Control of Winter Moth (*Operophtera brumata*, L.) in PNW Blueberries

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Blueberries grown in the Pacific Northwest are a high value crop. In 1998, Oregon produced 23,000,000 pounds of berries on 2,500 acres with a farm-gate value of more than $11.5 million; Washington produced 10,500,000 pounds of fruit on 1,500 acres with a farm-gate value of more than $6.5 million (Oregon Agricultural Statistics Service).

Damage by winter moth larvae to blueberry flower buds reduces total potential yield; further economic losses are incurred when larval feeding on developing or ripe fruit causes downgrading and, thus, a reduction in the value of the crop. *Operophtera brumata* (L.) (Lepidoptera: Geometridae) is one of four species of winter moths that can occur in blueberry plantings. *O. brumata*, which is commonly referred to as the European winter moth, is not native to North America but an exotic introduced from Europe. The first record of the moth in North America was in Nova Scotia, Canada, in 1949 although there is strong indication that the pest was introduced to Nova Scotia sometime prior to 1930 (Cunningham 1981). First detection in the Pacific Northwest was on the southern end of Vancouver Island, Canada, in 1976 (Gillespie 1978) and in the Portland, Oregon, area by 1978, although insect collections indicate males were collected from Oregon in 1958 and 1973 (Ferguson 1978). The European winter moth was identified as a new pest in Oregon filbert orchards in 1980 (AliNiazee 1981) and in blueberries in the Lower Mainland of British Columbia in 1989 (Sheppard et al 1990). The other three species found in the Pacific Northwest (*O. bruceata*, *O. occidentalis*, *O. relegata*) are native to North America and are similar to *O. brumata* in appearance, habit, and life history; reported control methods are similar for all species. The four species are ravenous feeders and serious defoliators of many broadleaf plants, especially shade and fruit trees. Winter moths are unusual pests in that the adults emerge in the fall and the males fly to and mate with flightless females during the fall and early winter. Fall and winter is not a usual time for growers to monitor fields for pests. Thus, early indications of infestations commonly go undetected.

Winter moth larvae are difficult to control because eggs hatch very early in the spring and the young larvae burrow into and feed inside unopened buds. They are difficult to detect until they have migrated from bud to bud and much damage has occurred. Also, the larvae are usually not detected until bloom when most insecticides cannot be used due to pollinator hazard.

The winter moth has one generation per year. Adults emerge from pupa in the soil sometime in mid-autumn (from October to December). Upon emergence, the flightless female climbs up the blueberry plant where mating takes place. The eggs (up to 150 eggs per female) are laid, either singly or in groups of two or three, on twiggy branches, in crevices, or at bud axils. The eggs hatch in mid-March to mid-April. The newly emerged larvae feed on buds, the following instars feed on flowers and the last (5^{th}) instar may attack the developing fruit. From May until the beginning of July, the larvae drop to the ground, burrow down (2 to 4 inches) and pupate within earthen cells where they remain until fall. Fall rains trigger emergence of adults and the cycle begins anew.

Infestations of winter moth that are a result of in-field infestations (eggs having overwintered on trunks and branches of blueberry plants) can be reduced with a dormant oil spray that suffocates the eggs; inclusion of an insecticide with the oil is recommended. [Using a sticky substance like Tanglefoot® on the trunk of single-stem plants (e.g. fruit trees) can prevent females from climbing up into the plant for mating, but such a practice is not practical in the multi-stemmed blueberry plant.] Native soil-dwelling arthropods provide some predation of the winter moth pupae (Roland and Embree 1995) and some parasitism of the larvae by native parasitoids also occurs (Kimberling et al 1986). Introduction of parasitic insects from Europe provided greater than 75% control of winter moth larvae in shade trees in eastern Canada (Roland and Embree 1995). *Cyzenis albicans* (a tachinid fly) has been reported to parasitize larvae infesting blueberries in Canada's Fraser Valley. Its population was apparently not affected by a clean up spray of Malathion (Roland and Szeto 1990). *Cyzenis albicans* and *Agrypon flaveolatum* (an ichneumonid wasp) have been introduced into Oregon filbert orchards for winter moth control; however, only 10% parasitism of the larvae was achieved (Roland and Embree 1995).

Careful inspection of buds and newly expanding plant growth will indicate the need for pesticide sprays after winter oil application. Because larvae are present well into June and because the larvae can "balloon" on silk from surrounding vegetation into blueberry plantings, fields must be monitored even after insecticides have been applied.

