Impact of Matador® and Delegate® on lodgepole pine filled seed production in southern interior BC seed orchards: 2015 trial

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Introduction

This report outlines methodology and results from the second of two years of trials to control western conifer seed bug (*Leptoglossus occidentalis)* populations (referred to as "Lepto" through the remainder of this paper) in lodgepole pine seed orchards in south central British Columbia. A report on previous trials undertaken in 2014 with Matador® (Woods et al., 2015) outlines the background for these trials. Some of this background is repeated here, but readers are directed to the earlier report for more detail.

The production of filled seed in lodgepole pine seed orchards located in the North Okanagan of British Columbia have long been below levels considered adequate to meet objectives of the Forest Genetics Council of BC (FGC, 2009) and to allow orchard businesses to operate at a financially sustaining level of production and sales. Results from the 2014 Matador trial implemented in four seed orchards showed an increase in operational filled seed production of from 182% to 300% for treated blocks relative to non-treated control blocks. Filled-seed yields from individual cone samples protected from insect predation by insect-exclusion bags, in both treated and control orchard blocks, supported the result that Matador significantly increased filled-seed production.

The success of the 2014 Matador trial led to the question of whether this result was repeatable across years. As Lepto populations were high in 2014, it is possible that in a year with lower populations the improvements in seed set would not be realized. In addition, three other questions were raised that warranted further experimentation:

Does Delegate®, an insecticide also showing promise for Lepto control, increase seed set as effectively as Matador?

How much does the application of Matador and Delegate delay seed loss due to Lepto predation, thus allowing a longer cone harvest window?

Can a routine Lepto survey methodology be implemented to quantify populations and aid decisions related to spray timing?

These questions were investigated in the trials reported here and results are presented for both operational seed yields and for sample collections.

The importance of treatment timing

Previous work by Strong (2015) on the timing of Leptoglossus emergence and feeding suggests two key periods for control; late May through June when overwintering Leptoglossus begin to feed on developing ovules in maturing cones (early season), and early July through to September (late season) when newly hatched nymphs begin to feed on developing seeds and mature to adults. There is evidence that the early feeding kills ovules and limits seed development, resulting in a reduction in the total formed seeds (filled and empty) in a cone. The latter feeding has been shown to reduce the number of filled and viable seeds and takes place over a longer period. The 2014 Matador trial results supported this expectation and suggested that filled-seed losses were about equally caused by early- and late-season predation.

The trials reported here timed spray applications to reduce Lepto populations in the early June and early July periods, with timing modifications at each orchard based on surveys of Lepto populations.

The importance of harvest timing

Earlier work compiled by Webber (2014) has shown that the number of filled seeds per cone (FSPC) declines from early July to late September. Seed maturity defines the earliest possible collection date and varies from year-to-year and with different clones (Giampa, unpublished). Orchard managers, therefore, attempt to collect cones at the earliest possible seed maturity date, and then race against seed losses by hiring large picking crews to harvest cones as quickly as possible. This situation adds operational difficulties to orchard operations with limited staff and equipment resources and who must work with due attention to safety and work quality.

Quantification of the rate of FSPC decline in orchard blocks treated to control Lepto relative to blocks that are not treated would assist orchard managers with decisions on harvest scheduling and could reduce pressure for early harvest.

The trials reported here include weekly evaluations of FSPC from a set number of parental clones in orchard blocks treated to reduce Lepto populations and from non-sprayed control blocks during the July to September period.

Methods

Nine orchards located on five sites in south-central British Columbia collaborated on this trial (Table 1). Three sites (Grandview, Eaglerock, and Vernon Seed Orchard Company) are central to the North Okanagan area where problems with filled seed production in lodgepole pine have been most prevalent. Two sites, Sorrento and Kettle River, are located in ecosystems that are somewhat cooler than those of the North Okanagan.

Orchards were divided into a control block that did not receive pesticide treatment and a treatment block. One orchard (338) was divided into three blocks representing a control, treatment with Matador®, and treatment with Delegate.

Table 1 Site location, climatic information, and pesticide used for nine lodgepole pine seed orchards.

