Control of codling moth by post–harvest application of Ethephon 2SL and Lorsban 4E

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Abstract: Studies were conducted to examine the effects of pH on the efficacy of spray solutions of Lorsban 4E and Ethephon 2SL on codling moth mortality and pear fruit maturity. It was found that a low pH (3 to 5) improves the efficacy of Lorsban 4E in killing codling moth adults compared to a pH of 7. The efficacy of ethephon to accelerate fruit maturation and fruit drop after harvest was improved at a pH of 2.6 (unbuffered) and 4.6 compared to pH of 6.9. We recommend no pH modification (unbuffered) to the post-harvest application of Ethephon 2SL + Lorsban 4E. The effects of pH on additional insecticides will be evaluated this winter.

Introduction: The termination of the registration of Penncap-M and the use restrictions on Guthion and likely termination of the registration of Guthion along with the development of resistance in codling moth (CM) to Guthion and other commonly used insecticides has caused a paradigm shift to occur in pear pest control. Pear pest management relies on mating disruption for CM control and supplemental insecticides to maintain a low CM population. CM pheromone disruption has been demonstrated to be efficacious under low CM population pressure. Several supplemental insecticide applications may be required to maintain a low CM population. The supplemental insecticides may cause a substantial increase in pear psylla and twospotted spider mite populations. When no supplemental insecticides are applied, these secondary pests may be held under control by beneficial arthropods. Thus environmentally benign methods are needed to supplement pheromone mating disruption. The objectives are to evaluate the long-term effectiveness of a post-harvest CM suppression program using Ethephon 2SL (ethephon) and Lorsban 4E (chlorpyrifos) on CM populations and rattail fruit production.

Past research supported by the CPAB and PPMRF has demonstrated that the application of ethephon shortly after harvest will result in rapid maturation and drop of unharvested fruit. CM larvae that infest unharvested fruit treated with ethephon do not complete their larval development. The pears rot faster than the larvae can complete their development. This suppresses the overwintering CM population and thus decreases the CM population the following spring. Ethephon 2SL was recently registered by Makhteshim-Agan as a post-harvest application on pears in combination with an insecticide. In addition research by Drs. Welter and Dunley has shown that chlorpyrifos exhibits negative correlated cross-resistance to organophosphate, pyrethroid and some insect growth regulator insecticide resistant CM. This unique characteristic of Lorsban 4E can be used to slow the development of resistance not only to existing insecticides but potentially to the insecticides of the future. The addition of chlorpyrifos to ethephon will kill the hatching CM larvae from eggs that were oviposited on the fruit before the application of ethephon. Thus a combination of both Lorsban 4E and ethephon applied shortly after harvest will suppress the overwintering CM population and at the same time reduce insecticide resistance.

One unanticipated problem with the combination of ethephon and an insecticide is that ethephon reduced the pH of the spray solution to very low levels, i.e. of pH 2 or 3. The effects of the low

pH on the various insecticides have not been determined and insecticide manufacturers have expressed concern that the low pH might adversely affect the efficacy and/or longevity of their product. To eliminate this potential problem, we have recommended that the ethephon spray solution be buffered to raise the pH. However, it was not known if the buffering of the spray solution reduces the efficacy of ethephon to increase pear maturity. Thus research was required to determine the effects of pH on the toxicity of candidate insecticides and to determine the effects on buffering on the efficacy of ethephon.

1. Effects of pH on pesticide efficacy

Methods and Materials:
Dose–response bioassays were conducted to determine the toxicity of chlorpyrifos for CM larvae and adults at varying pH of the spray solution. CM adults and larvae were reared on an artificial diet in the laboratory of Dr. S. C. Welter. Infested pear fruit or treated adults were then held in a temperature cabinet at 24.5° C with photoperiod of 16:8 hr (L:D). Mortality was determined 24 hours after application.

