate contact activity. Surface residues are relatively short lived. Therefore, Proclaim is expected to have a fit in IPM programs.

Relative efficacy table for insecticides on Lepidoptera pests of apple.

Insecticide	Codling moth	Leafrollers	Lacanobia fruitworm
Chloronicotinyls			
Actara	Not tested	Not tested	Not tested
Assail	High	Low	Low
Calypso	Moderate-High	Low	Low
Clutch	Not tested	Not tested	Not tested
Provado	Not tested	Not tested	Not tested
Growth Regulators			
Applaud	Not tested	Not tested	Not tested
Azadirachtin	None	Low	Low-Moderate
Confirm	Low	Moderate	Moderate
Diamond	Moderate-High	Low	High
Dimilin	Moderate	Low	Not tested
Esteem	Moderate	Moderate-High	Not tested
Intrepid	Moderate	High	High
Miscellaneous			
Avaunt	Low-Moderate	High (PLR) Low (OBLR)	High
Bacillus thuringiensis	Low	Moderate	Low
CM granulosis virus	Moderate-High	None	None
Horticultural Oil	Moderate	Low	Not tested
Success/Entrust	Moderate	High	Moderate
Surround	Moderate	Moderate	Moderate
Proclaim	Moderate-High	High	Low

Relative efficacy table for insecticides on mites.

Insecticide	European red mite	Twospotted spider mite	Pear rust mite
Miticides			
Acramite	Moderate	High	Low
Envidor	Moderate	Moderate	None
Fujimite*	Moderate	Moderate	Not tested
Kanemite	Moderate	High	Not tested
Mesa*	Moderate	Moderate	None
Nexter*	High	Moderate	Moderate-High
Zeal	High	High	None

* These miticides also have pear psylla activity.

Relative efficacy table for insecticides on pests of pear.

Insecticide	Pear psylla	Grape mealybug	Codling moth
Chloronicotinyls			
Actara	High	High	Not tested
Assail	High	High	High
Calypso	High	High	High
Clutch	High	High	Not tested
Provado	High	High	Not tested
Growth Regulators			
Applaud	High	High	Not tested
Azadirachtin	Moderate	Very low	Very low
Confirm	None	None	Low
Diamond	High	None	High
Dimilin	Moderate	None	Moderate
Esteem	Moderate	None	Moderate
Intrepid	None	None	Moderate
Miscellaneous			
Avaunt	Not tested	Not tested	Not tested
Bacillus thuringiensis	None	None	Low
CM granulosis virus	None	None	Moderate-High
Horticultural Oil	Moderate	Low	Moderate
Success/Entrust	Low	None	Moderate
Surround	Moderate	Very low	Low-Moderate
Proclaim	Not tested	Not tested	Moderate-High

Information on limitations on uses of insecticides.

Insecticide	Max rate/a/ app	Max AI per year	Number of apps. per year	Worker reentry interval	Pre-harvest interval	Toxicity category*	Bee hazard rating*
Chloronicotinyls							
Actara (Pear)	5.5 oz	8.0 oz	---	12 hr	35/14 d	IV	I
Assail	3.4 oz	13.5 oz	4	12 hr	7 days	IV	III
Calypso	8 fl oz	16 fl oz	---	12 hr	30 days	---	---
Clutch	Not registered as of printing						
Provado	8.0 fl oz (apple) 20.0 fl oz (pear)	40.0 fl oz	---	12 hr	7 days	III	II
Growth Regulators							
Applaud	Not registered as of printing						
Azadirachtin	Based on product	Exempt from tolerances, may be used on day of harvest				IV	IV
Confirm	20.0 fl oz	120 fl oz	6	4 hr	14 days	IV	IV
Diamond	Not registered as of printing						
Dimilin (Pear)	48 fl oz	64 fl oz	4	12 hr	14 days	---	IV
Esteem	5.0 oz	10.0 oz	2	12 hr	45 days	IV	IV
Intrepid	16 fl oz	64 fl oz	4	4 hr	14 day	IV	IV
Miscellaneous							
Avaunt	6.0 oz	24 oz	4	12 hr	28 day	III	---
Bacillus thuringiensis	Based on product			4 hr	4 hr	IV	IV
CM granulosis virus	Based on product			---	---	IV	IV
Horticultural Oil	---	---	---	---	---	IV	IV
Success/Entrust	10 fl oz/ 3.0 oz	29 fl oz/ 9.0 oz	3/pest	4 hr	7 day	IV	III
Surround	50 lbs	---	---	4 hr	4hr	IV	IV
Proclaim	Not registered as of printing						
Miticides							
Acramite	1.0 lb	1.0 lb	1	12 hr	7 day	IV	IV
Envidor	Not registered as of printing						
Fujimite							
Kanemite							
Mesa							
Nexter	10.67 oz	10.67 oz	1	12 hr	25/7 day	I	I
Zeal	3.0 oz	3.0 oz	1	12 hrs	28 days	---	---

* Source: Washington State University, 2004 Crop Protection Guide for Tree Fruits in Washington (EB0419, "The Spray Guide").