Orchard no.	Seed planning unit	Site	Latitude	Elev. (m)	Mean annual temp. (C)	Mean annual precip. (mm)	Mean summer precip. (mm)	Pesticide
339	Thompson Ok. high elev.	Eaglerock	50°24	520	7.2	536	240	Matador
237	Prince George	Kettle River	49°13	636	6.7	453	185	Matador
238	Central Plateau	Kettle River	49°13	636	6.7	453	185	Delegate
337	Nelson low elev.	Grandview	50°23	483	7.1	481	209	Delegate
338	Thompson Ok. low elev.	Grandview	50°23	483	7.1	481	209	Matador & Delegate
240	Bulkley Valley	Sorrento	50°52	521	6.8	585	248	Matador
241	Central Plateau	Sorrento	50°52	521	6.8	585	248	Delegate
234	Bulkley Valley	VSOC	50°14	495	7.2	536	240	Matador
236	Prince George	VSOC	50°14	495	7.2	536	240	Delegate

Temperature and precipitation data from ClimateWNA (Wang et al., 2012). UBC Center for Forest Conservation Genetics online model.

Pesticide application

Matador 120EC is a is a photostable, synthetic pyrethroid insecticide that is registered for use on many pests, including the apple brown bug in apple orchards and the tarnished plant bug in peach orchards. The application rate recommended on the label for the tarnished plant bug is 104 ml of product per hectare, delivered through an air-blast sprayer.

Delegate is a spinosyn insecticide derived from the fermentation of the bacterium *Saccharopolyspora spinosa*. It is registered for use on coddling moths and other pests common to stone fruits, tree nuts, and blueberries.

Both Matador and Delegate were applied to label specifications for pests similar to Lepto. Table 2 shows orchard spray and control block sizes for these trials.

Table 2 Orchard areas and number of ramets for pesticide-sprayed and non-sprayed (control) areas.

Orchard no.	Site	Spray-block area (ha)	Spray block no. ramets	Control-block area (ha)	Control block no. ramets	Pesticide
234	VSOC	4.7	2,042	1.7	825	Matador
237	Kettle River	5.0	2,382	4.8	2,293	Matador
240	Sorrento	5.0	2,240	1.9	846	Matador
338	Grandview	5.0	2,444	2.7	1,280	Matador
339	Eaglerock	4.9	2,216	1.9	818	Matador
236	VSOC	4.8	2,295	4.0	1,912	Delegate
238	Kettle River	4.8	2,277	1.4	668	Delegate
241	Sorrento	3.1	1,413	1.2	586	Delegate
337	Grandview	1.3	634	0.8	357	Delegate
338	Grandview	2.0	958	2.7	1,280	Delegate

Matador and Delegate pesticide-label application rates were planned, but some site differences resulted due to different equipment, dilution rates, sprayer settings, tractor speeds, etc. (Table 3). Dilution rates and the application rate used for the product-water mix were determined for each site, with the goal of applying the solution to the point of run-off. Applications were timed to control Lepto populations at the beginning of each of the two feeding periods (late May and early July), with timing adjustments based on Lepto survey results. Product costs per hectare are shown in Table 3. Control blocks were not sprayed with water or any other pesticide other than some weed control products at the ramet base on some sites. Orchard management in the spray and control blocks was otherwise identical across both blocks on each site.

Table 3 Matador and Delegate application rates and timing across the four trial sites. All applications were done with a tractor-pulled airblast sprayer.

