The Ovicidal and Larvicidal Capabilities of Recent Reduced Risk Insecticides on Codling Moth *Cydia pomonella*

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Abstract I propose an analysis of two insecticides, Chlorantraniliprole and Methoxyfenozide on a major agricultural pest, Codling Moth, *Cydia pomonella*. Crop losses are derived from consumer expectancy of impeccable crops placing severe pressure upon farmers. Today the consumers expect perfect crops, including apples, resulting in severe financial losses for farmers. The continued application of insecticides including organophosphates has led to increased resistance and severe impacts upon non-target species. Reduced-risk insecticides limit impacts upon non-target species and the environment. Two more recent reduced-risk insecticides Chlorantraniliprole and Methoxyfenozide are promising ovicides (egg killers) or larvicides (larvae killers). I examined the application of each by dipping or spraying, prior to or after oviposition (egg deposition), with or without surfactants. After I dipped or sprayed each insecticide prior to or after oviposition, with or without surfactants, upon each individual apple, I then studied, analyzed and determined if efficacy of each improved. I discovered that both Chlorantraniliprole and Methoxyfenozide mortality rates averaged 50% or greater. I found Chlorantraniliprole was most effective when I dipped it prior to oviposition. Methoxyfenozide was most effective when I dipped or sprayed it after oviposition. Both insecticides targeted Codling Moth before damage occurred.

Introduction

Consumers expect many top crops produced today to be undamaged. (Hall *et al.* 2004) Because these crops are grown and cared for in an imperfect world, crops are frequently damaged and apples are no exception. (Brunner 2003) Marketing damaged apples, if minimal nonetheless, results in significant financial losses for the farmer. Extensive apple loss is derived from *Cydia pomonella*, the Codling Moth. Codling moth (*Cydia pomonella*), an invasive species of European origin, is one important cause of extensive apple loss. (Bessin 2003) Multiple generations (two to three) per year has increased the moth's ability to adapt and resist insecticides. (Walgenbach 2008) As a consequence, farmers desperately increase use rates hoping to prevent any further damage. (Bessin 2003) Not only have resistant species significantly increased, but the severity and extent of some resistance problems have increased alarmingly, including *Cydia pomonella*. (Denholm and Roland 1992) Because the adults are less susceptible to insecticide exposure, the development of new insecticides target the developmental stages of *Cydia pomonella*. (Brunner 2003) Although the egg is most vulnerable, little is known about susceptibility to insecticides targeting eggs. (Smith and Salkeld 1966) These insecticides are known as ovicides (egg killers) and larvicides (larvae killers). Older insecticides are non-specific or non-discriminatory, killing both the pest and beneficial species. (Walgenbach 2008) Increasing use rates of older insecticides has resulted in the mass extermination of beneficial insects that protect these top crops from other secondary pests including the aphid, which upon application, become the primary issue. (Daane *et al.* 2005) Increased usage has also negatively impacted humans. A 1982 national study of hospital cases of acute pesticide poisoning demonstrated that Sri Lanka, a country with a population of 12 million, had approximately 10,000 persons admitted to hospitals for acute pesticide poisoning annually, resulting in almost 1,000 deaths. (Jeyaratnam 1990) There are about 25 million cases of occupational poisoning, which means agricultural workers are most at risk. (Jeyaratnam 1990)

In this study, I tested two **recent reduced-risk** insecticides, Chlorantraniliprole and Methoxyfenozide and determined the effectiveness and concentrations required to eliminate eggs and larvae before damage. Little is known whether these insecticides are ovicidal (egg killers), larvicidal (larvae killers), or neither. Chlorantraniliprole belongs to a new class of chemical compounds, the anthranilic diamides, claiming to provide larvicidal potency and long-lasting activity. (DuPont 2007) Chlorantraniliprole controls pest populations by activating insect ryanodine receptors. These receptors are required for muscle function of the insect. The contraction of muscle requires calcium from cell cytoplasm. (DuPont 2007) Ryanodine receptors control the release of calcium but Chlorantraniliprole binds to the Ryanodine receptors resulting in massive release of calcium following muscle inertness and consequentially death. (DuPont 2007) Target species include Codling Moth, Oriental Fruit Moth, Armyworms, Cabbage Looper, Thrips, and other pests. (Dow AgroSciences 2006) Methoxyfenozide is a diacylhydrazine acting as a molt accelerating chemical. (Dow AgroSciences 2003) It works best against most lepidopterous pests. Methoxyfenozide is an agonist, or a chemical that alters the function a receptor, of the insect molting hormone 20-hydroxyecdysone. (Dow AgroSciences 2003) The insecticide is absorbed into the insect's circulatory system binding with with ecdysone receptors. Feeding stops and premature molting begins soon after. (Dow AgroSciences 2003) Premature molting results in starvation, dehydration, and death.

