New Reduced Risk IPM Tools for Pears

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Abstract: Two new reduced risk insecticides (Altacor and Delegate) have been evaluated for codling moth (CM) control in pears over the past three 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 also provided control of pear psylla. Delegate received California registration in November 2007 while registration of Altacor is expected next season. 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 Calypso, Guthion 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. Also since 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: Two new reduced risk insecticides (Altacor 35WG and Delegate 25WG) are on the brink of California registration. Delegate received California registration in November 2007 while registration of Altacor is expected next season. These two insecticides 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. They will soon be added to the insecticide arsenal to combat control of CM and other lepidopterous pests. 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 (rynaxpyr), 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 muscle. 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 some 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 will have a short re-entry interval. 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 dipterous leafminers and some homoptera, e.g. whitefly. Altacor will fit well in a codling moth management program in pears as a summer treatment (2A flight).

Delegate (spinetoram), 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. Since spinetoram is chemically modified, it is unlikely that it will ever obtain an organic label. 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 insect. 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 hour 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: Trials were conducted from 2005 to 2007 in a commercial 'Bartlett' pear orchard in Fairfield, CA. This orchard was planted on a 25 ft. x 25 ft. spacing (70 trees/ac). Eleven treatments were replicated four times in a randomized complete block design. 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. Degree-days were calculated with a spring biofix for the first generation and June biofix for the second generation using a single sine horizontal cutoff model with a lower threshold of 50˚F and an upper threshold of 88˚F. Maximum and minimum air temperatures were obtained from the IMPACT weather station at Cordelia, CA. Flight activity of male CM was monitored with a pheromone trap placed high in the canopy of an untreated tree. Control of the CM was evaluated at commercial harvest by inspecting a maximum of 250 fruit per tree. Control of pear psylla (PP) nymphs, European red mite (ERM) and pear rust mite (PRM) was evaluated by leaf-brushing 10 exterior and 10 interior leaves collected from each tree weekly from mid June through harvest. The plates with the contents from the brushed leaves were counted under magnification (20X) in the laboratory.

Results and Discussion:

Harvest Evaluation: The CM infestation in the untreated check ranged from over 42% to 82% (Table 1). Thus, these trials provided a stringent test of the experimental materials. The CM infestation in all of the experimental treatments was significantly lower than in the untreated check (Table 1). In 2005, Delegate provided control comparable to the grower standard and there was a rate effect between 6.0 oz/ac and 7.2 oz/ac with both three and four application treatments. The Delegate at 7.2 oz/ac treatments had numerically lower CM infestation than the grower standard. Only the low rate of Delegate applied three times had elevated CM infestation levels. Altacor also provided excellent control and was comparable to the grower standard. Unfortunately there was not a strong rate effect, with 2.0 oz/ac as effective as 4.0 oz/ac. Delegate at 7.2 oz/ac provided greater than 95% corrected mortality while Altacor at both 2 and 4 oz provided 94.5% corrected mortality compared to the grower standard, which had a corrected mortality of 94.1%. In 2006, Delegate combined with PureSpray Green horticultural oil, Delegate followed by Calypso and Calypso followed by Delegate had numerically lower CM infestation compared to the grower standard. Delegate without PureSpray Green horticultural oil had CM infestation higher than the grower standard. Altacor at the 2 oz/ac rate had elevated CM infestation compared to the grower standard while Altacor at the 3 oz/ac rate had similar CM infestation compared to the grower standard. Unfortunately in 2006, the 4 oz rate was not included in the trial. In 2005, Altacor at 2, 3 and 4 oz/ac had CM infestations lower compared to the grower standard. It appears that the CM infestation in 2005 study was artificially suppressed at the 2 oz/ac rate (unknown reason) and that under high population pressures Altacor should be applied at the 4 oz/ac rate and be combined with a low rate of PureSpray Green horticultural oil. Delegate at 7.0 oz/ac combined with a low rate of PureSpray Green horticultural oil had corrected mortality of 98.1% while Altacor at 3 oz/ac without PureSpray Green horticultural oil had corrected mortality of 93.1%. The grower standard had a corrected mortality of 95.2%. In 2007 CM infestation in the untreated check was over 48%. CM was not as severe as in past years. The low CM infestation was attributed to ideal pear growing conditions, i.e. cool to moderate temperatures that slowed CM development. In 2007 CM could only produce one and half generations instead of the normal two generations. With fewer generations of CM, only three cover sprays were applied instead of the normal four cover sprays. Delegate and Altacor provide numerically equivalent or superior control compared to the grower standard. Delegate at both 6.4 oz/ac and 7.0 oz/ac provided 99.0% corrected mortality while Altacor at 3 oz/ac and 4 oz/ac provided 97.5% and 98.4% corrected mortality, respectively. The grower standard provided 96.9% corrected mortality. The grower standard was changed in 2007 as compared to previous years. The grower standard in 2007 was a combination of Assail and Warrior instead of