Larval Bioassays
Larval mortality was determined at four rates of chlorpyrifos and a water-blank check in solutions of pH 2 and 7. The four rates of chlorpyrifos were: 1) 12 ppm, 2) 24 ppm, 3) 48 ppm and 4) 72 ppm. Each rate and water-blank was replicated four times. Chlorpyrifos was applied to pear fruit using a Potter spray tower. Thirty neonate CM larvae were then confined to each pear surface using pill capsules. The larvae were placed on the pears 3 hours after application.

In a second experiment, 16 pear fruit were treated with a pH 3 water blank solution and four pears were treated with pH 7 water blank solution. The blank solutions were applied to pear fruit using a Potter spray tower. Before confining 30 CM larvae, pears sprayed with a solution of pH 3 were held for 3 hours, 48 hours, 96 hours, and 8 days and pears sprayed with a solution of pH 7 were held for 3 hours. Each waiting period was replicated four times.

Adult Bioassays
Adult mortality was determined at three rates of chlorpyrifos in solutions of pH of 3, 5 and 7. The three rates of chlorpyrifos were: 1) 479 ppm, 2) 838 ppm and 3) 1197 ppm. Latron B-5028 at a rate of 0.25% v/v was used to break the surface tension of the solution to allow it to penetrate scales of the adult CM. Adult male CM were treated with 2 µl/adult. There were 10 adults per replication and each rate was replicated eight times.

Results and Discussion:
The effects of low pH of the spray solution on the acute toxicity of chlorpyrifos to CM larvae were evaluated. In the water-blank check, a pH of 2 resulted in an increased larval mortality compared to a pH of 7 (Fig. 1). Thus, the increased mortality in the chlorpyrifos solution of pH 2 was the result of the acidity of the water and not necessarily the chlorpyrifos. In an attempt to circumvent the high check mortality in the pH 2 solution, the waiting period before infestation was increased and the pH of the solution was increased to 3. It was observed that by lengthening the waiting period and increasing the pH, there was a decreased CM larval mortality in the water check (Table 1). However, larval mortality similar to pH 7 solution could not be attained with a

reasonable amount of waiting time. Thus, determining the effects of pH on insecticide efficacy using CM larvae will not be possible.

The effects of low pH of the spray solution on the acute toxicity of chlorpyrifos to CM adults showed an increased mortality when the pH was adjusted from pH of 7 to a pH of 5 especially at the concentrations of 479 ppm and 838 ppm (Fig. 2). There was little improvement from a pH of 5 to a pH of 3. At the higher concentration of 1197 ppm there was little difference in mortality of the adult CM among all three pH solutions. This study indicates that a pH below 5 increased the efficacy of chlorpyrifos. The effects of low pH on acute toxicity to CM adults will be determined for two more insecticides (Assail - a neonicotinoid and Warrior - a pyrethroid) this winter. Since larval evaluations are not possible, we will not examine the effect of pH on Intrepid (ecdysone agonist). Intrepid is a larvicide that needs to be consumed to be effective.

Conclusions

It is not possible to determine the effects of pH of spray solution on pesticide efficacy using CM larvae since check blank solutions of pH less than 3 are toxic to the larvae. However, it is possible to examine the effects of varying pH of a spray solution on pesticide efficacy using CM adults. It was found efficacy improved with lower pH. We recommended that the pH of a spray solution of chlorpyrifos be 5 or less.

Table 1. Percent Mortality 24 hours after infestation of CM Larvae in various pH solutions after various waiting periods before infestation

	Percent Mortality +/- Standard Deviation			
pH of Solution	3hrs	48hrs	96 hrs	8 days
pH 3	49.3 +/- 8.7	32.5 +/- 10.3	31.0 +/- 3.2	20.5 +/- 4.1
pH 7	7.5 +/- 5.2			

