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Field Degradation of Insecticides used for Spotted Wing Drosophila in Cherries

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Abstract
The recent introduction of spotted wing drosophila (SWD) into cherry-producing orchards of the western United States has resulted in the need for insecticide-based management programs close to harvest. These treatments have become problematic due to inconsistencies among export markets regarding maximum residue levels (MRLs) that are allowed on imported fruit. As a result, fruit that was treated and harvested in a safe manner according to the U.S. Environmental Protection Agency may or may not qualify for export to countries that have lower MRLs, or in some cases no MRLs at all. This project addresses this issue by evaluating the degradation curves of six insecticides when applied at 21 days to harvest and four insecticides when applied at 7 days to harvest. Results were used to propose treatment programs based primarily on Warrior II, Success and Malathion that would be effective, would allow for the export of fruit, and would incorporate the rotation of chemistries as part of a resistance management program. Data from this project also documented the effects of simulated post-harvest washing on residue levels on fruit at harvest. Generally speaking, residue levels on fruit that were processed had lower residues than fruit harvested directly off of the tree. However, these reductions were not consistent, predicable or significant enough to recommend that growers rely on washing as part of a residue reduction program.

Introduction
Maximum Residue Limits (MRLs) are a measurement of the maximum level of pesticide residues that are allowed on a commodity for human consumption. These levels, commonly referred to as tolerances, are dictated by government organizations in their efforts to ensure that food products are safe to eat.

In the United States, MRLs for all pesticides are established by the U.S. Environmental Protection Agency. Initially, laboratory studies are used to determine the No Effect Level (NOEL). This is the level at which no detectable adverse effects could be detected in a wide range of safety tests. A 100X safety factor is added to the NOEL to account for potential inaccuracies in scaling up research data to human scale. For most products, an additional 10X safety factor is added to account for potential impacts to infants. As a result, tolerances (or MRLs) for treated commodities are typically set at a level at about 1000 times lower than the level that would have a negative impact if the person were to be exposed to normally consumed amounts of a food product (lets say of cherries) on a daily basis for their entire life.

One of the most significant problems with MRLs is that all countries in the world have the right to establish their own levels (Table 1), thus leading to discrepancies on the amount of residues that are tolerated on food imported from other countries. These differences are common as different countries use different datasets and criteria while establishing their own tolerances. This can lead to serious import and export regulations when a pesticide is used on a commodity in one country that has a tolerance, but then is harvested and shipped to another country that has a lower tolerance or has not established a tolerance. The end result is that the normal, allowable, safe use of a pesticide in one country can cause the resulting food product to be rejected from importation into another country.

The recent introduction of spotted wing drosophila (SWD) into cherry-producing areas of the western United States has heightened concerns regarding MRLs for countries that import U.S. cherries. Current management programs for SWD require one or more insecticide treatments within the last few weeks of harvest. The problem is that these treatments, though considered safe according to the U.S. and California Environmental Protection Agencies, have the potential to cause fruit to be rejected when it is shipped to countries where tolerances for residues are not established or are established at levels lower than those in the US. The purpose of this project is to address this issue by improving our understanding of the degradation rates of key insecticides used for SWD so that safe and effective management programs can be developed that still allow for the exportation of fruit.

Materials and Methods

Degradation curve development

Degradation rates of six common insecticides used for spotted wing drosophila were evaluated in two field trials during the spring of 2011. The first trial was located in a mature orchard in the Edison region of Kern County using trees of the variety 'Brooks'. The second trial was conducted in a mature cherry orchard near Arvin, CA using the variety 'Champagne Coral'. From here forward these will be referred to as the Brooks and the Coral trials. Each trial contained five plots that were each sprayed with one or more insecticide treatments at either 21 or 7 days to harvest (Table 2). Plot size in the Brooks trial was three rows wide by 12 trees long, containing at least 12 'Brooks' trees. Plot size in the Coral trial was 1 row wide by 12 trees long, containing at least 6 'Champagne Coral' trees. Applications were made in 100 gal/ac of water using a Pul-Blast (Rear's MFG. Co., Eugene, OR) air blast sprayer. Applications were made to both sides of the trees at a ground speed of 2.5 m.p.h. with the fan set to high. The sprayer was equipped with two nozzles with #6 discs directed towards the center of the canopy and two nozzles with #5 discs directed towards the top and bottom of the canopy, respectively. Each nozzle used DC46 cores and 4514-32 slotted strainers. The bottom and top two positions on the sprayer were equipped with plugs to set them in the off position.

For treatments made 21 days to harvest, residue samples were collected one hour prior to treatment and then 0, 3, 7, 14, and 21 days after treatment (DAT). Data for the 0 DAT evaluation were collected after residues had dried within 2 hours after application. For treatments made 7 days to harvest, residue samples were collected one hour before treatment and then 0, 1, 2, 3 and 7 days after treatments. For each evaluation approximately 300 g of cherries from each plot were collected, counted and weighed; a subset of 30 cherries was also measured for fruit diameter. Samples were placed into insulated shipping containers with ice-packs and sent via overnight shipping to PrimusLabs™ (Santa Maria, CA).