Guthion. This substitution was the result of the length of the re-entry interval and eventual phase out of Guthion. The addition of horticultural oil to Altacor or Delegate provided only marginal improvement in CM control. Also there was little or no rate response with either Delegate or Altacor. The lack of a rate response could be attributed to the lower CM infestation in 2007 as compared to previous years.

Foliar Evaluations:

Pear Psylla – In 2005 the summer was exceptionally cool with only one day over 100˚F (July 23) and only nine days above 90˚F recorded at the IMPACT weather station at Cordelia, CA. The cool weather favored population increases in PP. PP populations were significantly higher in the 3.0 oz/ac rate of Altacor compared to the untreated check (Table 2). Delegate, and the high rate of Altacor had numerically lower but not significantly lower PP populations compared to the untreated check. All four Delegate treatments showed consistently lower PP populations compared to the untreated check. In 2006, PP populations were significantly lower in Delegate and Altacor treatments compared to the grower standard and significantly lower in the Delegate treatments compared to the untreated check. PP populations were significantly higher in both Altacor treatments compared to the untreated check but not significantly higher compared to the grower standard. It is not known why there was an increase in the PP population but Altacor may be suppressing a PP mortality agent. In 2007, PP population was significantly lower in all Delegate and Altacor treatments compared to the untreated check. There was no significant difference among all Delegate treatments, Altacor combined with PureSpray Green horticultural oil and the grower standard. PP populations were significantly higher in both Altacor treatments without oil compared to the grower standard.

Pear Rust Mite – In 2005 PRM populations were significantly increased in all Delegate treatments compared to the grower standard or untreated check (Table 2). Altacor treatments had much reduced numbers of PRM and were comparable to the grower standard and untreated check. In 2006 again PRM populations were significantly increased in all Delegate treatments compared to the untreated check and grower standard. There were also elevated PRM populations in Altacor treatments. The increase in PRM populations in 2006 in the Altacor treatments may be a carry over from the 2005 study, which was conducted in the same orchard. In 2007, PRM populations were significantly lower in Delegate at 6.4 oz/ac with and without oil and all Altacor treatments compared to the untreated check. Delegate at 7.0 oz/ac again had significantly higher PRM compared to the grower standard. The orchards was treated on 10 March with 2 1/2 gal of liquid lime sulfur and 10 lb sulfur per 100 gal to suppress the PRM population and to make a more uniform PRM population among the treatments at the beginning of the season. Despite this treatment, the high rate of Delegate caused a significant increase in the PRM population. The high PRM populations that were observed in the Altacor treatments in 2006 did not appear in the 2007 study with Altacor and it was concluded that high PRM populations in the Altacor treatments in 2006 were the result of population carry over from 2005 study and not the result of the Altacor.