There were three components to this research:

(1) Monitoring adult moth flight activity
(2) Evaluating efficacy of pesticide sprays targeted at winter moth eggs
(3) Evaluating efficacy of pesticide sprays targeted at winter moth larvae

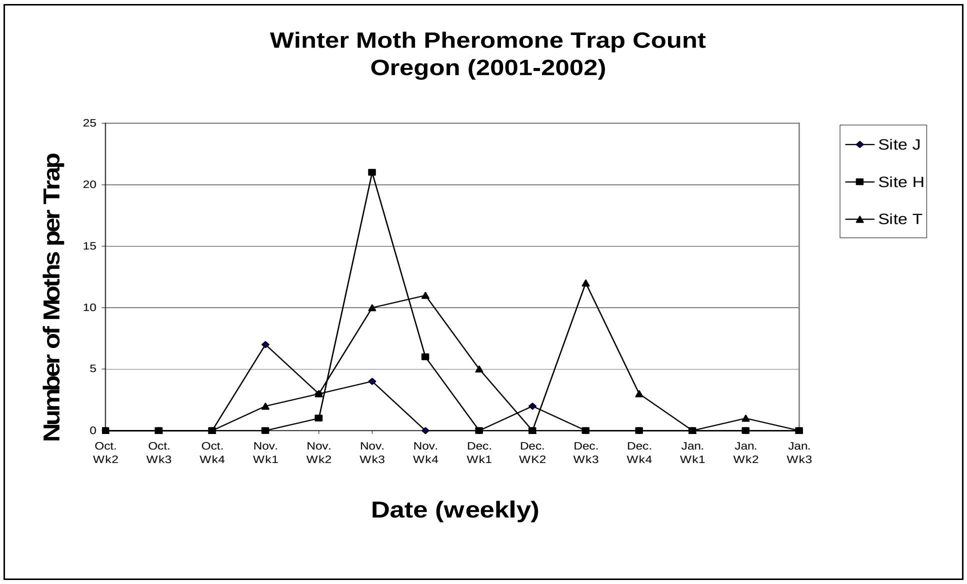
Results:

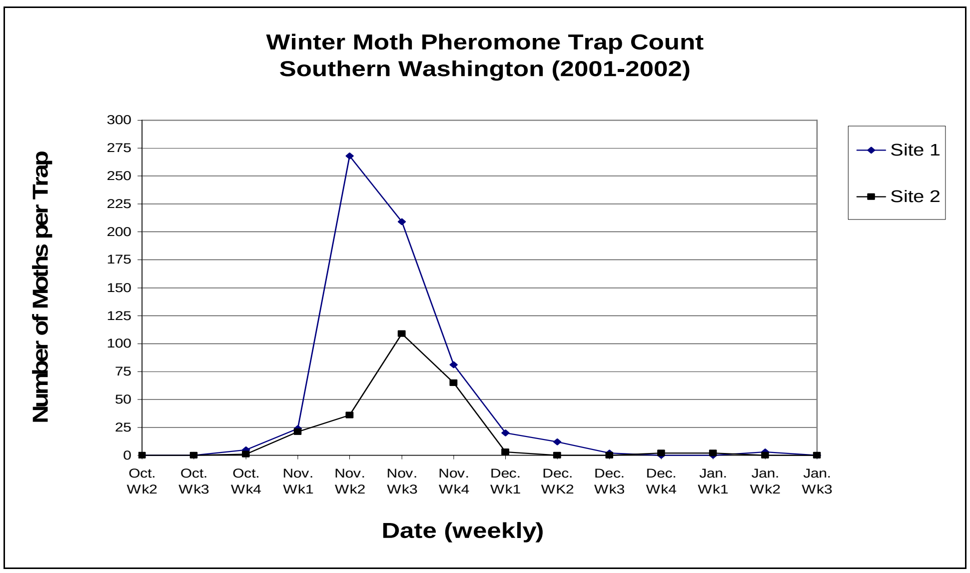
(1) Monitoring of adult moth flight activity

