Insecticide Degradation vs SWD Population Dynamics in Northwest Washington Blueberry

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INTEGRATED RESISTANCE MANAGEMENT OF SWD IN BLUEBERRIES

1. Monitor fields and surrounding area with traps after fruit reaches 'red back' stage.
2. If SWD is detected, treat crop with registered insecticide.
3. Strategy for IRM is founded on the effective use of alternative sequences or rotations of insecticides possessing different mode of actions (MOA). Complete coverage of the canopy is important.
4. Evaluate your management program by monitoring for presence of flies with traps.
5. Sample fruit for larval infestation using the zip-lock bag and salt-water solution method.
6. The label is the law. Be cognizant of REI, PHI and MRLs for export markets due to disparity between import tolerances.

FIELD PROTOCOL

Trials were conducted at WSU NWREC on 8 year-old 'Duke' blueberries. Four bush, unreplicated plots were randomly selected in four rows. Treatments were applied with a CO_2 backpack sprayer equipped with a 36" boom arranged with 2- 8002VS nozzles centrally spaced 18" apart with 2, 12" drop tubes each equipped with an 8002VS nozzle directed at right angles toward the bush. The boom was operated to deliver 100 gal/ac at 40 psi. Seven treatments were insecticides registered for use in WA and three were non-labeled insecticides. All treatments contained methylated seed oil adjuvant at 0.0025 v/v. Water volumes of 40 to 100 gpa for these foliar applications are common and dependent on plant size and amount of canopy foliage present. The treatments were applied to mature leaves on 11 September 2012. Two top canopy leaves were taken at different daily intervals from each bush to 14 days after treatment (DAT). The two leaf samples per bush were placed in 100x20 mm Petri dishes with a 0.5" moistened cotton dental wick and 5 mm^3 of diet media. Five even-aged spotted wing drosophila (SWD) adults were added to the Petri dish arenas from our lab colony. Mortality was evaluated after 24 hours.

Contact with treated blueberry foliage is the primary method of intoxication by the flies. Canopy foliage provides larger surface areas for high-pressure sprayer coverage that can mitigate resting and feeding sites for adults between their egg-laying activities. We feel the leaf bioassay is a more accurate technique compared with ripening berries for assessing commercial control when applying dilute rates of SWD protective sprays by ground equipment to blueberries. Our field and lab bioassays of treated blueberry fruit reflected the difficulty of achieving good coverage on blueberry fruit clusters that are located in the center of the bush where SWD adults prefer the

shady microenvironments. Contact coverage within the canopy of blueberry is critical for precise and rapid knockdown of female SWD seeking ripening fruit. After calibrating output of one's high-pressure sprayer, evaluate spray distribution throughout the canopy of the bush by placing 1 inch^2 water sensitive paper at different angles and positions on leaves/twigs with paper clips. Run your water filled sprayer by several bushes at standard sprayer speed and known pressure to acquire a visual image of droplet densities and penetration into the canopy.

Labeled insecticides evaluated for SWD control on blueberries for Washington included: Brigade WSB (bifenthrin) @ 16 oz/acre (0.1 lb(AI)/acre); Danitol 2.4 EC (fenpropathrin) @ 16 fl oz/acre (0.4 lb(AI)/acre); Mustang Max (zeta cypermethrin) @ 4 fl oz/acre (0.025 lb(AI)/acre); Entrust 2SC (spinosad) @ 6.4 fl oz/acre (0.01 lb(AI)/acre); Malathion (malathion) 8 @ 32 fl oz/acre (2.0 lb(AI)/acre); Delegate WG (spinetoram) @ 6 oz/acre (0.094 lb(AI)/acre) and Lannate LV @ 24 fl oz/acre (0.45 lb(AI)/acre). ***Unlabeled insecticides*** trials were: Endigo ZC (lambda-cyhalothrin, thiamethoxam) @ 4.5 fl oz/acre (0.08 lb(AI)/acre) lambda-cyhalothrin, (0.05 lb(AI)/acre) thiamethoxam; Leverage 360 (ß-cyfluthrin, imidacloprid) @ 3.2 fl oz/acre (0.025 lb (AI)/acre) ß-cyfluthrin, (0.125 lb(AI)/acre) imidacloprid) and Warrior II (lambda-cyhalothrin) @ 1.92 fl oz/acre (0.03 lb(AI)/acre).