These recently introduced insecticides are believed to have potential because both insecticides do not harm non-target species for insects must ingest them to become effective. Since beneficial insects such as bees and ladybird beetles do not consume the crops thus, there is little to no threat against them. (Trisyono *et al.* 2000) Ovicides and larvicides are the ideal solutions attacking pests when most vulnerable and before crop damage has occurred.

My research questions and hypotheses are:

1. Do Chlorantraniliprole and Methoxyfenozide effectively eliminate (> than 50% mortality) Codling Moth eggs and larvae? I hypothesize that Chlorantraniliprole and Methoxyfenozide will eliminate more than half the eggs and larvae (mortality rates > than 50%)
2. Does the application type of Chlorantraniliprole and Methoxyfenozide influence the overall effectiveness of each insecticide upon Codling Moth? I hypothesize that increased mortality rates will reflect the application of each insecticide through the dip method rather than the spray method.
3. Does the time of application, prior to oviposition or after oviposition, affect the overall efficacy of the insecticides? My hypothesis is that applying the insecticides after oviposition will increase the mortality rate for exposure is much greater.

4. Does the presence of surfactants affect the overall efficacy of each insecticide and which surfactant provides the best results? My hypothesis is that the presence of surfactants will increase the efficacy of each insecticide the most effective surfactant being MSO for it is applied in the largest concentration.

Methods and Procedures

General Approach In order to determine residue and contact ovicidal and larvicidal efficacy of Chlorantraniliprole and Methoxyfenozide on the Codling Moth eggs and determine if surfactants improve the efficacy, I conducted an experiment in which I manipulated the application of each by dipping or spraying, prior to or after oviposition, with or without surfactants. Applying the insecticides prior to and after oviposition allowed me to determine whether the insecticides are killing the egg, the larvae, or neither. If Chlorantraniliprole and Methoxyfenozide possess mortality rates equal to or greater than 50%, then these insecticides can be classified as ovicides/larvicides.

Indentification of System under Study I am examining *Cydia pomonella*, the Codling Moth. Residue-free apples obtained from Professor Robert Van Steenwyk's greenhouse will be used in the experiment to ensure that all previous insecticides are removed so as not to affect the mortality rates of my research. My research took place from early January to late April.

Data Collection and Set-Up My objective was to compare the ovicidal and larvicidal capabilities of Chlorantraniliprole and Methoxyfenozide and determine whether each insecticide was a viable ovicide, larvicide, or neither. To test this, I compared mortality rates of *Cydia pomonella* eggs and larvae that were exposed to each insecticide based on application method, application timing, and application with or without surfactants. About 16 apples were collected (cut in half for experimentation meaning 4 per insecticide 4 per trial). The cut surface of each apple was sealed with paraffin to prevent desiccation. Each Codling Moth I obtained was given courtesy of Professor Stephen Welter. I gathered several males and females (about 15 of each sex) and placed them within four 60 cm x 30 cm x 36 cm containers consisting of fine wire-mesh screen and fed them with a honey-water solution. The food source sustaining the adult moths was composed of 5% honey the remaining water. These 16 untreated apples slices (for easier examination) were placed in the colony. The apple slices were exposed to the colony for 24 to 48 hours (Brunner and Doerr 2003), allowing for the deposition of 10 to 150 eggs upon each slice. If eggs were deposited upon one another or in close proximity, they were removed.

