New Reduced Risk Insecticides for Codling Moth Control, Larvicidal Toxicity and Longevity and Ovicidal Toxicity in Pears - 2009

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Abstract: Two relatively new reduced risk insecticides (Altacor and Delegate) have been evaluated for codling moth (CM) control in pears over the past five years. These insecticides have proven to provide superior CM control to that of the grower standard treatment of Guthion, Imidan, Assail and/or Warrior. In addition Delegate has also provided control of pear psylla. These materials have very low mammalian toxicity and will have minimal personal protection equipment requirements and short re-entry intervals. Altacor and Delegate have excellent eco-toxicological profiles and are gentle on beneficial insects and mites. They have unique modes of action that will allow for the development of a stable resistance management program. Future pear resistance management control programs should consist of pheromone mating disruption combined with one or two in-season insecticide applications. The insecticide applications should alternate between various modes of action. For example the 1A or 1B CM application could be Delegate while the 2A application could be Altacor. In addition, Intrepid, Assail or Imidan could be worked into the resistance management program so that CM populations are never exposed to the same mode of action more than once a year. Altacor proved to be most effective when applied prior to CM oviposition. In addition, Altacor applied before oviposition at 20 ppm was more effective than applied after oviposition at 100 ppm. Because Delegate has excellent pear psylla activity, Delegate could be used as an alternative to Agri-Mek or as a supplemental application to Agri-Mek. This strategy would help delay the development of pear psylla resistance.

Introduction: Delegate (spinetoram) and Altacor (chlorantraniliprole) have unique modes of action that provide superior control of codling moth (CM) and other lepidopterous pests compared to the conventional grower standard of Guthion, Imidan, Assail and others. Since both insecticides have unique modes of action, their judicious use along with existing insecticides will allow for the development of effective resistance management strategies.

Altacor, which is produced by Dupont, E.I. de Nemours & Inc., is in a novel insecticide class, anthranilic diamide, and has a unique mode of action. Altacor activates the ryanodine receptors in insect muscles. This releases stored calcium ions that impairs muscle contraction leading to paralysis and death of the insect. The ryanodine receptors in mammals are structurally different than receptors in insects and insects are 400 to 3,000 times more sensitive to rynaxpyr than mammals, thus accounting for the low toxicity level in mammals compared to insects. The unique mode of action of rynaxpyr will aid in the development of resistance management programs that will delay development of insecticide resistance to Altacor and other insecticides. Altacor is a larvicide with ovicidal activity but little or no adulticide activity. Thus, good coverage will be required to achieve excellent control. Since Altacor has extremely low mammalian toxicity (greater than 5,000 mg a.i./kg acute oral), minimal personal protection

equipment will be required and Altacor has a short re-entry interval (4 hr). Altacor also has a favorable eco-toxicological profile with very low toxicity to non-target organisms, e.g. mallard duck at greater than 2,400 mg a.i./kg and trout at greater than 23.8 mg a.i./l and has very low toxicity to honey bees and important beneficial insect and mite species. Altacor will control most lepidopterous pests and has activity against some dipterous leafminers and homoptera, e.g. whitefly. Altacor will fit well in a codling moth management program in pears as a summer treatment (2A flight).