Samples were all processed the day of arrival at PrimusLabs™ according to standard residue testing protocols that are outlined in the U.S. Food and Drug Administration Pesticide Analytical

Manual (PAM). Residue levels for spinosad and spinetoram were determined through extraction by liquid-liquid partitioning with methylene chloride followed by reversed-phase high-performance liquid chromatography (HPLC) with ultraviolet (UV) detection to a lower detection limit of 0.05 ppm (Li-Tain et al, 1997). Additional insecticides were extracted according to FDA LIB 4178 (Luke et al) and quantified to a level of 0.01 using electrolytic conductivity (ELDC) detectors and gas chromatograph mass spectrometers (GC-MS) for zeta-cypermethrin and lambda-cyhalothrin, flame photometric (FPD) and pulsed-flame photometric (pFPD) detectors for malathion, or thermionic specific detector (TSD) and gas chromatograph-mass spectrometers (GC-MS) for fenpropathrin.

Effects of post-harvest processing on residue levels
The effects of hydrocooling and fruit processing on pesticide residues were evaluated at the Brooks and Coral research sites by testing for residues on fruit prior to and after simulated packing procedures. On 28 Apr cherry samples were collected from plots that had been treated with Danitol, Warrior II and Mustang on 15 Apr (13 days after treatment) and from plots that had been treated with Danitol, Malathion, Delegate and Success on 26 Apr (2 days after treatment). Two 300 g samples were collected from each plot at approximately 10:00 hrs. The first sample from each plot was placed in a cooler with ice packs and was shipped overnight directly to PrimusLabs™ for residue testing. The second sample from each plot was left in ambient temperatures of approximately 70°F for four hours to simulate post-harvest field conditions. Cherries were then placed into a bucket of water at 50°F for 5 minutes to simulate hydrocooling in the field. They were then placed into a walk-in cooler at 40°F to simulate shipping and overnight storage. Ideally these temperatures would have been closer to 50°F, but a 40°F cooler was all that was available. In the morning at approximately 08:00 hrs the cherries were removed from cold storage and dumped for 4 minutes into 50°F water to simulate a dump tank at a packing facility, after which they were transferred into 38°F water for 6 minutes to simulate hydrocooling. Then they were placed into storage in a 40°F cooler for one hour, after which they were packaged into insulated shipping containers and sent via overnight shipping for residue testing at PrimusLabs™.

Results

Application and environmental conditions
Field trials were successfully established at both the Brooks and Coral orchards in Kern County, CA. During the length of the trial environmental conditions were fairly typical for weather in Kern County during the three weeks prior to harvest (Table 3). High temperatures were typically in the mid-70s with lows in the mid-40s to mid-50s. Weekly averages for solar radiation ranged from 612 to 739 langleys per day. Daily average relative humidity ranged from 71.8 to 85.9% for the daily high and between 21.8 and 41.4% for the daily low, and there was no rain.

The first set of applications was made on 15 Apr at approximately 21 days to harvest. At the time of application fruit size averaged 19.0 mm for the Brooks trial and 14.0 mm for the Coral trial (Table 4). Average fruit weight was 3.77 g for the Brooks and 1.87 g for the Coral. After applications were made, fruit size and diameter consistently increased. By harvest, Brooks fruit averaged 28.0 mm and weighed 9.95 g whereas Coral fruit averaged 21.7 mm and 5.24 g. These data are important due to the way residue evaluations are collected. For example, in the case of the Brooks trial, 300 g of fruit at the time of application would have consisted of approximately 80 cherries whereas a 300 g sample at harvest required only 30 fruit. As a result, simple math would suggest that residue levels over a 21-day period should be reduced by just over one half simply because less than half the number of cherries were included in a 300 g sample. These data, though not discussed as part of the remaining results and conclusions, are listed in Table 3 as a reference for anybody who has an interest in doing additional manipulation of the data that requires knowledge of changes in fruit size and weight.

Degradation curve development

Applications of the spinosyns Delegate and Success resulted in relatively low residue levels that degraded quickly (Tables 5, 6; Figures 1, 2). When applied 21 days to harvest, residue levels for both insecticides ranged from 0.06 to 0.19 ppm during the evaluations at 0 and 3 DAT. At the current pre-harvest interval of 7 days the residue levels at both research sites and both insecticides were below the lower detection threshold of 0.05 ppm. When applications of Delegate and Success were made 7 days to harvest, similar results were found with residue levels ranging from non-detectable to 0.09 ppm through three days after treatment, followed by levels below the minimum detection level for both products at both sites by the pre-harvest interval of 7 days.

Applications of Malathion at 21 and 7 days to harvest at the 1.5 pt/ac rate (which is lower than the maximum label rate due to risk of phytotoxicity) resulted in residue levels that ranged from non-detectable to 0.12 ppm through 2 DAT and from non-detectable to 0.06 ppm at the pre-harvest interval of 3 DAT (Tables 5, 6; Figure 6). These levels were below the 2011 MRLs for the U.S., Canada, Japan, Korea, Taiwan and Australia (range from 0.50 to 8.0 ppm), but were in some cases still above the MRL of 0.02 ppm for the EU (Table 1). By 7 DAT residue levels for Malathion ranged from non-detectable to 0.02 ppm.

Residue levels for pyrethroids (Tables 5, 6; Figures 3-5) were more variable among treatments than for spinosyns and had relatively long residuals. Applications of Danitol produced the highest residue levels and had the slowest degradation. When applied 21 or 7 days to harvest, Danitol residue levels at the pre-harvest interval of 3 days ranged from 0.89 to 2.93 ppm. These numbers are comfortably within the U.S. and Japanese 2011 MRLs for fenpropathrin (5.0 ppm), but exceed tolerances for Canada (0.10 ppm), Korea (0.50 ppm), Taiwan (0.50 ppm) and the EU (0.01 ppm). Australia does not have an MRL established. Residue levels at both research sites remained above the MRLs for Korea, Taiwan, the EU and Australia on all evaluation dates 7, 14 and 21 DAT.