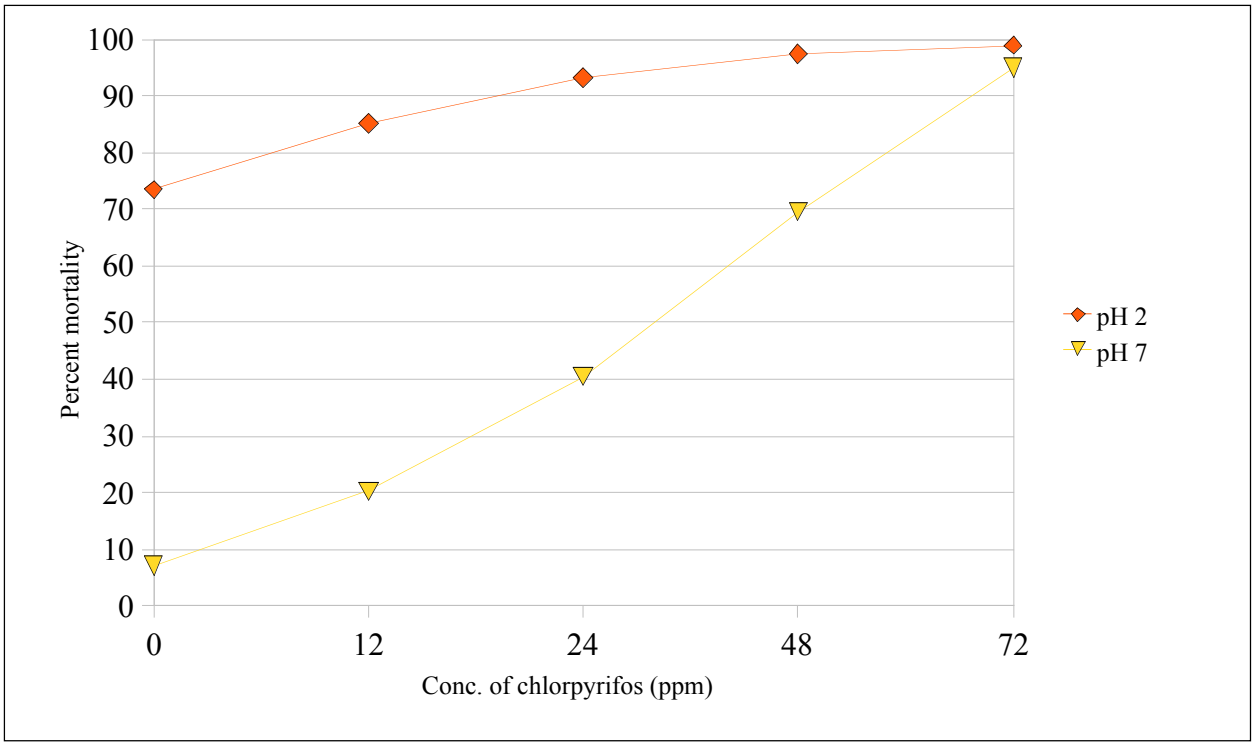

Figure 1. Percent mortality of CM larvae of chlorpyrifos in various pH solutions 24 hrs after infestation.