Toxicity rating based on inhalation, dermal absorption, eye effect and skin irritation.

Bee harzard rating; I Hazardous at any time on blooming crops and weeds, II Not hazardous if applied in late evening except during high temperatures (directly toxic), III Not hazardous if applied in evening or early morning except during high temperatures, IV Not hazardous to bees at any time.

Summary table of pesticides, timing and targets for pest management on apple.

	Delayed dormant	Pink-Bloom	Petal fall	10-14 days post-petal fall	Early summer	Mid- to late summer
Chloronicotinyls						
Actara (Pear)	For use on pears only					
Assail		Campy, Thrips	Rosy aphid		CM, RAA	CM, GAA
Calypso		Campylomma	Rosy aphid		CM, RAA	CM, GAA
Clutch	Preliminary data suggests spectrum of activity similar to Assail and Calypso					
Provado			GMB, WALH, RAA		WALH, RAA	GMB, WALH, GAA
Growth Regulators						
Applaud						Grape mealybug
Azadirachtin			Leafminer		Green aphids	Green aphids
Confirm			LR, CM	LR, CM	CM, Lacanobia	CM, Lacanobia
Diamond			Codling moth	Codling moth	Codling moth	
Dimilin (Pear)	For use on pears only					
Esteem	San Jose scale		LR, CM	LR, CM	San Jose scale	
Intrepid	Cutworms	Leafroller	LR, CM	LR, CM	CM, Lacanobia	CM, Lac, LR
Miscellaneous						
Avaunt	Cutworm		Leafhoppers		WALH, Lac	Lacanobia
Bacillus thuringiensis		Leafroller	Leafroller	Leafroller	Leafroller	Leafroller
CM granulosis virus					Codling moth	Codling moth
Horticultural Oil	SJS, Aphid, mites			Codling moth	Codling moth, leafhoppers	Codling moth
Success/Entrust		Thrips	Leafroller, Leafminer	Leafroller	Codling moth, Lacanobia	LR, CM, Lac, Leafminer
Surround	Leafroller		Leafhoppers		Lac, Leafhoppers	Lac,Leafhoppers
Proclaim			Leafrollers	Leafrollers	Leafrollers	Leafrollers
Miticides						
Acramite					Spider mites	Spider mites
Envidor					Spider mites	Spider mites
Fujimite					Spider mites	Spider mites
Kanemite					Spider mites	Spider mites
Mesa					Spider mites	Spider mites
Nexter					Spider mites	Spider mites
Zeal					Spider mites	Spider mites

Summary table of pesticides, timing and targets for pest management on pear.

	Dormant	Delayed dormant	Clusterbud (Pink)	Petal fall	10-14 days post-petal fall	Early summer	Mid- to late summer	Post Harvest
Chloronicotinyls								
Actara (Pear)			PP, GMB	PP, GMB		Pear psylla	PP, GMB, GAA	
Assail		Pear psylla	PP, GMB	PP, GMB		PP, CM	PP, GMB, CM	
Calypso		Pear psylla	PP, GMB	PP, GMB		PP, CM	PP, GMB, CM	
Clutch	Preliminary data suggests spectrum of activity similar to Assail and Calypso							
Provado				PP, GMB		Pear psylla	PP, GMB	
Growth Regulators								
Applaud			PP, GMB	PP, GMB		Pear psylla	PP, GMB	
Azadirachtin			Pear psylla	Pear psylla	Pear psylla	Pear psylla	Pear psylla	
Confirm				Leafroller	CM, LR	CM, Lac	CM, Lac, LR	
Diamond		Pear psylla	Pear psylla	Pear psylla	PP, CM	PP, CM	PP, CM	
Dimilin (Pear)		Pear psylla	Pear psylla	Pear psylla	PP, CM	Codling moth		
Esteem		PP, SJS	Pear psylla	PP, LR	PP, CM, LR	Codling moth		
Intrepid				CM, LR	CM, LR	CM, Lac	CM, Lac, LR	
Miscellaneous								
Avaunt						Lacanobia	Lacanobia	
Bacillus thuringiensis			Leafroller	Leafroller	Leafroller	Leafroller	Leafroller	
CM granulosis virus					Codling moth	Codling moth	Codling moth	
Horticultural Oil		PP, SJS, Mites	Pear psylla	Pear psylla	PP, CM	PP, CM	PP, CM	
Success/Entrust				Leafroller	Leafroller	Codling moth	CM, LR	
Surround	PP	Pear psylla	Pear psylla			Lacanobia		
Proclaim				Leafroller	Leafroller	Codling moth	CM, LR	
Miticides								
Acramite						Spider mites	Spider mites	
Envidor						Spider mites	Spider mites	
Fujimite			Pear psylla			Mites, PP	Mites, PP	
Kanemite						Spider mites	Spider mites	
Mesa			Pear psylla			Mites, PP	Mites, PP	
Nexter			Pear psylla	Pear psylla, Pear rust mites		Mites, PP, PRM	Mites, PP, PRM	
Zeal						Spider mites	Spider mites	