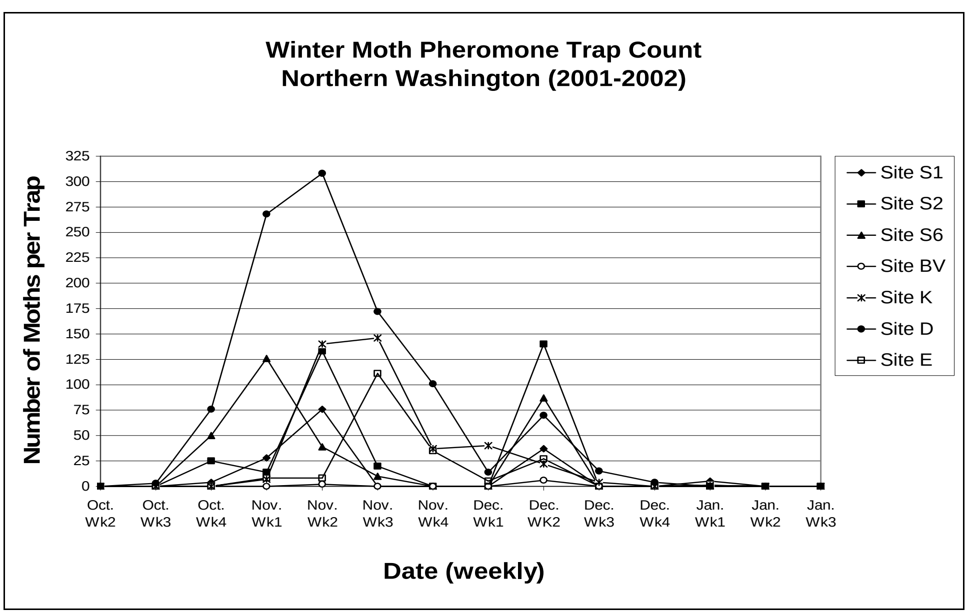
Adult winter moth flight was monitored in 12 commercial blueberry fields in Oregon and Washington with pheromone-baited traps. Baited cone traps were placed in fields in the middle of October 2001 and checked weekly until the third week of January, 2002. The winter moth sex pheromone (ZZZ-1, 3, 6, 9-nonadecatetraen) was successful in attracting the males of both the winter moth (*Operophtera brumata*) and the Bruce spanworm (*Operophtera bruceata*); the larvae of both species cause damage to blueberry buds.

Similar to trap counts from 2000-2001, two peaks in adult flight activity were apparent in most fields monitored in 2001-2002: mid-November and early December. Unlike the previous year, the southern Washington sites had just one peak flight that occurred in mid-November. The number of moths trapped varied by geographical region: the southern Washington sites averaged the highest number of moths during peak flight, the average of the northern Washington sites had the next highest, and the Oregon sites averaged the lowest. At most sites, adult flight activity declined rapidly by the third week of December and did not increase thereafter.

Unlike the results from trapping in 2000-2001, geographical and seasonal differences in species complex were not apparent in 2001-2002: the Bruce spanworm (*Operophtera bruceata*) was the dominant species at most sites throughout the entire season, especially during the peak flight in mid-November. However, during early December, some sites had as much as 60% winter moth (*Operophtera brumata*) in the traps.


Winter Moth Pheromone Trap Count
Oregon (2001-2002)
Number of Moths per Trap
0
5
10
15
20
25
Oct. Wk2
Oct. Wk3
Oct. Wk4
Nov. Wk1
Nov. Wk2
Nov. Wk3
Nov. Wk4
Dec. Wk1
Dec. WK2
Dec. Wk3
Dec. Wk4
Jan. Wk1
Jan. Wk2
Jan. Wk3
Date (weekly)
Site J
Site H
Site T


Winter Moth Pheromone Trap Count
Southern Washington (2001-2002)
Number of Moths per Trap
0
25
50
75
100
125
150
175
200
225
250
275
300
Oct. Wk2
Oct. Wk3
Oct. Wk4
Nov. Wk1
Nov. Wk2
Nov. Wk3
Nov. Wk4
Dec. Wk1
Dec. WK2
Dec. Wk3
Dec. Wk4
Jan. Wk1
Jan. Wk2
Jan. Wk3
Date (weekly)
Site 1
Site 2


Winter Moth Pheromone Trap Count
Northern Washington (2001-2002)
Number of Moths per Trap
0
25
50
75
100
125
150
175
200
225
250
275
300
325
Oct. Wk2
Oct. Wk3
Oct. Wk4
Nov. Wk1
Nov. Wk2
Nov. Wk3
Nov. Wk4
Dec. Wk1
Dec. WK2
Dec. Wk3
Dec. Wk4
Jan. Wk1
Jan. Wk2
Jan. Wk3
Date (weekly)
Site S1
Site S2
Site S6
Site BV
Site K
Site D
Site E