Chlorantraniliprole was applied at 100 parts per million (ppm) to simulate a 50% mortality rate similar to Brunner's study. (Brunner and Doerr 2003) Methoxyfenozide was applied at 19 ppm similar to Broschert's study to simulate a 50% mortality rate. (Brochert, et al 2008) These serve as my controls. A Potter spray tower was used providing a uniform spray upon each slice of apple. I put the apples in individual plastic containers. The specimens were placed in constant growth chambers at 25 degrees Celsius for that temperature accelerates growth considerably. Codling Moth eggs began hatching six days after spraying (most eggs should hatch by then). The number of eggs deposited and the number which developed and hatched were recorded. Eggs that showed no sign of development meant that the insecticide killed the specimen before development. On the other hand, if the egg was allowed to develop into a "black head" and/or was able to chew its way out of the egg and onto the apple's surface, then the insecticide killed the specimen after the second instar stage.

Examining the effect of each insecticide prior to oviposition provided concrete evidence as to whether Chlorantraniliprole and Methoxyfenozide were considered ovicides, larvicides, or neither. Again 16 organic "clean" apples were collected from Professor Robert Van Steenwyk's greenhouse. The appropriate concentration of insecticide was applied to each apple slice prior to oviposition. I applied 20 ppm of Chlorantraniliprole following Brunner's study. (Brunner and Doerr 2003) and 1.6 ppm of Methoxyfenozide was applied following Brochert's study. (Brochert, et al 2008) I then examined the efficacy of each surfactant tested. I replicated the same procedural methods but added MSO at 16 oz/100 gal, Silwet -77 at 4 oz/100 gal, and Latron B-1965 at 1 oz/100gal to each apple prior to and after oviposition recommended by Professor Robert Van Steenwyk. The surfactants should increase the adherence of each insecticide to the apple slice, which should increase efficacy.

Techniques of Analysis For an analysis of my data, I followed Brunner's and Brochert's methods of statistical inference. Statistical significance (mean separations) were determined using Statographics (an ANOVA statistical program calculating statistical significance based on p=0.05). I collected data for Chlorantraniliprole and Methoxyfenozide from early Janurary to late April. The first week of February, I determined the larvicidal and ovicidal capabilities of Chlorantraniliprole. I completed the rest of my research concerning Methoxyfenozide in late April. Lastly, I completed the statistical analysis of my data by the end of the month.

Results

Insecticide Mortality Rates Both Chlorantraniliprole and Methoxyfenozide effectively eliminated (greater than 50% mortality) Codling Moth eggs and larvae. The mean mortality rate for Chlorantraniliprole at 20 ppm sprayed before oviposition was 58.5 (n=284, standard deviation=3.89). The mean mortality rate for methoxyfenozide at 19 ppm sprayed after oviposition was 60.8 (n=125, standard deviation=6.68). However Methoxyfenozide had one or more replicates in which the mortality rate was less than 50%. The mean mortality was 47.13 (n=381, standard deviation=13.46). Treatments for which this occurred involved experimenting with either compromised apples (apples that became moldy during the oviposition process) or a malfunctioning incubator.

Table 1. Mortality of *Cydia. pomonella.* exposed to methoxyfenozide at 19 ppm in combination with the surfactant Latron at 0.0625% applied through the dip method (mean mortality=47.13, n=381, standard deviation=13.46).

Total Eggs	Hatched	Not Hatched	% Mortality
88	35	53	60.2
75	33	40	53.3
90	64	26	28.9
128	69	59	46.1

Application Type Does the application type of Chlorantraniliprole and Methoxyfenozide influence the overall effectiveness of each upon Codling Moth? I determined whether the dip method or spray method was more effective for Chlorantraniliprole and Methoxyfenozide. For table 2, I analyzed the mean mortality rates of Chlorantraniliprole application types. For table 3, I analyzed the statistical significance of my findings for chlorantraniliprole using Statographics.

Table 2. A comparison of every possible chlorantraniliprole dip/spray *Cydia pomonella* mortalities (out of 32 possible replicates only 23 can be recorded for dip and 29 for spray either because there were less than ten eggs upon the apple, the apple was moldy and unable to be counted, or the incubator was broken altering my results significantly) (dip standard deviation=13.4, spray standard deviation=9.5).