Delegate, which is produced by Dow AgroSciences, is a second-generation spinosyn and will supercede all labeled uses of Success (spinosad) in the future. Like spinosad, spinetoram is a byproduct of a bacterial (*Saccharopolyspora spinosa*) fermentation. However, spinetoram is a chemical modification to two spinosyns isomers J and L. The chemical modification increases efficacy and photostability of spinetoram. Spinetoram is 3 to 4 times more efficacious than spinosad on an active ingredient basis. Since spinetoram is chemically modified, it will not obtain an organic label such as spinosad. The mode of action of spinetoram is the continuous involuntary transmission of nervous impulses in the central nervous system by activation (firing) of spinosyn specific sites on the nicotinic acetylcholine receptors at the nerve synapse. The specific nicotinic acetylcholine receptors that are affected by spinosyns continue to activate after repeated exposure, instead of showing a decreasing response. This causes continuous activation (firing) of the central nervous system, leading to paralysis and death of the insect. Mammal's nicotinic acetylcholine receptors are slightly different from insect's receptors. This small difference means mammals are much less sensitive to spinetoram than insects. This unique mode of action of spinetoram will aid in the development of resistance management programs that will delay development of insecticide resistance to Delegate and other insecticides. Since Delegate has extremely low mammalian toxicity (greater than 5,000 mg a.i./kg acute oral), minimal personal protection equipment will be required and Delegate will have a 4 hours re-entry interval. Delegate also has a favorable eco-toxicological profile with very low toxicity to non-target organisms, e.g. mallard duck at greater than 5,620 mg a.i./kg and trout at greater than 3.5 mg a.i./l. Delegate has little toxicity to predatory insects such as hemipteran, lacewings and coccinellids, a low level of toxicity to predatory mites and high level of toxicity to parasitic hymenoptera if they come in direct contact with fresh residues. Delegate is highly toxic to honey bees when the bees come in direct contact with fresh residues. However, bee toxicity can be largely mitigated by applications two hours after sundown and three hours before sunrise. Thus if the bees are not exposed to moist residues or do not have direct contact with Delegate, there is very little toxicity. Delegate is a larvicide with some adulticidal activity but little or no ovicidal activity. Thus, good coverage will be required to achieve excellent control. Delegate will control most lepidopterous pests and is also very active against thrips and pear psylla. Delegate also has excellent activity against fruit flies such as walnut huskfly and cherry fruit fly, katydids, sawflies and dipterous leafminers. Delegate will fit well in a codling moth management program in pears as a spring treatment (1A or 1B CM flight) because of its efficacy against pear psylla and CM.

Methods and Materials:

Application Strategy Study: The field trial was conducted in a commercial 'Bartlett' pear orchard in Fairfield, CA. This orchard was planted with 25 ft. x 25 ft. spacing (70 trees/ac). Six treatments were replicated four times in a randomized complete block design.

Treatments and Timings:

Treatment	Rate lb (AI)/ac	No. appl.	Application dates (degree days from 1st or 2nd biofix)
1. Delegate 25WG	4.5 oz	2	22 April (288 DD from 1st biofix), 22 May (680 DD from 1st biofix)
Altacor	2.0 oz	2	26 June (250 DD from 2nd biofix), 17 July (681 DD from 2nd biofix)
2. Delegate 25WG	7.0 oz	2	22 April (288 DD from 1st biofix), 22 May (680 DD from 1st biofix)
Altacor	4.0 oz	2	26 June (250 DD from 2nd biofix), 17 July (681 DD from 2nd biofix)
3. Altacor	2.0 oz	2	22 April (288 DD from 1st biofix), 22 May (680 DD from 1st biofix)
Delegate 25WG	4.5 oz	2	26 June (250 DD from 2nd biofix), 17 July (681 DD from 2nd biofix)
4. Altacor	4.0 oz	2	22 April (288 DD from 1st biofix), 22 May (680 DD from 1st biofix)
Delegate 25WG	7.0 oz	2	26 June (250 DD from 2nd biofix), 17 July (681 DD from 2nd biofix)
4. Warrior II + Agri-Mek 0.15EC*	2.56 oz 16.0 oz	1	22 April (288 DD from 1st biofix)
Assail 30 WG +	6.0 oz	2	22 May (680 DD from 1st biofix) & 26 June (250 DD from 2nd biofix)
Warrior II	2.56 oz		
Imidan 70 WP**	5.5 lb	1	26 June (250 DD from 2nd biofix) & 17 July (681 DD from 2nd biofix)
5. Untreated	----		

* Purespray Green horticultural oil was applied at 1.0% at 250 DD
** Imidan was adjusted to a pH of less than 5.0

Each replicate was an individual tree. Foliar sprays were applied with a hand-held orchard sprayer operating at 250 psi with a finished spray volume of 200 gal/acre (2.87 gal/tree). Applications were scheduled based on degree-days (DD). DD were calculated with a biofix of 27 March for the first generation and a biofix of 14 June for the second generation. CM biofix is

set when sunset air temperatures meet or exceed 62˚F and there is a sustained moth flight. Treatments were targeted to the beginning of egg hatch at 250 DD for the first peak (A peak) and 650 DD for the second peak (B peak) of each flight. Maximum and minimum air temperatures were obtained from the CIMIS weather station at Suisun Valley, CA. Flight activity of male CM was monitored with a pheromone trap placed high in the canopy of an untreated tree. The trap was placed on 20 March and inspected weekly from 26 March through 5 August. Control of first generation CM (overwintering flight) was evaluated on 8 June by inspecting 125 fruit per replicate on the tree for CM infestation. Control of the second generation (summer flight) was evaluated at commercial harvest on 5 August by removing 250 fruit per replicate and inspecting them for CM infestation in the lab. Control of PP nymphs and motile TSSM was evaluated by leaf-brushing 10 exterior and 10 interior leaves collected from each tree weekly from 1 June through 27 July. The plates with the contents from the brushed leaves were counted under magnification (20X) in the laboratory.