Orchard no.	Site	Pesticide	Application dates (2015)	Application rate (ml or g product /ha)	Dilution rate in water (ml or g / 1000 L)	Liters solution applied per ha	Product cost per ha
234	VSOC	Matador	June 5	121	104	1160	$29
234	VSOC	Matador	July 20	121	104	1160	$29
237	Kettle River	Matador	June 9&10	76	69	1090	$18
237	Kettle River	Matador	July 8	76	69	1090	$18
240	Sorrento	Matador	May 4	102	175	582	$24
240	Sorrento	Matador	June 24&25	115	175	659	$28
338	Grandview	Matador	April 30	104	96	1076	$25
338	Grandview	Matador	June 15	104	96	1076	$25
339	Eaglerock	Matador	May 12	104	277	375	$25
339	Eaglerock	Matador	June 15	104	277	375	$25
339	Eaglerock	Matador	July 6	104	277	375	$25
236	VSOC	Delegate	June 5	401	380	1056	$60
236	VSOC	Delegate	July 20	527	380	1387	$79
238	Kettle River	Delegate	June 10	456	397	1149	$68
238	Kettle River	Delegate	July 10	456	397	1149	$68
241	Sorrento	Delegate	May 4	425	734	580	$64
241	Sorrento	Delegate	July 3&7	468	734	637	$70
338	Grandview	Delegate	May 1	420	390	1076	$63
338	Grandview	Delegate	June 16	420	390	1076	$63
337	Grandview	Delegate	May 1	420	390	1076	$63
337	Grandview	Delegate	June 16	420	390	1076	$63
337	Grandview	Delegate	July 17	420	390	1076	$63

Operational seed production

The primary purpose of these trials is to compare the use of Matador or Delegate versus no spray on large areas under operational orchard management conditions.

Cones were collected operationally in both the spray and control blocks at each site on the days shown in Table 4. Sacks of cones from spray and control areas were labeled separately, stored temporarily at each orchard site under the same conditions, and shipped in mid September, 2015 to the Provincial Tree Seed Center (TSC) for extraction. Staff at the TSC extracted and germination-tested seed from the spray and control lots separately, but did not treat the lots differently during the drying, extraction, and germination-testing process.

Table 4 Operational cone collection dates (all 2015) for the spray and control blocks in each orchard.

Orchard no.	Site	Pesticide	Spray-block collection dates	Control-block collection dates
234	VSOC	Matador	July 28 - Aug. 6	July 27-30
237	Kettle River	Matador	Aug. 1 - 5	Aug. 6 - 9
240	Sorrento	Matador	July 31 - Aug. 12	Aug. 10 - 15
338	Grandview	Matador	July 21 - Aug. 10	July 20 - 31
339	Eaglerock	Matador	Aug 10 - Aug 21	July 27 - Aug. 10
236	VSOC	Delegate	Aug. 19 - 24	Aug. 24 - 26
238	Kettle River	Delegate	July 27 - 31	July 31 - Aug. 1
241	Sorrento	Delegate	July 27 - Aug. 3	July 29 - Aug. 3
337	Grandview	Delegate	Aug 10 - 13	Aug 10 - 15
338	Grandview	Delegate	July 20 - Aug 5	July 20 - 31

Harvest timing collections:

Cone collections were made at the dates shown in Table 5 from a sample of ramets representing the same set of parental clones in both the spray and control blocks from each orchard. Either one or two cones were collected weekly from each sample ramet. Cones for each collection were put together in a single paper bag that was then labeled by orchard, spray or control, and date. Bags of cones were stored in dry conditions at each site and then transported to the Kalamalka forestry Center in late September. All cones were dried in ambient conditions at the Kalamalka Forestry Center for about two months, and then kiln-dried to open the cones. Seeds were manually removed from the cones using standard Center protocols. All formed (non flat) seeds extracted from the cones in each of the labeled bags were counted. The number of cones in each bag was recorded. Seeds were x-rayed to allow counts of the number of filled seeds among the formed seed that were extracted. For each of the samples from Table 5, data were tabulated for the number of cones, the number of formed seeds, and the number of filled seeds. Statistics of interest were calculated from these data, including the total formed seeds per cone (TSPC), filled seeds per cone (FSPC), and the percent filled seed (FSPC/TSPC).

Table 5 Listing of harvest-timing cone collections showing the orchards, start and end dates of weekly collections, number of parental clones, and the number of cones collected from each parental clone on each date.