Applications of Mustang at 21 days to harvest resulted in residue levels ranging from 0.08 to 0.23 ppm from the time of application through 7 DAT (Tables 5, 6; Figure 4). At the pre-harvest interval of 14 days residue levels ranged from 0.09 to 0.11 ppm. This is comfortably within the U.S., Japan and EU MRLs that range from 1.0 to 2.0 ppm, but is about equivalent to the Canada default MRL of 0.1 ppm and above the Australian MRL of 0.01 ppm. Korea and Taiwan do not have MRLs established for zeta-cypermethrin, such that any residues would disqualify fruit from these markets. By 21 DAT residue levels ranged from 0.02 to 0.05 ppm, which would have qualified fruit for all major markets where MRLs exist except for Australia, but would still disqualify fruit from Korea and Taiwan where tolerances are not established and default MRLs do not exist.

Applications of Warrior II at 21 days to harvest resulted in residue levels ranging from 0.10 to 0.31 ppm from the time of application through 7 DAT. At the pre-harvest interval of 14 days residue levels ranged from 0.08 to 0.11 ppm. These levels were approximately one-half to one-fifth lower than the 2011 MRLs for all major export markets (0.20 to 0.50 ppm).

Effects of post-harvest processing on residue levels
Simulated post-harvest processing had variable results on residue levels (Table 7). Of the six pyrethroid samples tested thirteen days after application, Danitol residues were decreased by an average of 22.0%, Warrior residues were decreased by an average of 15.7% and Mustang levels were increased by an average of 5.6%. Simulated processing two days after application of Danitol resulted in an average reduction of just over half of the residues (51.7%) whereas changes in residue levels for Delegate, Success and Malathion could not be determined due to one or both residue levels being below the minimum detection levels of 0.01 (Malathion) or 0.05 (Delegate and Success).

Overall these data suggest that post-harvest processing can wash some residues from treated fruit. However, differences in the percentage reductions among Danitol (22.0%), Warrior (15.7%) and Mustang (5.6% increase) suggest that the amount of residues that can be washed varies among pesticides. Additionally, comparisons of the percentage residue reductions for Danitol thirteen days after application (22.0%) compared to Danitol two days after application (51.7%) suggests that the ability to wash residues from fruit changes over time. The net result is that cherry producers can make a general assumption that post-harvest processing is going to likely help reduce pesticide residues, especially when residues are initially high. However, the high variability in the results of this study suggest that making predictions about residue reductions will be sufficiently complex that growers should rule out post-harvest reductions as a reliable method for ensuring that fruit does not exceed residue tolerances. Growers need to continue ensuring that residue levels are below MRLs for intended markets at the time of picking and prior to processing.

Conclusions

Current management programs for SWD are based on three general types of treatments. These are long-residual products with PHIs of at least 14 days, middle-range products with a 7 to 10 day PHI, and products for use close to harvest with a PHI not to exceed three days.

Long-residual products are those that are typically applied at the initiation of the straw stage of development when fruit becomes susceptible to attack by SWD. Of the products tested, Danitol, Mustang and Warrior II all had relatively long residuals. Of these Warrior II has the best overall profile as a long-residual product whose application resulted in residue levels in this study that were below the MRLs of all major export markets for cherries. Data also suggest that growers who export fruit should avoid the use of Danitol; Mustang use should be avoided on fruit that is for export to Canada, Korea and Taiwan.

Of the middle-range products for use 7 to 10 days to harvest, Delegate and Success both produced residue levels below the lower detection limit of 0.05 ppm at the PHI of 7 DAT. This suggests that either insecticide is equally valuable for use. However, between these two products Success has a better MRL profile of 0.05 to 1.00 ppm for major export markets whereas MRLs for Delegate include a default MRL in Canada of 0.01 ppm while for Taiwan no MRLs have been established such that any detection would disqualify fruit.

Malathion and Danitol are the only two insecticides in our study that have PHIs of 3 days or less. At a use rate of 1.5 pt per acre residue levels for Malathion in our studies were low enough to allow for the export of fruit to all major export markets with the exception of the EU. Growers planning on shipping fruit to the EU should probably avoid Malathion because residue levels in our trials, even at 7 days after treatment, were still close to the EU MRL of 0.02 ppm. In weighing their options these growers might also consider the use of permethrin or pyrethrin, which are considered to have very short residuals, but were not tested as part of this project.

When all things are considered, data from this project can be used to outline potential spray programs that should be effective for SWD and still allow for the export of fruit. For example, areas requiring three insecticide applications could consider using Warrior II at the initiation of straw, followed by an application of Success 7 to 14 days to harvest, and followed by an application of Malathion 3 to 7 days to harvest. This should allow fruit to be shipped to all major export markets with the possible exception of the EU (depending on how quickly Malathion residues degrade). In areas where only two applications are needed, the second and third applications described above could be combined into one application of either Success or Malathion around 7 days to harvest (with the same concern as previously listed). As needed, additional applications of Malathion and or permethrin or pyrethrin (not tested) would be the most likely candidates for treatments between harvests.