Longevity and Toxicity of Delegate and Altacor: This trial was conducted using the same commercial pear orchard in Suisun Valley, CA. The orchard was planted with 25 ft. x 25 ft. spacing. Five treatments were replicated four times in a randomized complete block design. The treatments were:

Treatments and Timings:

Treatment	Rate lb (AI)/ac	No. appl.	Application dates (degree days from 1st or 2nd biofix)
1. Delegate 25WG	4.5 oz	2	22 May (680 DD from 1st biofix) & 26 Jun (250 DD from 2nd biofix)
2. Delegate 25WG	7.0 oz	2	22 May (680 DD from 1st biofix) & 26 Jun (250 DD from 2nd biofix)
3. Altacor 35WG	2.0 oz	2	22 May (680 DD from 1st biofix) & 26 Jun (250 DD from 2nd biofix)
4. Altacor 35WG	4.0 oz	2	22 May (680 DD from 1st biofix) & 26 Jun (250 DD from 2nd biofix)
5. Untreated	-	-	

Treatments were assessed weekly from 27 May through 1 Aug by removing 13 fruit per replicate and infesting them with four neonatal CM larvae. Two larvae were placed in ½ of a pill capsule. Two ½ pill capsules were attached to each pear with hot wax. Mortality was determined after 24 hrs. If one or more of the larvae were alive after 24 hrs, then the capsule was considered alive. This was because of the potential for cannibalism between the CM larvae, which could cause artificially high larval mortality.

Ovicidal Toxicity of Altacor: The laboratory study was conducted at UC Berkeley. Four experimental treatments and water check were replicated four times. The experiment was

conducted in a matched pair design with each experimental treatment matched with a water check. The treatments were:
1) Altacor at 20 PPM applied by Potter spray tower before oviposition,
2) Altacor at 20 PPM applied by dipping the apple halves before oviposition,
3) Altacor at 100 PPM applied by Potter spray tower after oviposition,
4) Altacor at 100 PPM applied by dipping the apple halves after oviposition.

Each replicate consisted of an apple half. Apples were cut into halves and the cut half of the apple was sealed with hot paraffin. 30 CM adults (50% male, 50% female) were placed in 60 cm x 30 cm x 36 cm fine wire-mesh screen enclosed cage. If eggs were deposited upon one another or in close proximity, they were removed. There was a minimum of 10 eggs per apple and the apples were discarded if there was less than 10 eggs. The apples were placed in constant growth chambers at 23.7°C with photoperiod of 18:6 (L:D) for 24 hours. Six days after treatment, eggs were counted and mortality rates determined by counting the number of eggs that hatched, the number of eggs that hatched and died, and the number of eggs that did not hatch.

Results and Discussion:

Application Strategy Study:

CM Evaluations:

Flight Activity: The overwintering CM flight began between 20 and 26 March (Fig. 1). Biofix was set on 27 March (Appendix). CM biofix is set when sunset air temperatures meet or exceed 62˚F and there is a sustained moth flight. This temperature is the minimum required for CM oviposition. The overwintering flight was bimodal this year. The first peak of the overwintering generation occurred between 8 April to 22 April at about 250 DD. The first peak often occurs at 300 DD after biofix. The second peak of the overwintering generation occurred on 12 May at 508 DD. The flight of moths from the overwintering larvae was completed by 14 June at 1017 DD. The first flight is usually completed between 1,000 to 1,100 DD in pear orchards. The second biofix was set on 14 June. The peak of the second CM flight occurred on about 18 June at 234 DD. The second peak of the second flight occurred on 10 July at 526 DD after which the flight decreased until harvest on 15 August at 1040 DD.

First Generation: CM Infestation was low in all treatments during the first generation evaluation (Table 1). Infestation is usually low during the first generation. It has been observed in previous years that an infestation of 0.25% at the first generation evaluation can lead to a significant CM infestation at harvest if not controlled. There was no significant difference among the experimental treatments and the grower standard. However, the high rate of Delegate followed by Altacor (Tr. 2), the high rate of Altacor followed by Delegate (Tr. 4) and the grower standard (Tr. 5) were significantly lower than the untreated check (Tr. 6). There was a slight rate effect where lower rates of both insecticides had higher infestation than the high rates.