Rep	% Mortality Through Dip Application	% Mortality Through Spray Application
1	55.6	55.2
2	34.6	35.3
3	47.1	46.0
4	60.0	54.8
5	72.7	48.8
6	61.5	39.3
7	53.3	57.8
8	55.0	42.9

9	54.6	50.0
10	50.0	25.0
11	38.8	47.1
12	35.0	43.3
13	80.0	61.5
14	66.0	61.1
15	57.7	58.2
16	42.5	53.1
17	31.2	34.7
18	42.9	42.1
19	26.7	31.8
20	39.3	53.1
21	44.1	45.5
22	54.3	55
23	38.7	54.6
24		50.0
25		38.8
26		34.9
27		54.6
28		35.5
29		45.5
30		
31		
32		

Table 3. Significance of mortality and mean mortality of *Cydia Pomonella* exposed to chlorantraniliprole applied through the dip/spray method (dip standard deviation=13.4, spray standard deviation=9.5, $p<0.05$=no significance, $p>0.05$=significance).

Application Type	Count	Mean Mortality	Significance
Spray Application	29	46.7	No
Dip Application	23	49.6	Yes

According to my findings, dipping Chlorantraniliprole was statistically more significant ($p>0.05$). My data for Methoxyfenozide differed. I organized my data in a table comparing the dipping of Methoxyfenozide and the spraying of Methoxyfenozide. Out of 32 possible replicates 29 provided usable data for dip and 29 for spray; in other replicates there were less than ten eggs upon an apple slice, the slice was moldy and unable to be counted, or the incubator was broken. According to my findings, efficacy of Methoxyfenozide did not depend upon application type ($p<0.05$).

Table 4. Significance of mortality and mean mortality of *Cydia Pomonella* exposed to methoxyfenozide applied through the dip/spray method (dip standard deviation=16.8, spray standard deviation=10.6, p<0.05=no significance, p>0.05=significance).

Application Type	Count	Mean Mortality	Significance
Spray Application	29	49.4	No
Dip Application	29	55.7	No

Application Timing Does the time of application, prior to oviposition or after oviposition, affect the overall efficacy of the insecticides? On average, mortality was greater if Chlorantraniliprole was applied before rather than after oviposition (table 5) ($p>0.05$). I analyzed the mean mortality rates of Chlorantraniliprole application timings. The mean mortality rate of Chlorantraniliprole application prior to oviposition was 51.6 (before oviposition standard deviation=11.7). The mean mortality rate after oviposition was 42.7 (after oviposition standard deviation=8.6).

Table 5. Significance of mortality and mean mortality of *Cydia Pomonella* exposed to chlorantraniliprole applied before/after oviposition (before oviposition standard deviation=11.7, after oviposition standard deviation=8.6, p<0.05=no significance, p>0.05=significance).

Application Timing	Count	Mean Mortality	Significance
After Oviposition	21	42.7	No
Before Ovipostition	31	51.6	Yes

My findings for methoxyfenozide differed. Out of 32 possible replicates 30 provided usable data before oviposition and 28 after oviposition; in other replicates there were less than ten eggs upon an apple slice, the slice was moldy and unable to be counted, or the incubator was broken. On average, mortality was greater if Methoxyfenozide was applied after rather than before oviposition (table 6) ($p>0.05$). I analyzed the mean mortality rates of Methoxyfenozide application timings. The mean mortality rate of Methoxyfenozide application prior to oviposition was 52.8 (before oviposition standard deviation=9.3). The mean mortality rate after oviposition was 52.3 (after oviposition standard deviation=18.3).

Table 6. Significance of mortality and mean mortality of *Cydia Pomonella* exposed to methoxyfenozide applied before/after oviposition (before oviposition standard deviation=9.3, after oviposition standard deviation=18.3, p<0.05=no significance, p>0.05=significance).