When organized in the manner described above growers should be able to successfully treat for SWD and do so in a manner that utilizes multiple modes of action as part of a resistance management program while still allowing fruit to qualify for key export markets. However, because of the complexity of treatment programs for SWD and the potential for residue-based export restrictions of fruit, growers should develop plans for SWD management well before harvest. Plans should be made only after consulting with representatives of the packing house and should include multiple options for control programs depending on where the fruit will be shipped. They should also be flexible enough to account for one or more treatments based on in-field monitoring programs.

Growers should also be conservative while estimating how data from this project relate to their individual orchards. This is because residue levels are dependent on many factors such as equipment type, application type, water volume, drive speed, rate used, tree size, canopy density, exposure to sunlight, precipitation, etc. It is important to remember that this project only represents two orchards in Kern County during the 2011 harvest season, and results are expected to vary among locations throughout the western United States.

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Disclaimer

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Table 1. Pesticide MRLs for six SWD insecticides in major U.S. cherry export markets for the 2011 season[1].

Trade Name	Common Name	US MRL (ppm)	Canada MRL (ppm)	Japan MRL (ppm)	South Korea MRL (ppm)	Taiwan MRL (ppm)	EU MRL (ppm)	Australia MRL (ppm)
Danitol	Fenpropathrin	5.00	0.10	5.00	0.50	0.50	0.01	-
Delegate	Spinetoram	0.20	0.20	0.01	0.10	-	0.05	0.20
Malathion	Malathion	8.00	6.00	6.00	0.50	0.50	0.02	2.00
Mustang	Zeta-cypermethrin	1.00	0.10	2.00	-	-	2.00	0.01
Success	Spinosad	0.20	0.20	0.20	0.05	0.20	1.00	1.00
Warrior II	Lambda cyhalothrin	0.50	0.20	0.50	0.50	0.40	0.30	0.50

[1]Source: Excerpt from a California Cherry Advisory Board internal memo dated March 18, 2011, based on the CCAB's Online Export Manual: http://www.calcherry.com/industry. Since MRLs change frequently be sure to check for updated and current MRLs prior to shipping fruit to export markets.

Table 2. Insecticides tested, rates and timing of application

Plot #	Insecticide	Formulation	Manufacturer	Active ingredient	Rate form. prod. per acre[1]	A.i. per acre (lbs.)	App. date (days to harvest)
1	Danitol®	2.4EC	Valent	Fenpropathrin	21 1/3 fl	0.40	15 Apr 2011 (21)
	Warrior II	2CS	Syngenta	λ-cyhalothrin	2.56 fl oz	0.04	
	Mustang®	1.5EW	FMC	Zeta-cypermethrin	4.3 oz	0.05	
2	Delegate™	25WG	Dow	Spinetoram	7 oz	0.11	
	Success®	2SC	Dow	Spinosad	8 fl oz	0.12	
3	Malathion	8 Aquamul	Loveland	Malathion	1.5 pt	1.50	
4	Danitol®	2.4EC	Valent	Fenpropathrin	21 1/3 oz	0.40	26 Apr 2011 (7)
	Malathion	8 Aquamul	Loveland	Malathion	1.5 pt	1.50	
5	Delegate™	25WG	Dow	Spinetoram	7 oz	0.11	
	Success®	2SC	Dow	Spinosad	8 fl oz	0.12	

[1]With the exception of Malathion, application rates were defined as the highest rate allowable per the pesticide label. Due to the risk of phytotoxicity the Malathion rate was lowered to a level that is generally considered to be effective on SWD, but that minimizes the risk of damaging the leaves and fruit.

Table 3 Environmental conditions[1] from the time of application to harvest

Application date	Weather data collection dates	Daily Average					
		Temperature (°F)		Solar Radiation (Ly)	Precip-itation (in)	Relative Humidity (%)	
		High	Low			High	Low
15 Apr (~21 days to harvest)	15 Apr to 21 Apr	74.3	55.7	612	0.0	85.9	41.4
	22 Apr to 28 Apr	73.8	47.0	660	0.0	80.9	32.1
	29 Apr to 5 May	80.7	47.6	690	0.0	72.6	23.5
26 Apr (~7 days to harvest	26 Apr to 28 Apr	74.3	46.3	738	0.0	78.0	31.2
	29 Apr to 2 May	75.3	44.3	709	0.0	71.8	21.8

[1]Estimated environmental data retrieved from the Arvin CIMIS weather station within 12 miles of both research orchards. Air temperature and relative humidity are a daily max/min measured at 1.5m. Solar radiation is the daily global radiation measured by Licor pyranometer at 2m.