European Red Mite – In 2005 the ERM and twospotted spider mites (data not presented) populations did not develop and there was no significant difference among the treatments (Table 1). In 2006, ERM populations were significantly higher in the 2 oz/ac of Altacor treatments compared to all other treatments. The 3 oz/ac rate of Altacor had an elevated ERM population

but it was not significantly higher than the untreated check. In 2007, the ERM population did not develop and there was no significant difference among the treatments. The higher population of ERM in the Altacor treatments observed last year did not appear in this year. Thus, it is doubtful that Altacor causes ERM flare-ups

Conclusions: These trials were conducted against a very high CM population from 48% to 82% of the fruit infested with CM at harvest in the untreated check. These trials should be considered a rigorous test of the experimental materials. Delegate and Altacor showed great promise as reduced risk CM products. The addition of horticultural oil to both Delegate and Altacor appears to marginally increase their efficacy. It appears that Delegate also provides PP control. However, Delegate caused population increase of PRM. This increase in PRM is thought to be the result on suppression of the Western flower thrips, which feeds on PRM. Delegate in other studies has shown to provide excellent thrips control. Thus it appears that Altacor and Delegate can compete favorably with the grower standard and provide two new modes of action in suppressing CM. No phytotoxicity was observed with either Altacor or Delegate.

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Table 1. Mean percent infested fruit inspected at commercial harvest in Fairfield, CA

Treatment	Rate form/ac	No. appl.	Mean[a] Percent CM infestation	Mean Percent Corrected Mortality
		2005		
1. Delegate 25WG	6.0 oz	3	8.7 b	89.4
2. Delegate 25WG	7.2 oz	3	3.6 a	95.6
3. Delegate 25WG	6.0 oz	4	5.9 ab	92.8
4. Delegate 25WG	7.2 oz	4	4.1 a	95.0
5. Altacor 35WG[b]	2.0 oz	3	4.5 a	94.5
6. Altacor 35WG[b]	3.0 oz	3	6.5 ab	92.1
7. Altacor 35WG[b]	4.0 oz	3	4.5 a	94.5
8. Imidan 70WP[bc] +	7.0 lb	1	4.8 a	94.1
MK-936 0.18EC	16.0 oz			
Guthion 50WP	3.0 lb	2		
9. Untreated check		--	82.0 c	------
		2006		
1. Delegate 25WG	7.0 oz	4	4.6 ab	93.9
2. Delegate 25WG[d]	7.0 oz	4	1.4 a	98.1
3. Delegate 25WG[d]	7.0 oz	2	1.3 a	98.3
Calypso 4F[d]	8.0 oz	2		
4. Calypso 4F[d]	8.0 oz	2	2.5 a	96.7
Delegate 25WG[d]	7.0 oz	2		
5. PureSpray Green		4	25.2 c	66.4
6. Altacor 35WG	2.0 oz	4	11.8 b	84.2
7. Altacor 35WG	3.0 oz	4	5.2 ab	93.1
8. Imidan 70WP[c,d] +	7.1 lb	1	3.6 ab	95.2
Agri-Mek 0.15EC	10.0 oz			
Guthion 50WP	3.0 lb	2		

	Imidan 70WP[c]	7.1 lb	1		
9.	Untreated check		--	74.9 d	------
			2007		
1.	Delegate 25WG [d]	6.4 oz	3	0.4 a	99.2
2.	Delegate 25WG	6.4 oz	3	0.5 a	99.0
3.	Delegate 25WG	7.0 oz	3	0.5	99.0
4.	Altacor 35WG[d]	3.0 oz	3	1.1 a	97.7
5.	Altacor 35WG	3.0 oz	3	1.2 a	97.5
6.	Altacor 35WG	4.0 oz	3	0.8 a	98.4
7.	Imidan 70WP[c,d] +	5.5 lb	1	1.5 a	96.9
	Warrior 1CS	3.2 oz			
	Agri-Mek 0.15EC	13.7 oz			
	Assail[d]	6.0 oz	2		
	Warrior 1CS	3.2 oz			
	Agri-Mek 0.15EC	13.7 oz			
8.	Untreated check			48.5 b	------

[a] Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, $P < 0.05$).
[b] Treatment includes 0 .25% PureSpray Green Oil by volume.
[c] Treatment pH was adjusted to less than 5.5
[d] Treatment includes 1% PureSpray Green Oil by volume at 250 DD from 1st biofix, 0.5% at 650 DD from 1st biofix, and 0.25% at 250 DD & 650 DD from 2nd biofix.