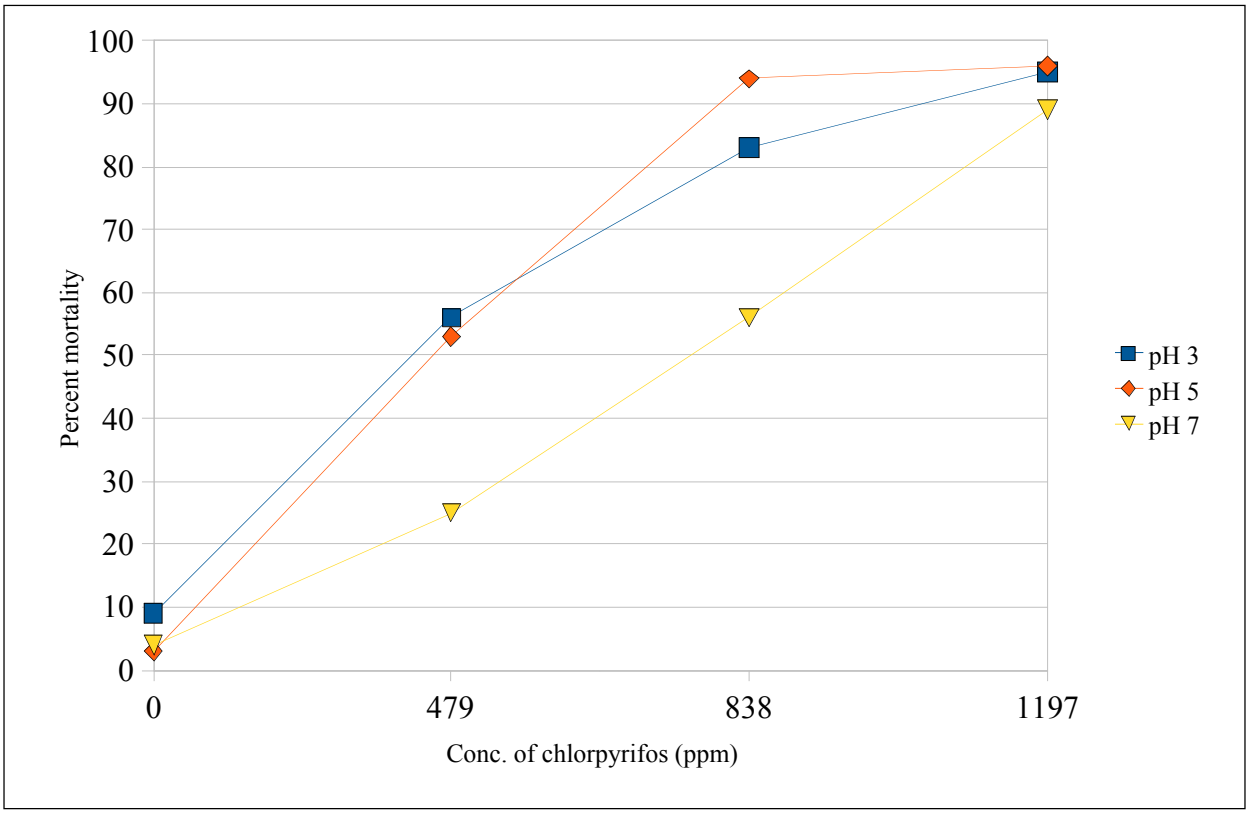

Figure 2. Percent mortality in adult CM 24 hrs after treatment of chlorpyrifos in pH 3, 5 & 7.

2. Effects of buffering on efficacy of Ethephon

Methods and Materials:

Ethephon efficacy trials at various pH of the spray solution were conducted in a commercial pear orchard in the Sacramento delta. Four treatments were replicated 5 times in a random complete block design. The four treatments were: 1) 4 pt of Ethephon/ac at a pH of 2.8 (unbuffered), 2) 4 pt of Ethephon/ac at a pH of 4.6, 3) 4 pt of Ethephon/ac at a pH of 6.9 and 4) untreated check. The pH of the spray solution was buffered using sodium bicarbonate. The treatments were applied post-harvest on August 13 using a hand-held orchard sprayer delivering about 150 gal/acre. Each replicate used one individual tree and there was at least one buffer tree in each direction. Fruit maturity (fruit color and pressure) was determined on 10 normal and 10 rattail fruit before application. Fruit maturity was determined on 10 normal and 5 rattail fruit per replicate weekly for 4 weeks after application. Fruit drop was determined by flagging 10 normal and 5 rattail fruit per replicate before application and recording the dropped fruit per replicate for 4 weeks after application.

Results and Discussion:

Normal fruit pressure before application (8/13) was 11.5 kg/cm^2 with a standard deviation of 2.6 kg/cm^2. The mean pressure for rattail fruit was 16.0 kg/cm^2 with a standard deviation of 4.8 kg/cm^2. Normal fruit pressure one week after application (8/20) did not change dramatically (Table 4). However fruit pressures was reduced in the 2.6 and 4.6 pH treatments. Normal fruit pressure two weeks after application (8/28) did show a significant decrease in the 2.6 and 4.6 pH treatment compared to the untreated control. Normal fruit pressure 3 and 4 weeks after application (9/5 & 9/12) showed little or no statistical difference from that of the untreated control. This is due to a bias in the selection of the normal fruit that was chosen each week to measure fruit pressure. Each week it became increasingly difficult to locate mature fruit on the trees, particularly in the 2.6 and 4.6 pH treatments. The fruit that was found was often low to the ground or near the center of the tree. It is believed that these fruit received less ethephon than the exposed fruit on the tree, most of which had already fallen off by week 3. Rattail fruit pressure, like normal fruit, one week after application (8/20) did not change dramatically (Table 4). However, fruit pressures were reduced in the 2.6 and 4.6 pH treatments. Rattail fruit pressure two and three weeks after application (8/28 & 9/5) did show a significant decrease in the 2.6 pH treatment compared to the untreated control. It is important to note that CM larvae cannot survive in fruit with pressure of less than 6.5 kg/cm^2, which was achieved in normal fruit at two weeks after application in the 2.6 and 4.6 pH treatments and in rattail fruit in the 2.6 pH treatment two weeks after application. Beside the rapid decrease in fruit pressure, fruit drop was accelerated particularly in the normal green fruit. Fruit drop in normal fruit was significantly increased in the 4.6 pH treatment one week after application and in the 2.6 and 4.6 pH treatments two, three, and four weeks after application (8/28, 9/5 & 9/12) (Table 5). Fruit drop in normal fruit was not significantly increased in the 6.9 pH treatment. Fruit drop in rattail fruit was only significantly increased in the 4.6 and 6.9 pH treatments four weeks after application (9/12). Thus Ethephon, regardless of pH, had only a minor impact on rattail fruit drop.

Table 4. Mean pressure of normal and rattail fruit over four weeks in the Sacramento delta, CA

Treatment	Mean[a] pressure (kg/cm^2)			
	8/20/08	8/28/08	9/5/08	9/12/08
	Normal fruit			
1. Ethephon pH 2.6 (unbuffered)	9.8 a	5.0 a	6.1 ab	4.8 a
2. Ethephon pH 4.6	9.7 a	4.6 a	4.6 a	3.6 a
3. Ethephon pH 6.9	11.2 a	6.8 ab	7.7 b	5.3 a
4. Untreated	11.9 a	8.8 b	6.4 ab	6.3 a
	Rattail fruit			
1. Ethephon pH 2.6 (unbuffered)	13.3 a	4.4 a	3.9 a	2.0 a
2. Ethephon pH 4.6	13.7 a	8.0 ab	4.4 ab	1.3 a
3. Ethephon pH 6.9	14.0 a	10.5 ab	5.5 ab	3.8 a
4. Untreated	16.6 a	14.1 b	10.1 b	10.5 b

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

Table 5. Mean percent dropped normal and rattail fruit over four weeks in the Sacramento delta, CA

Treatment	Mean[a] percent			
	8/20/08	8/28/08	9/5/08	9/12/08
	Normal fruit			
1. Ethephon pH 2.6 (unbuffered)	10% ab	47% bc	70% bc	78% bc
2. Ethephon pH 4.6	16% b	59% c	86% c	90% c
3. Ethephon pH 6.9	10% ab	30% ab	54% ab	68% ab
4. Untreated	3% a	19% a	43% a	54% a
	Rattail fruit			
1. Ethephon pH 2.6 (unbuffered)	0% a	4% a	4% a	4% a
2. Ethephon pH 4.6	0% a	0% a	12% a	20% b
3. Ethephon pH 6.9	0% a	0% a	20% a	28% b
4. Untreated	4% a	4% a	4% a	4% a

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

Conclusions

The efficacy of Ethephon 2L as measured by fruit pressure and cumulative percentage of normal and rattail dropped fruit was seriously affected when pH of the spray solution was buffered to pH of 6.9. The effects were not observed in normal fruit when the spray solution was buffered to a pH of 4.6 but were observed in rattail fruit. A pH of 4.6 showed a slightly decreased normal fruit pressure and an increased normal fruit drop compared to the non-buffered solution. In rattail fruit, a pH of 4.6 showed a slightly increased fruit pressure but an increased fruit drop compared to the non-buffered solution. Thus, our recommendation would be to not buffer the ethephon spray solution. If the insecticide being combined with the ethephon required a lower pH we could only recommend buffering to pH of 4.6 or less.

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