Table 4 Physical characteristics of fruit used for residue analysis

Application date	Eval-uation date	Days after treatment	Brooks		Coral	
			Avg. maximum diameter (mm)	Average fruit weight (g)	Average maximum diameter (mm)	Average fruit weight (g)
15 Apr (~21 days to harvest)	15 Apr	0[1]	19.0 ± 1.4	3.77 ± 0.22	14.0 ± 1.4	1.87 ± 0.20
	18 Apr	3	20.6 ± 1.7	4.52 ± 0.38	14.6 ± 1.4	2.19 ± 0.39
	22 Apr	7	22.7 ± 1.6	5.94 ± 0.43	17.0 ± 1.6	2.77 ± 0.47
	29 Apr	14	27.7 ± 1.7	8.90 ± 0.84	21.1 ± 1.6	4.67 ± 0.35
	6 May	21	28.0 ± 2.0	9.95 ± 0.48	21.7 ± 1.9	5.24 ± 0.47
26 Apr (~7 days to harvest	26 Apr	0[1]	25.0 ± 1.9	7.16 ± 0.26	17.6 ± 1.1	3.27 ± 0.22
	27 Apr	1	25.9 ± 1.4	8.36 ± 0.61	19.7 ± 1.6	3.80 ± 0.30
	28 Apr	2	26.3 ± 2.0	8.54 ± 0.73	20.0 ± 1.6	4.22 ± 0.06
	29 Apr	3	27.7 ± 1.7	8.90 ± 0.84	21.1 ± 1.6	4.67 ± 0.35
	3 May	7	26.2 ± 2.3	8.85 ± 0.21	21.6 ± 1.7	5.29 ± 0.07

[1]Cherries collected between 2 and 3 hours after treatment.

Table 5. Residue levels following insecticide applications approximately 21 days to harvest

Insecticide	Residue levels (ppm)				
	0 DAT	3 DAT	7 DAT	14 DAT	21 DAT
Delegate	0.14-0.12	0.06-0.08	ND[1] to ND	ND to ND	
Success	0.18-0.19	0.07-0.10	ND to ND	ND to ND	
Warrior II	0.29-0.30	0.19-0.31	0.10-0.12	0.08-0.11	0.05-0.07
Mustang	0.21-0.23	0.09-0.14	0.08-0.12	0.09-0.11	0.02-0.05
Danitol	1.96-1.99	1.61-2.93	1.18-2.10	0.75-1.22	0.54-0.69
Malathion	0.04-0.11	ND-0.06	ND-0.02	ND to ND	

[1]Not detectable at a lower detection level of 0.01 (Malathion) or 0.05 (Delegate and Success)

Table 6. Residue levels following insecticide applications approximately 7 days to harvest

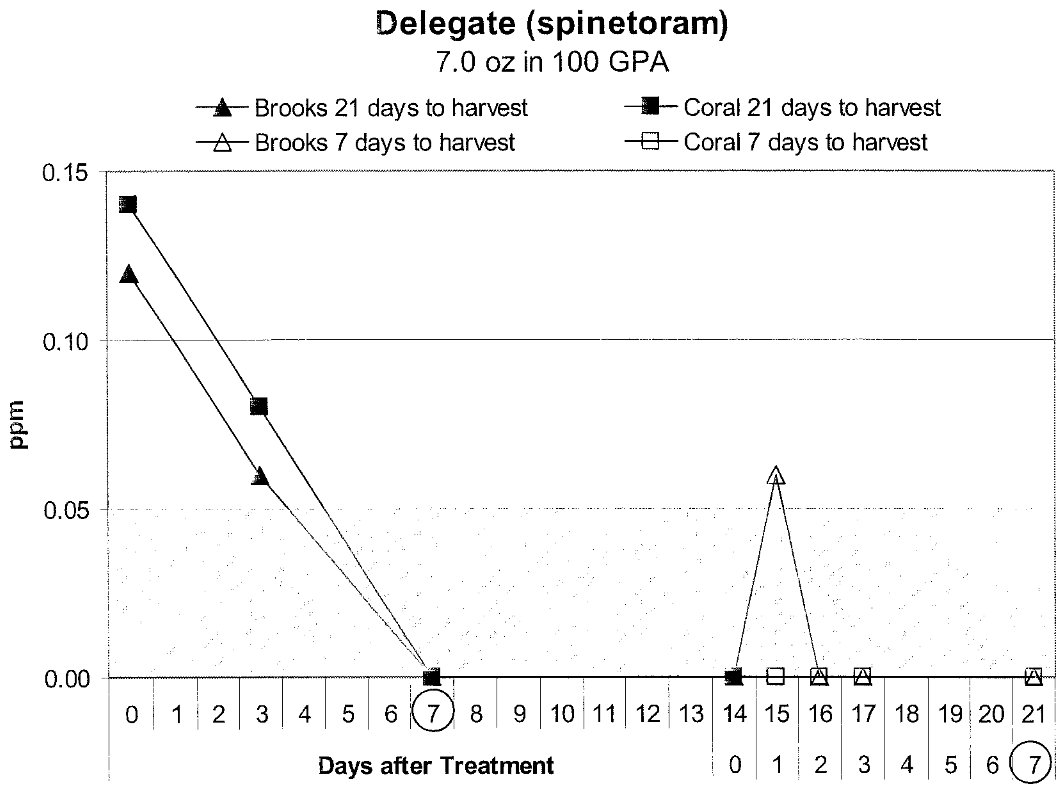
Insecticide	Residue levels (ppm)				
	0 DAT	1 DAT	2 DAT	3 DAT	7 DAT
Delegate	ND[1]-ND	ND-0.06	ND-ND	ND-ND	ND-ND
Success	ND-ND	ND-ND	0.06-0.08	0.05-0.09	ND-ND
Danitol	0.93-1.32	1.02-1.96	1.16-1.74	0.89-1.72	0.76-1.86
Malathion	0.04-0.12	0.04-0.05	ND-0.03	ND-0.01	0.01-0.01