Table 2. Mean percent infested fruit inspected at commercial harvest in Fairfield, CA

	Treatment	Rate form/ac	No. appl.	Mean[a] pear psylla	Mean[a] pear rust mite	Mean[a] European red mite
			2005			
1.	Delegate 25WG	6.0 oz	3	60.5 a	6114 b	2.3 a
2.	Delegate 25WG	7.2 oz	3	87.0 a	4343 b	12.0 a
3.	Delegate 25WG	6.0 oz	4	65.3 a	5482 b	6.0 a
4.	Delegate 25WG	7.2 oz	4	65.5 a	5715 b	7.0 a
5.	Altacor 35WG[b]	2.0	3	133.3 ab	402 a	8.3 a
6.	Altacor 35WG[b]	3.0 oz	3	208.8 bc	652 a	1.3 a
7.	Altacor 35WG[b]	4.0 oz	3	96.3 ab	269 a	1.3 a
8.	Imidan 70WP[bc] + MK-936 0.18EC Guthion 50WP	7.0 lb 16.0 oz 3.0 lb	1 2	246.0 c	237 a	2.8 a
9.	Untreated check			117.5 ab	563 a	11.3 a
			2006			
1.	Delegate 25WG	7.0 oz	4	16.8 a	2982 abc	8.8 a
2.	Delegate 25WG[d]	7.0 oz	4	12.3 a	3931 bc	2.0 a
3.	Delegate 25WG[d] Calypso 4F[d]	7.0 oz 8.0 oz	2 2	13.3 a	3548 bc	1.8 a
4.	Calypso 4F[d] Delegate 25WG[d]	8.0 oz 7.0 oz	2 2	14.3 a	4134 c	2.3
5.	PureSpray Green		4	38.3 b	1896 ab	4.5 a
6.	Altacor 35WG	2.0 oz	4	90.5 c	3165 b	118.3 b
7.	Altacor 35WG	3.0 oz	4	103.3 c	2999 abc	55.0 a
8.	Imidan 70WP[c,d] + Agri-Mek 0.15EC	7.1 lb 10.0 oz	1	135.8 d	1432 a	19.0 a

	Guthion 50WP	3.0 lb	2			
	Imidan 70WP[c]	7.1 lb	1			
9.	Untreated check			58.3 b	1134 a	6.5 a
			2007			
1.	Delegate 25WG[d]	6.4 oz	3	16.1 a	4.3 a	0.6 a
2.	Delegate 25WG	6.4 oz	3	18.6 a	9.4 a	0.5 a
3.	Delegate 25WG	7.0 oz	3	20.6 a	61.0 b	2.1 a
4.	Altacor 35WG[d]	3.0	3	25.5 a	7.0 a	0.6 a
5.	Altacor 35WG	3.0 oz	3	40.8 b	9.3 a	2.3 a
6.	Altacor 35WG	4.0 oz	3	44.7 b	6.6 a	1.5 a
7.	Imidan 70WP[c,d] +	5.5 lb	1	21.9 a	4.5 a	1.6 a
	Warrior 1CS	3.2 oz				
	Agri-Mek 0.15EC	13.7 oz				
	Assail[d] +	3.0 lb	2			
	Warrior 1CS	3.2 oz				
	Agri-Mek 0.15EC	13.7 oz				
8.	Untreated check			59.1 bc	52.4 b	5.1 a

[a] Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, $P < 0.05$).
[b] Treatment includes 0 .25% PureSpray Green Oil by volume.
[c] Treatment pH was adjusted to less than 5.5
[d] Treatment includes 1% PureSpray Green Oil by volume at 250 DD from 1st biofix, 0.5% at 650 DD from 1st biofix, and 0.25% at 250 DD & 650 DD from 2nd biofix.