RESULTS

We used a provisional 90% mortality threshold to compare our treatments with each other for daily residual activity that extended to 14 DAT (Table 1). Field aging residues at 7 DAT showed the pyrethroids Danitol, Mustang Max, Warrior II and combination product Leverage 360 exceeded the threshold, followed by Brigade (87.5%) and Endigo (89.7%) (Table 1). Longevity for pyrethroid residues on blueberry has been reported for other woody perennial plants such as roses. The incorporation of a MSO surfactant may have provided enhanced residual extension compared with our standard incorporation of the non-ionic surfactants R-11 and R-56.

The average mortality responses we observed from adult SWD exposed for 24 hr to maximum field rates of insecticides on blueberry foliage (Table 1) were used to construct Table 2. The effective residual activity periods shown will provide the user with a guide to prepare his/her individualized insect resistance management (IRM) program well in advance of the fruiting season. Once SWD spray protection has begun, current wisdom dictates rotations to different mode of action insecticides based on their respective 5-7 day retreatment intervals (Table 3). Individual IRM programs will be affected by the variable ripening periods for the grower's cultivar(s) and prospective international markets predicated on each country's MRL tolerances. Current research recommends applying the full label rate for each insecticide chosen until researchers develop efficacy data to determine rational rates resulting in zero larval pack-out for domestic and export markets. The exceptional efficacy, long residual, 3 day PHI and concurrence of MRL tolerances for Danitol (e.g., Canada, Japan, Taiwan) makes it advisable to work it in early or late in a rotation to meet its 2 applications/year restriction. This allows protective coverage during early, extended SWD trickle-in migration and late fruiting cultivars. The example spray program (Table 4) provides 66 days of contact coverage during the relative ripening periods for late-season highbush cultivars grown in Central Willamette Valley, OR,

2012. The same cultivar grown in northwestern Washington would begin harvest about two weeks later, in early August, for 1st generation SWD and 2nd generation emerging in early September.

Table 1. Bioassay efficacy of field-aged insecticides on blueberry foliage on adult SWD, 2012

Treatment/form	Rate form/acre	Percent Mortality									
		1 DAT	2 DAT	3 DAT	6 DAT	7 DAT	8 DAT	9 DAT	10 DAT	13 DAT	14 DAT
Brigade WSB	16 oz	95a	100a	71.7ab	90a	87.5b	86.7a	76a	83.1ab	70.8ab	74.4bc
Danitol 2.4EC	16 fl oz	100a	100a	70.4ab	100a	95ab	92.3a	82a	95a	83.1a	95a
Mustang Max	4 fl oz	100a	100a	43.8cd	90a	91.4ab	70ab	80.2a	20d	75a	5.6d
Warrior II	1.92 fl oz	95a	93.8a	50bcd	87.9ab	100a	83.1ab	76.7a	64.6bc	80.6a	85ab
Malathion 8	32 fl oz	100a	100a	77.5a	64.6b	0c					
Delegate WG	6 oz	62.5bc	35.8b	3.6e	7.1c	0c					
Entrust 2SC	6.4 fl oz	24.1de	9.8c	5e	5c	0c					
Lannate LV	24 fl oz	42.5cd	34.2b	10e	6.3c	0c					
Endigo ZC	4.5 fl oz	78.1ab	100a	38.3d	95a	89.7ab	69.2ab	21.7b	48.1c	45b	57.1c
Leverage 360	3.2 fl oz	83.9ab	95a	65abc	95a	91.9ab	60.6b	90.8a	96.9a	80.2a	100a
Untreated check		5e	0c	0e	0c	0c	0c	0c	0d	0c	0d

Means within columns followed by the same letter are not significantly different by Fisher's Protected LSD, $P<0.05$), PRC ANOVA SAS.