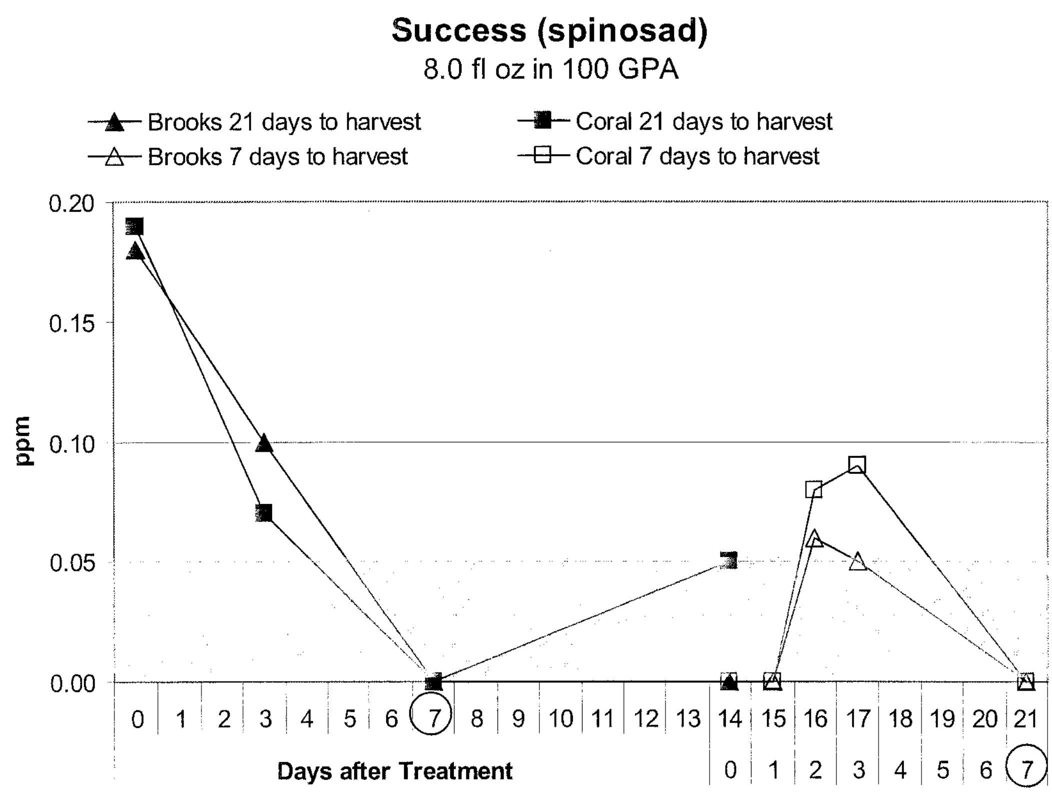
[1]Not detectable at a lower detection level of 0.01 (Malathion) or 0.05 (Delegate and Success)

Table 7. The effects of simulated post-harvest processing on residue levels.

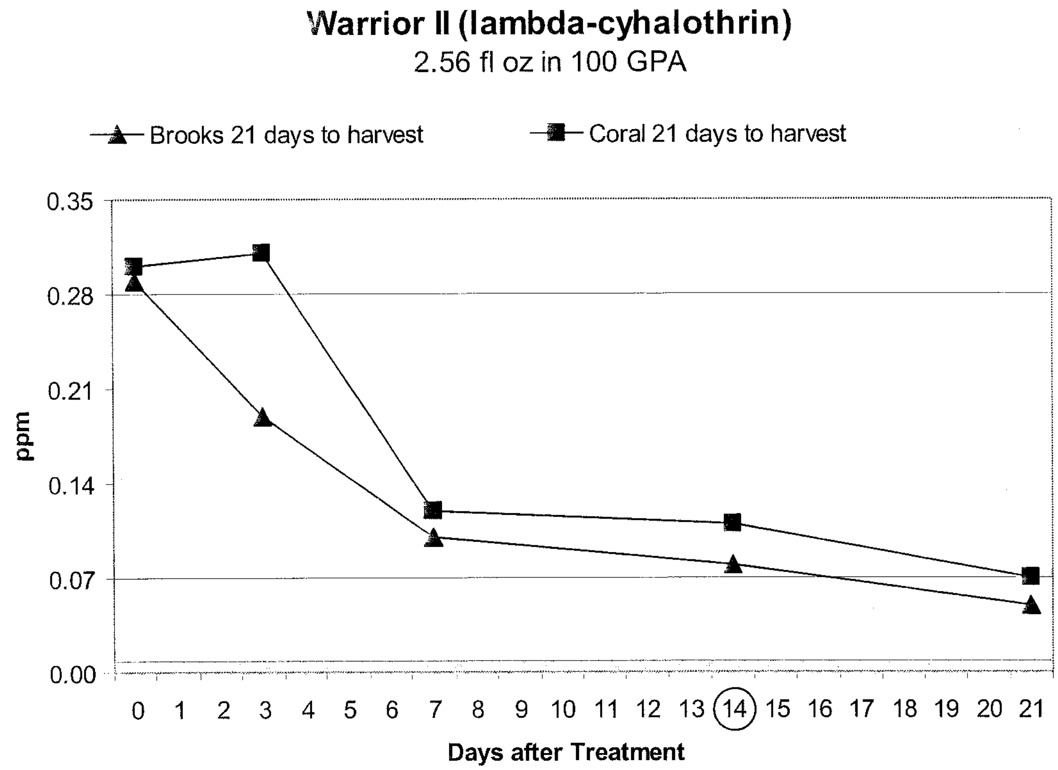
Insecticide	Days after application	Site	Residues		Difference	
			Initial	After simulated processing	Ppm	Change (%)
Danitol	13	Brooks	1.07	0.78	-0.29	-27.1
	13	Coral	1.13	0.94	-0.19	-16.8
Mustang	13	Brooks	0.08	0.08	+0.00	+0.0
	13	Coral	0.09	0.10	+0.01	+11.1
Warrior	13	Brooks	0.12	0.11	-0.01	-8.3
	13	Coral	0.13	0.10	-0.03	-23.1
Danitol	2	Brooks	1.16	0.64	-0.52	-44.8
	2	Coral	1.74	0.72	-1.02	-58.6
Delegate	2	Brooks	N.D.[1]	N.D.	Unk[2].	Unk.
	2	Coral	N.D.	N.D.	Unk.	Unk.
Malathion	2	Brooks	0.03	N.D.	Unk.	Unk.
	2	Coral	N.D.	0.01	Unk.	Unk.
Success	2	Brooks	N.D.	N.D.	Unk.	Unk.
	2	Coral	N.D.	N.D.	Unk.	Unk.