Commercial Harvest: The CM infestation at commercial harvest in the untreated check was only 31.6% (Table 1). CM infestation was not as severe as in past years. CM infestation is normally from 70 to 80% in the untreated check. The low CM infestation was attributed to having few untreated trees in the experimental orchard this year. Thus there was not a large

second summer generation of CM produced in the orchard to infest nearby trees. There was no significant difference in the percent stings, strikes or total CM infestation among experimental treatments and grower standard and all preformed very well. However, all the experimental treatments had numerically higher infestations than the grower standard. In past research the high rate of Delegate and Altacor had numerically lower infestation compared to the grower standard. All the experimental treatments had significantly lower infestation compared to the untreated check. Also, no rate effect with either material was apparent at harvest. Thus when CM infestation at harvest is considered, there is no benefit of having Altacor applied for the first generation and Delegate applied for the second generation or having Delegate applied for the first generation and Altacor applied for the second generation.

Foliar Evaluations:

Twospotted Spider Mite: Twospotted Spider Mite (TSSM) populations were very low throughout the study. However, there were significantly fewer TSSM in both rates of Delegate followed by Altacor (Tr. 1 & 2) and the grower standard (Tr. 5) compared to the untreated check during the first CM generation insecticide applications from 1 June to 22 June (Table 2). There was no significant difference among the experimental treatments. However during the second CM generation from 29 Jun to 27 Jul, there was no significant difference among any of the experimental treatments and the untreated check (Table 3). Only the grower standard and untreated check were significantly different. When the entire season is considered, there was no significant difference among the experimental treatments. Thus when TSSM infestation is considered, there is no benefit of having Altacor applied for the first generation and Delegate applied for the second generation or having Delegate applied for the first generation and Altacor applied for the second generation.

Pear Psylla: Pear psylla (PP) populations were significantly lower in the grower standard during the first CM generation applications compared to both rates of Altacor followed by Delegate (Trs. 3 & 4) and the untreated check (Table 4). There was no significant difference between both rates of Delegate followed by Altacor (Trs. 1 & 2) and the grower standard (Tr. 5) or the untreated check. Thus it appears Delegate suppressed the PP while Altacor had little or no effect on PP as compared to the untreated check. During the second CM generation from 29 Jun to 27 Jul, when the low rate Delegate was applied to the plot previously treated with Altacor (Tr. 3), there was a significant increase in PP compared to when both rates of Altacor were applied to the plot previously treated with Delegate (Trs. 1 & 2) and the grower standard (Table 5). It is believed that the low PP populations in the Altacor plots (Trs. 1 & 2) were the result of first generation applications of Delegate. Thus for the entire season, Delegate applied for the first generation followed by Altacor for the second generation had significantly lower PP populations than the high rate of Altacor applied for the first generation followed by Delegate for the second generation (Tr. 4). It appears that control of PP early in the season is key to season effective long management.

Table 1. Mean percent codling moth-infested fruit inspected at first generation and at commercial harvest at commercial harvest in Fairfield, CA - 2009

Treatment	Rate form oz/ac	No. appl.	Mean[a] percent infested fruit: First generation	Commercial harvest: Sting	Strike	Total
1. Delegate 25WG	4.5	2	0.3 a	0.1 a	0.3 a	0.4 a
Altacor 35WDG	2.0	2				
2. Delegate 25WG	7.0	2	0.0 ab	0.2 a	0.2 a	0.4 a
Altacor 35WDG	4.0	2				
3. Altacor 35WDG	2.0	2	1.0 a	0.4 a	0.3 a	0.7 a
Delegate 25WG	4.5	2				
4. Altacor 35WDG	4.0	2	0.0 ab	0.4 a	0.2 a	0.6 a
Delegate 25WG	7.0	2				
5. Warrior II +	2.56	1	0.0 a	0.0 a	0.0 a	0.0 a
Agri-Mek 0.15EC[b]	16.0					
Assail 30WG +	6.0	2				
Warrior II	2.56					
Imidan 70 WP[c]	88.0	1				
6. Untreated check	--------	--	2.5 b	13.0 b	18.6 b	31.6 b

[a] Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, $P \leq 0.05$).

[b] Purespray Green horticultural oil was applied at 1.0% at 250 DD

[c] Imidan was adjusted to a pH of less than 5.0