Appliction Timing	Count	Mean Mortality	Significance

After Oviposition	28	52.8	Yes
Before Ovipostition	30	52.3	No

Insecticide with Surfactant I then determined whether surfactants increased efficacy of Chlorantraniliprole (table 7) and Methoxyfenozide. Out of 16 possible replicates 11 provided usable data for the Chlorantaniliprole/Silwet, 14 for Chlorantraniliprole/Latron, 10 for Chlorantraniliprole/MSO, and 16 for Chlorantraniliprole control; in other replicates there were less than ten eggs upon an apple slice, the slice was moldy and unable to be counted, or the incubator was broken (table 7). I analyzed Chlorantraniliprole combined with Silwet, MSO, Latron, and water (the control). The mean mortality rate of Chlorantraniliprole combined with Silwet was 43.9 (silwet standard deviation=9.8), with MSO was 50.6 (mso standard deviation=11.8), with Latron was 45.1 (standard deviation=9.9), and the control was 51.2 (control standard deviation=13.0). Chlorantraniliprole combined with surfactant did not significantly increase efficacy ($p<0.05$). Therefore, mortality did not depend upon the presence of surfactants (table 7).

Table 7. Significance of mortality and mean mortality of *Cydia Pomonella* exposed to chlorantraniliprole combined with surfactant (silwet standard deviation=9.8, mso standard deviation=11.8, latron standard deviation=9.9, control standard deviation=13.0, $p<0.05$=no significance, $p>0.05$=significance).

Surfactant with Chlorantraniliprole	Count	Mean Mortality	Significance
Silwet	11	43.9	No
Latron	14	45.1	No
MSO	10	50.6	No
Control	16	51.2	No

My findings for Methoxyfenozide were similar. Out of 16 possible replicates 15 provided usable data for the Methoxyfenozide/Silwet, 13 for Methoxyfenozide/Latron, 14 for Methoxyfenozide/MSO, and 16 for Methoxyfenozide control; in other replicates there were less than ten eggs upon an apple slice, the slice was moldy and unable to be counted, or the incubator was broken. I analyzed Methoxyfenozide combined with Silwet, MSO, Latron, and water (the control). The mean mortality rate of Methoxyfenozide combined with Silwet was 56.7 (silwet standard deviation=21.8), with MSO was 46.5 (mso standard deviation=9.1, with Latron was 53.1 (standard deviation=13.4), and the control was 51.7 (control standard deviation=10.2).

Methoxyfenozide combined with surfactant did not significantly increase efficacy ($p<0.05$). Therefore, mortality did not depend upon the presence of surfactants.

Discussion

My results indicated that Chlorantraniliprole and Methoxyfenozide were both effective insecticides with mortality rates greater than 50% (tables 4, 5 and 6). Both insecticides targeted Codling Moth before apples were damaged (every mortality rate I recorded concerned deaths before hatching or immediately thereafter). I found Chlorantraniliprole was most effective when I dipped it prior to oviposition (table 3 and 5). Methoxyfenozide was most effective when I dipped or sprayed it after oviposition (table 4 and 6). Chlorantraniliprole or Methoxyfenozide combined with surfactant did not significantly increase efficacy ($p<0.05$) (table 7).

I hypothesized that Chlorantraniliprole and Methoxyfenozide would eliminate 50% or more of Codling Moth eggs and larvae. According to my results, I found the mean mortality rate of Chlorantraniliprole was 50.0 overall (standard deviation=9.7) and the mean mortality rate of Methoxyfenozide was 52.5 overall (standard deviation=13.7). Because $p<0.05$, the two insecticides were not statistically different from one another. And the overall effectiveness of each was 50% or greater.

I then hypothesized that increased mortality rates would reflect the application of each insecticide through dipping rather than spraying. It is understandable that dipping the insecticide is more effective for the apple is exposed to a more concentrated dose of the insecticide. Dipping also ensures that every surface of the apple is exposed to the insecticide while I cannot guarantee that every surface of the apple will be exposed when spraying. I found that mean mortality of Chlorantraniliprole was more significant ($p>0.05$) (table 3). The average mortality of *Cydia pomonella*, when I dipped Chlorantraniliprole was greater (49.6) compared to when I sprayed Chlorantraniliprole (46.7) (table 3), which I hypothesized. On the other hand, I found Methoxyfenozide differed. According to my findings, efficacy of Methoxyfenozide did not depend upon application type ($p<0.05$) (table 4). Therefore when I applied Methoxyfenozide, I did not find a significant increase in mortality between dipping and spraying, which was not what I expected.