(2) ***Evaluate efficacy of pesticide sprays targeted at winter moth egg*s**

This trial was conducted in a field of 6-year old 'Hardiblue' blueberries located near Bellingham, WA. Experimental design was a randomized complete block with eight replications. Each plot consisted of one plant, separated by untreated plants. Treatments were applied using a CO_2 backpack sprayer equipped with a three-nozzle boom at 50 psi, delivering 100 gallons of water per acre. Treatments were applied on February, 20, 2002 before leaf emergence and after, presumably, all winter moth eggs had been deposited. Treatments were evaluated on May 1, 2002 by determining the amount of damage (chewing) to the blueberry buds. To evaluate bud damage, 20 branches were collected from each plot and the three topmost buds of each branch were inspected for signs of damage due to chewing by the winter moth larvae (60 buds per plot were inspected).

Treatment and rate	Damaged buds (%)
Sunspray 6E oil (92%USR) @ 3 gal/100 gal water/A ……...	15.2 b*
Actara 25W (thiamethoxam) @ 3 oz/A (0.05 lb ai/A)	
+ Sunspray 6E oil @ 3 gal/100 gal water/A ……………..	5.2 a
Diazinon 50WP @ 1 lb/A (0.5 lb ai/A)	
+ Sunspray 6E oil @ 3 gal/100 gal water/A ……………..	13.2 b
Untreated control ……………………………………………	33.0 c

*Means followed by the same letter within a column do not differ significantly, based on Fisher's protected LSD ($P \leq 0.05$)

Plants treated with Actara 25W + oil had significantly less bud damage than the other treated plants or the untreated control. Diazinon + oil and oil alone performed similarly; the addition of diazinon did not reduce amount of bud damage. All treated plants had significantly less bud damage than the untreated control.

(3) ***Evaluate efficacy of pesticide sprays targeted at winter moth larvae***

This trial is considered a laboratory trial because, although blueberry branches were collected from the field and treatments were applied to the branches on a concrete pad outdoors, the treated branches were brought indoors where they remained until each evaluation date.

To evaluate efficacy of pesticides on mortality of winter moth larvae, branches were collected from a commercial, field of organic blueberries in northern Washington (Mt. Vernon area), brought back to NWREC and then sprayed with various pesticide treatments. Blueberry branches that showed signs of larval activity (larvae were present or buds showed signs of chewing) were collected on March 28, 2002. Six twigs, with a minimum of eight buds each, were placed in a beaker of water to keep them fresh and viable during the evaluation period. Treatments were applied on March 29, 2002 and replicated eight times (four replicates used on each of two evaluation dates). Treatments were applied with a CO_2 backpack sprayer equipped with a single-nozzle boom at 40 psi, at 50 gal water per acre. A crop oil (Sunspray 6E Oil) at 1% v:v was added to each pesticide treatment. Treatments were evaluated on April 1, 2002 (3 DAT) and April 12, 2002 (14 DAT) by determining the number of live and dead larvae in each treatment.

Treatment and rate	% larval mortality	
	3 DAT	14 DAT
Actara 25W (thiamethoxam) @ 3 oz/A (0.05 lb ai/A) ………….	53.5 b*	71.0 b*
Confirm 2F (tebufenozide) @ 16 fl oz/A (0.25 lb ai/A) ………..	6.2 a	73.0 b
Diazinon 50WP @ 1 lb/A (0.5 lb ai/A) …………………………	70.8 bc	100 c
Success 2SC (spinosad) @ 6 fl oz/A (0.094 lb ai/A) …………...	93.8 c	100 c
Untreated control ………………………………………………..	0 a	0 a

*Means followed by the same letter within a column do not differ significantly, based on Fisher's protected LSD ($P \leq 0.05$)

At 3 DAT, twigs treated with Success had a significantly higher percentage of larval mortality than the other treatments. Larval mortality in Diazinon-treated twigs was comparable to the Success treatment. Actara-treated twigs had greater larval mortality than Confirm-treated twigs or the untreated control. Larval mortality of the twigs treated with Confirm was comparable to the untreated control, which was not unexpected because Confirm is an insect growth regulator and acts slowly; larvae stop feeding immediately but take three to seven days to die.

At 14 DAT, the Diazinon and Success treatments had the highest larval mortality. All pesticide treatments had significantly greater larval mortality than the untreated control.