In order for small fruit growers to control SWD at zero tolerance, the industry has had to replaced the IPM practice of timing control applications based on population sampling by coupling IRM practices that protect fruits at the onset of ripening with reginal or first-in-fied detection of SWD with apple cider vinegar or sugar-yeast charged monitoring traps. Our major concern with zero tolerance for SWD is the manifestation of acquired resistance by applying similar mode of action insecticides or repeated use of the insecticide across a generation of adult SWD. IRM is predicated on the strategy of rotating the effective IRAC MOA groups recommended for SWD control to provide a sustainable approach that will minimize the selection for insecticide resistance. This diversity should provide adequate chemical options for the grower to eliminate back-to-back applications with the same active ingredient within a SWD generation or treatment window rotation. By using tank-mixtures of registered insecticides from different target sites of actions, growers may delay the onset of resistance develop to both classes of chemistry.

The compounds recommended are effective contact and stomach-poison insecticides when applied in the manner consistent with their respective label. Applicators must pay special attention to the manufacturer's maximum seasonal usage statement expressed as weight or volume/acre of their product, PHI, application intervals and directions for ground and/or aerial applications in the label. Calibrate and retrofit ground sprayers relative to the blueberry bushes' height, width and canopy foliage to achieve maximum coverage at optimum psi, water sensitive paper, gallonage and ground speed. And most importantly, check all spray tips for uniform flow rates before, during and after application. Study the pesticide label before application. It is a legal document.

Table 2. Residual efficacy for SWD control on blueberry foliage

Group/Class	Trade Name	Days of Residual Activity	PHI
Organophosphate/1B	Malathion	3 to 5	1
	Imidan	3 to 5	3
Pyrethroid/3A	Mustang Max	5 to 7	1
	Brigade	5 to 7	1
	Danitol	**10 to 14**	3
	Asana	5 to 7	14
Spinosyn/5	Delegate	1 to 3	3
	Entrust[1]/Success	1 to 3	3
Pyrethrin/3A	Pyganic[1]	0 to 1	0 to 1
Carbamate/1A	Lannate[2]	1 to 3	3
Neonicotinoid/4A[3]	Assail	1 to 3	1
	Provado	1 to 3	3
	Actara	1 to 3	3
[1]OMRI approved	[2]Aerial	[3]Slow knockdown adulticides, translaminar activity on egg hatching.	

The conservative spray intervals in Table 3 are based on actual field residual toxicities, rather than empirical field observations. These intervals were determined by placing cohorts of SWD adults daily on field-treated leaves at 1 DAT through 14 DAT. The decline in mortality rates over time is directly related to the insecticide's residual degradation on the leaves. Flies spend more time on leaves than berries. Leaves provide shady, protected resting sites compared with berries; therefore flies will most likely contact and accumulate toxic insecticide levels from the leaves.

Table 3. Insecticides for Spotted Wing Drosophila in Blueberry, 2013

Trade Name	Chemical name	IRAC	PHI (d)	Max applications per year/crop	Retreatment Interval (d)
Lannate LV	methomyl	1A	3	4	5
Sevin XLR+	carbaryl	1A	7	5	7
Imidan 70WP	phosmet	1B	3	5	
Malathion 8	malathion	1B	1	3	5
Asana XL	esfenvalerate	3A	14	4	
Danitol 2.4EC	fenpropathrin	3A	3	2	14
Brigade 2EC	bifenthrin	3A	1	5	7
Mustang Max	zeta cypermethrin	3A	1	6	7
Actara	thiamethoxam	4A	3	3	7
Assail 30SG	acetamiprid	4A	1	5	7
Provado 1.6	imidacloprid	4A	3	5	7
Delegate WG	spinetoram	5	3	6	6
Entrust SC	spinosad	5	3	6	6

Many blueberry growers report insecticide efficacies of 7-10 days from date of application. Field dynamics may help to explain the discrepancy between actual residual toxicity and grower observations (Tables 1-3). SWD will immigrate into fields from overwintering refugia, once inside; field-generated populations become the primary source of re-infestation. This results in growers unknowingly conditioning their SWD population to adapt to their individual management schedules. How does this occur?