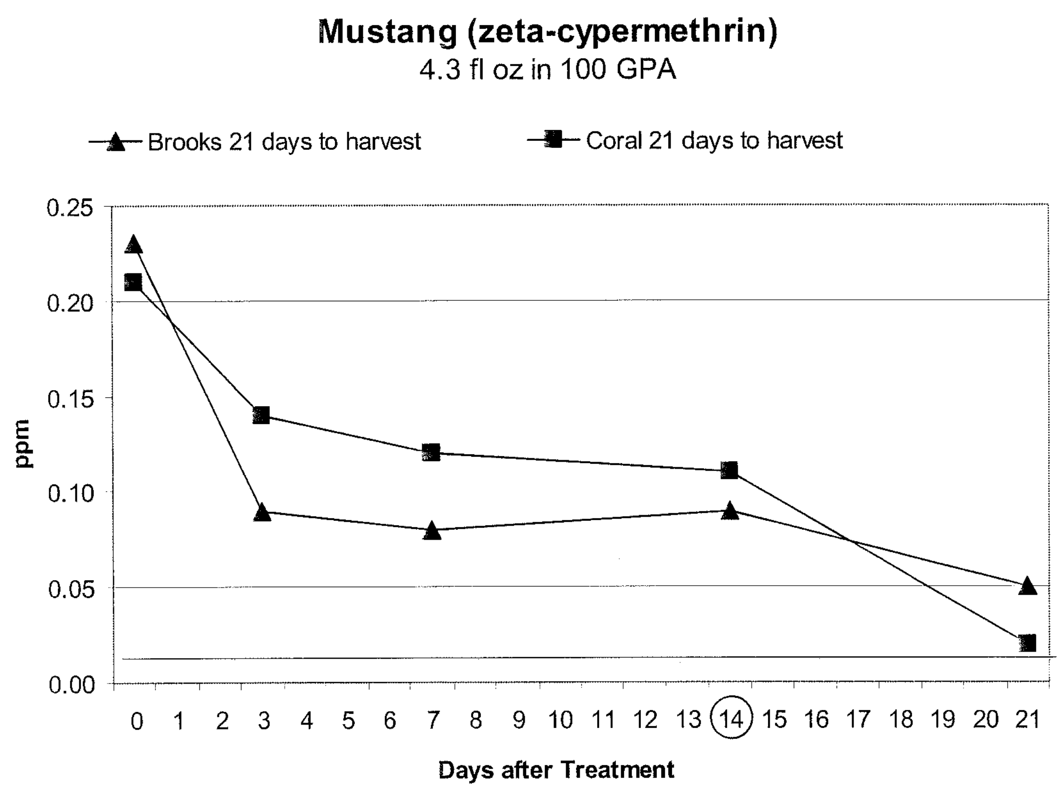
[1] Not detectable at a lower detection level of 0.01 ppm (Malathion) or 0.05 (Delegate and Success).
[2] Unknown. It is not possible to calculate a percentage change from a value defined as less than the minimum detection level.