I hypothesized that applying the insecticides after oviposition (rather than before oviposition) would increase each insecticide's efficacy. I found that the mean mortality rate of Methoxyfenozide applied after oviposition was greater (52.8) and significant ($p>0.05$) than when

I applied the insecticide before oviposition (52.3) (table 6). On the other hand, I discovered that the mean mortality of Chlorantraniliprole applied before oviposition was much greater (51.6) and significant than when I applied the insecticide after oviposition (42.7) (table 5). My results for Chlorantraniliprole agreed with my hypothesis while my finding for Methoxyfenozide did not agree with my hypothesis. Chlorantraninliprole's effectiveness is derived from the fact that it is a reduced risk insecticide that was designed to target egg development upon ovipostion. (DuPont 2007) Because eggs are most vulnerable when freshly laid, an insecticide already upon the surface of the target apple would most definitely reduce egg development. If Chlorantraniliprole was applied prior to oviposition, a more concentrated dose would be absorbed by the developing egg increasing percent morality. Methoxyfenozide's effectiveness is derived from the fact that it is a more potent insecticide altering the function of a receptor responsible for the insect molting hormone 20-hydroxyecdysone. (Dow AgroSciences 2003) Therefore, Methoxyfenozide targets Codling Moth after the egg and larvae develop and mature. Generally these two insecticides target the developmental stages of *Cydia pomonella*. The difference: one strikes early while the other strikes in the latter half of development

Lastly, I hypothesized that the presence of surfactants would increase the efficacy of each insecticide. I discovered that my results did not follow my hypothesis. There was no statistical significance for Chlorantraniliprole or Methoxyfenozide combined with any of the three surfactants or the control. Although the mean mortality was greatest for Chlorantraniliprole control (51.2) (table 7) and Methoxyfenozide combined with Silwet (56.7), both were not significantly more effective than either in combination with the other three possible surfactants. Although I found a 10% difference between the mean mortality rates of Chlorantaniliprole combined with MSO and Silwet (46.5 and 56.7 respectively) the difference was not significant ($p<0.05$). Chlorantraniliprole (table 7) and Methoxyfenozide combined with surfactants did not significantly increase efficacy ($p<0.05$). Thus, an increase in mortality did not depend upon the presence of surfactants. Maybe a larger concentration of surfactant is needed to make any difference in effectiveness or maybe surfactants work best on other Codling Moth infested crops such pears or walnuts.

Dipping is not a viable solution for farmers because the application method inflates data reported by companies such as DuPont and Dow AgroSciences. Spraying is the practical method of application for it is both cost effective (less active ingredient used) and less time-consuming (covers large plots of land). If using Chlorantraniliprole, farmers should spray apples before ovipostion. If using Methoxyfenozide, farmers should spray apples after oviposition. The appropriate timing at which each insecticide is applied will maximize mean mortality of *Cydia pomonella*.

Limitations When researching Chlorantraniliprole and Methoxyfenozide, I became aware of several limitations that impeded my study. Moth variability was significant. Many of the moths I received differed in sex, age, and hardiness. If I possessed older moths (two weeks or more) when I carried out research on Chloratraniliprole, while using younger ones for research on Methoxyfenozide, a deviance in effectiveness would certainly occur (older moths are more susceptible to exposure). If I received a batch of moths more resistant to insecticide exposure, for their predecessors were previously exposed, I would expect that insecticide to be less effective. During my research, I frequently found the incubator inoperable. I ran a few test trials without the incubator but found my results significantly different. Therefore, I waited frequently while mechanics fixed the machinery on several occasions. Many of the apple slices I used were not sealed properly and became moldy after one to two days. I was forced to throw many of them out because oviposition was impacted.

Confounding Factors As stated previously, the batches of moths I received were highly variable. The mean mortality of Chlorantraniliprole could be significantly smaller due to less resistant moths (old age/no previous exposure) or significantly larger due to more resistant moths (young age/previous exposure). Mean mortality would not be dependent upon the insecticide itself but rather, the general moth hardiness. I added alternated batches of moths to each cage every two days adding 15 to 30 of both females and males per cage to correct for the high variability due to healthy/resistant moths and unhealthy/less resistant moths. I began my experiment with large, green apples and later converted to small, red apples. When examining the number of eggs deposited per apple, I found the small, red apples were more desirable for oviposition. I frequently had egg counts between 10 and 150. On the other hand, the large, green apples had egg counts between 1 and 10. To prevent variability, I continued my experiment only using those small, red apples from the same sack to minimize death from other causes (one batch of apples could be unclean meaning previous pesticide exposure).