Two selective forces occur regularly in blueberry fields; insecticide applications and berry harvest. Additionally severe climatic events such as periods of prolonged high temperatures or rain can affect SWD field populations. Insecticide applications have the potential to eliminate >90% of the adult populations but have no effect on the protected cryptic life stages (i.e., pupating flies in the soil and overlapping stages of immature larvae within the berries). A properly applied insecticide will continue killing emerging adults that come in contact with residues on leaves and berries for several days. The abrupt disappearance of adult flies and the delay before emerging flies can survive the dissipating insecticide residues and build up

observable numbers, may be part of the reason growers report longer efficacy than actual field-aged residue toxicities reported in Table 1. The gap in fly appearance is also influenced by the harvest schedule, the second selective force. If picking marketable berries occurs at 1 DAT, a large portion of larvae will be removed from the field population. Regular picking and weekly spray intervals continually restrict the SWD population by tightening and adjusting them to fit each individual field management schedule.

Regardless, whether growers believe their spray interval is sufficient or whether the truth is the field populations have simply conformed to their spray regime, unless the spray interval is sufficiently short to maintain a toxic residue on the leaves, the population will continue to thrive in the field (i.e., appearing and disappearing in predictable intervals). Unpicked infested berries and pupating flies remain as SWD reservoirs. By maintaining toxic leaf residues for a period long enough to repeatedly kill the trickle of emerging adults prior to egg-laying and timely application of the next protective cover spray, growers could have a chance to eliminate SWD from infested fields. A predictable postharvest SWD population spike in late September/October is the result of an accumulation of adults surviving the earlier gaps to protect maturing fruit from their egg laying. This underscores the vulnerability resulting from extending spray intervals beyond the 90% toxicity residue threshold and manufacturer's recommendation (Table 1). Spraying at retreatment intervals may not be economically feasible for every grower but spraying at an interval short enough to keep larval infestations low enough to satisfy the processors export MRLs is crucial (Table 3). Insecticide MRLs in or on food commodities have become a significant concern for blueberry exports because they vary by country of destination. Now the goal for researchers is to assist growers in developing management schedules that fit their market objectives (e.g., domestic or international) for SWD-free blueberries (Tables 2-4). Assistance begins with baseline knowledge of which insecticides are most effective in killing SWD and their true field residual toxicity for promoting IRM, followed by determining residual degradation curves (ppm) and MRL tolerances for these insecticides.

Summary Insights for SWD Management:

- Growers must monitor their baited traps more frequently as their blueberry cultivar(s) approach the "red back" ripening stage (i.e., over half blue color). The critical treatment threshold is predicated on detection of first SWD trapped in-field or region-wide first detection.
- Chemically difficult to clean-up resident SWD populations if grower's first detection and application occurs after the "red back" ripening window (~5-7 days).
- Good spray coverage of the foliage and fruit is key to the economic control of adult SWD.
- Rotate different mode of action chemistries to delay the onset of tolerance and cross-resistance to insecticides in the same IRAC class.
- Apply full-labeled rate of each insecticide and consider PHIs, REIs and MRLs when formulating a SWD management program.

Table 4. Example of a provisional spray calendar, beginning at *Red back*, for late season PNW blueberries destined for domestic markets				
Treatment	Residual Activity	PHI	MRL	Notes
Danitol 2.4 EC	9 (10-14)	3	US - 3 K – 0.5	Maximum 2 applications/year 14 day treatment interval
Mustang Max	6 (5-7)	1	US – 0.8 C – 0 J – 0.5	Do not apply more than 24 fl. oz/ acre/season. Minimum treatment interval is 7 days
Imidan 70 WP	~ 5	3	US -10 C – 5 T – 0.02	Do not apply more than 5.125 lb/ acre/year
Mustang Max	6 (5-7)	1	US – 0.8 C – 0 J – 0.5	
Imidan 70 WP	~ 5	3	US -10 C – 5 T – 0.02	
Malathion 8 F or Aquamul	5 (3-5)	1	US – 8 J – 0.5 T – 0.01	Do not apply more than 1.25 pts/ acre/year. Minimum treatment interval is 5 days.
Mustang Max	6 (5-7)	1	US – 0.8 C – 0 J – 0.5	
Malathion 8 F or Aquamul	5 (3-5)	1	US – 8 J – 0.5 T – 0.01	
Mustang Max	6 (5-7)	1	US – 0.8 C – 0 J – 0.5	
Danitol 2.4 EC	9 (10-14)	3	US - 3 K – 0.5	
C = Canada, J = Japan, K = South Korea, T = Taiwan				

Important Website:

USDA FAS MRL Database – searchable by commodity, active ingredient and country.
http://www.mrldatabase.com/