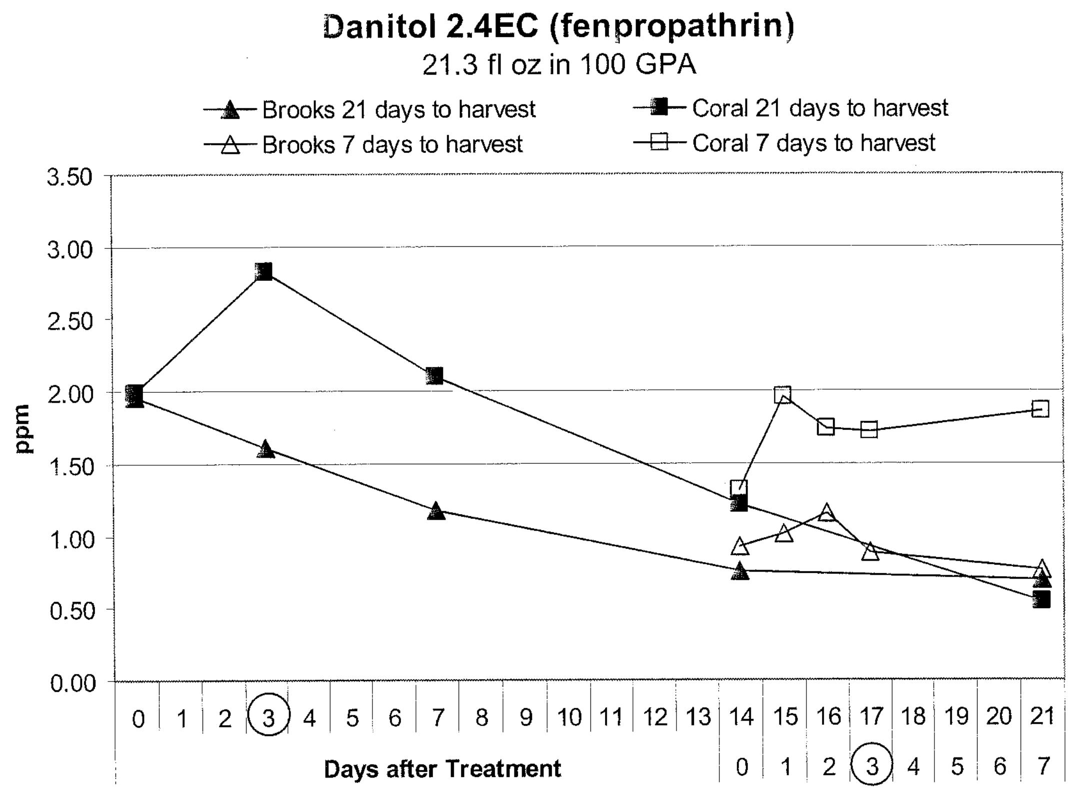


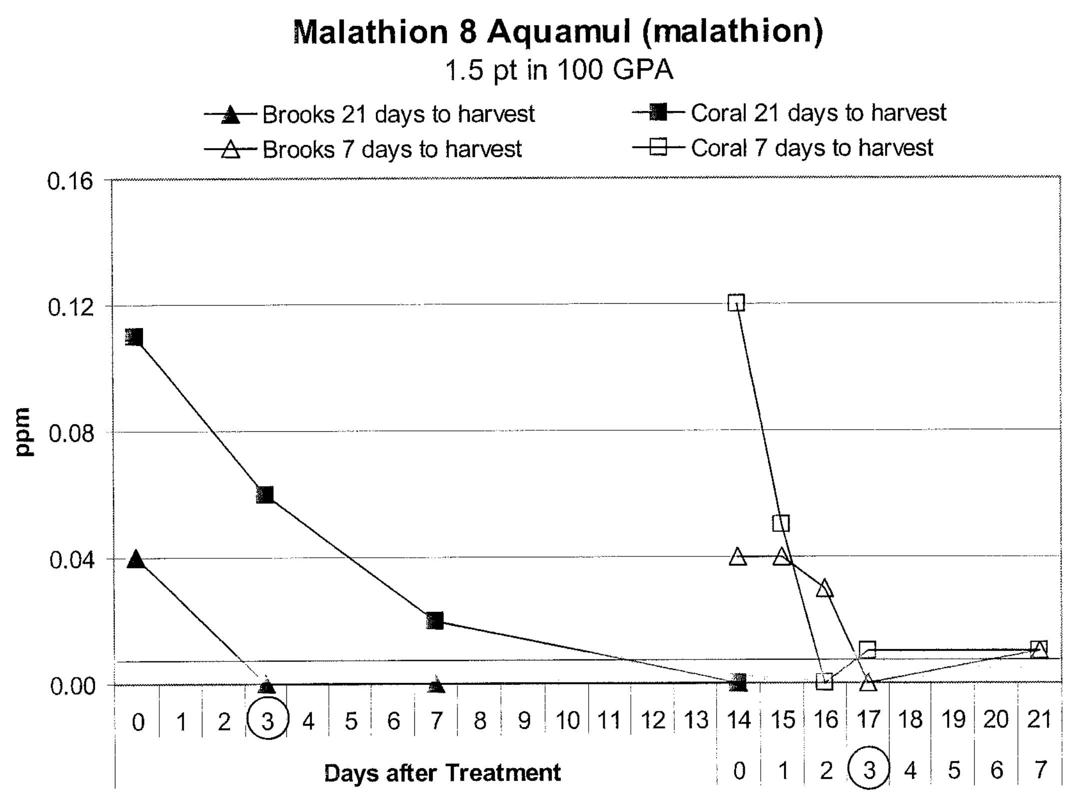
Figures 1, 2. Residue levels of Delegate and Success following applications at 21 and 7 days prior to harvest. Residue levels of non-detectable are reported a zero residues even though actual residue levels may be anywhere between 0.0 ppm and the minimum detection threshold of 0.05 ppm (indicated by the shaded area). Circled dates indicate pre-harvest interval (PHI).





Figures 3, 4. Residue levels of Warrior II and Mustang following applications at 21 and 7 days prior to harvest. Residue levels of non-detectable are reported a zero residues even though actual residue levels may be anywhere between 0.0 ppm and the minimum detection threshold of 0.01 ppm (indicated by the shaded area). Circled dates indicate pre-harvest interval (PHI).





Figures 5,6. Residue levels of Danitol and Malathion following applications at 21 and 7 days prior to harvest. Residue levels of non-detectable are reported a zero residues even though actual residue levels may be anywhere between 0.0 ppm and the minimum detection threshold of 0.01 ppm (indicated by the shaded area). Circled dates indicate pre-harvest interval (PHI).