Previous Research James F. Walgenbach, a professor from North Carolina State University found that Chlorantraniliprole allowed about 56% of the eggs to hatch when the insecticide was applied at 100ppm insecticide (Walgenbach 2008) At 10 ppm the percentage of eggs that hatched was about 62% while at 1000 ppm about 63% of the eggs hatched. Chlorantraniliprole has an optimum concentration at which it should be applied. My results for Chlorantraniliprole at 100 ppm mimic the results of Walgenbach to determine the optimum concentrantion. At a concentration of 100 ppm, the percentage of eggs that hatched was about 50%. At a concentration of 20 ppm the percentage that hatched was about the same…about 48%. (Walgenbach 2008) This does not agree with Walgenbach's results. As I stated previously, he obtained a different rate of hatching when he applied the insecticide at 10 ppm…62%. Unless the optimal concentration of Chlorantraniliprole lies between 20 ppm and 100 ppm, which it evidently may without further analysis our different procedural methods could have led to such differences concerning the lower concentration ranges of Chlorantraniliprole. Both Walgenbach and I agree that Chlorantraniliprole can reach mortality rates of 50% or more.

Examining Jay F. Brunner's research, I found that the mortality rate of Chlorantraniliprole at 100 ppm was 54.4%, similar to my results. (Brunner 2003) In fact, I based my research off of Brunner's methods of analysis. On the other hand, and increased concentration of 300 ppm actually increased the mortality rate to 71.7%. (Brunner 2003) Brunner also examined the mortality rates of the insecticide at 30 ppm and 10 ppm both being 44.7% and 39.1% where my results displayed a mortality rate of Chlorantraniliprole at 48%. (Brunner 2003) Our results for lower concentrations are close enough where I would agree with his findings. To this point I have been analyzing his findings of insecticides applied after oviposition. His findings concerning eggs on insecticide residues also mimic my results. At 100 ppm, the mortality rate increased to 70.6%. (Brunner 2003) Although my results were not as significant, they do show an increase in mortality rates similar to Brunner's.

Shortcomings My study was very specific examining the Codling Moth and apple interaction. How can this be applied to other pests and other fruits? Other researchers can examine fruits and vegetables such as pears and walnuts (for those crops are frequently susceptible to Codling Moth infestations) and determine whether they produce similar mortality rates to my study. Can Chlorantraniliprole and Methoxyfenozide stop the devastating effects of the weevil? What about the Colding Moth and Walnut interaction? I will continue my research on apples examining two reduced-risk insecticides that have just been released: Spinetoram and Cyantraniliprole. Since I am unsure as to whether Chlorantaniliprole, Methoxyfenozide, Spinetoram, and Cyantraniliprole are effective at targeting the Codling Moth on pears, I will continue my research with pears upon completion of my research on apples.

Crop losses are derived from consumer expectancy of perfect apples placing tremendous pressure upon farmers to keep pests from damaging the crop. Damaged apples do not appeal to consumers, therefore farmers risk financial losses. The continued application of insecticides including organophosphates has led to increased resistance and severe impacts upon non-target species. Reduced-risk insecticides provide the potential to reduce pest populations while exposing little harm to non-target species and the environment. I determined the greatest efficacy potential of two reduced-risk ovicides/larvicides (Chlorantraniliprole and Methoxyfenozide) by altering several factors. I examined the application of each by dipping or spraying, prior to or after oviposition (egg deposition), with or without surfactants. I found Chlorantraniliprole most effective when it was dipped prior to oviposition. I found Methoxyfenozide most effective when it was dipped or sprayed after oviposition. Surfactants did not increase the efficacy of either insecticide. Knowing how to maximize the efficacy of Chlorantraniliprole and Methoxyfenozide will prevent extensive apple losses and reduce financial losses for farmers.

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