Orchard no.	Site	Pesticide	# clones (cones)	Start date	End date	Comments
234	VSOC	Matador	10 (2)	July 15	Sept. 2	
237	Kettle River	Matador	11 (2)	July 5	Sept. 2	Aug. 5 missing
240	Sorrento	Matador	10 (2)	July 15	Sept. 2	
338	Grandview	Matador	10 (2)	July 14	Sept. 1	Aug. 18 missing
339	Eaglerock	Matador	9 (2)	July 16	Sept. 1	
236	VSOC	Delegate	10 (2)	July 15	Sept. 2	
238	Kettle River	Delegate	10 (2)	July 5	Sept. 2	Aug. 5 missing
241	Sorrento	Delegate	10 (2)	July 15	Sept. 2	
337	Grandview	Delegate	10 (2)	July 14	Sept. 1	
338	Grandview	Delegate	none			Not sampled

Leptoglossus surveys

Surveys of Leptoglossus occurrence were conducted weekly in both spray and control blocks for each orchard starting in early May until late July or early August. All surveys consisted of a timed 20-minute walk through each block during which the surveyor looked for and counted the number of Lepto seen. In most cases, the same person did the surveys for all orchards on each site. However, different people did surveys on each site, introducing a confounding of site estimates with the observational skills of the surveyor at each site.

Results and discussion

Leptoglossus surveys

Results from weekly 20 minute walk-through counts of Leptoglossus are shown in Table 6. These data suggest that Sorrento, Eaglerock and Grandview had higher Lepto populations than Kettle River or VSOC. Sorrento results are inconsistent, showing reasonably high populations in orchard 241 and lower populations in orchard 240. Similarly, Grandview orchard 338 appears to have had lower Lepto populations than orchard 337. VSOC had only one Lepto sighting during the season. This apparently low Lepto population may be due to an early season treatment of these orchards with Dimethoate to control European pine shoot moth.

Surveys were in most cases done by the same person on a site, but by different people across sites. This creates a confounding of site counts with surveyor acuity, however differences between orchards on a given site would not have this confounding. A source of variability in counts can also be the weather and light conditions at the time the survey is done. Lepto are more active during warm weather and are more difficult to see on cooler and cloudy days. These shortcomings to obtaining consistent and comparable results both between sites and between weeks within a site are difficult to overcome. These same shortcomings would also impact the reliability of the survey method under operational conditions.

Data in table 6 provide some evidence that both Matador and Delegate reduce Lepto populations. Coloured cells indicate weeks when sprays were applied. In general Lepto counts dropped off for several weeks after spraying (note that for some weeks, the survey was done before spraying, resulting in a count in a coloured cell). These data are not definitive, however, as there are also examples where control blocks showed the same pattern of Lepto reduction as the spray blocks even though the control blocks were not sprayed (337 June 15th).

Table 6 Results showing the number of Lepto counted in 20-minute weekly surveys done in spray and control blocks in each orchard. Surveys were done within the week of, but not necessarily on, the dates shown. Coloured cells indicate the week when the spray blocks were treated.

Orchard	Site	Treatment block	April 20	April 27	May 4	May 11	May 18	May 25	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 20	July 27	Aug. 3	Aug. 10	Aug. 17	Aug. 24
338	Grndv.	Matador	2	8	-	-	-	-	-	3		-	-	-	-	-					
338	Grndv.	Control	1	3	1	-	-	1	-	-		-	-	1	1	-					
337	Grndv.	Delegate			-	-	-	-	2	1		-	-	-	8	-	-	-			
337	Grndv.	Control			-	2	1	-	-	1		-	-	5	2	6	2	2			
237	Kettle	Matador		-	-	-	-	-	1	-	-	-	-	-	-	-					
237	River	Control		-	-	-	-	-	-	-	-	-	-	-	1	-					
238	Kettle	Delegate		-	-	-	1	1	-	-	-	-	-	1	-	-					
238	River	Control		-	-	-	1	1	-	-	-	-	-	1	-	-					
240	Sorrento	Matador		-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	2	2	-
240	Sorrento	Control		-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	5	3	2
241	Sorrento	Delegate		5	-	3	1	2	-	-	-	3	10	-	-	-	2	2	-	4	-
241	Sorrento	Control		2	1	1	1	-	-	-	1	5	6	-	1	2	-	1	-	2	3
234	VSOC	Matador	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-			
234	VSOC	Control	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-			
236	VSOC	Delegate	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
236	VSOC	Control	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	1	-
339	Eaglerk.	Matador	-	2	4	7	-	-	-	1	-	-	-	-	-	-	1				
339	Eaglerk.	Control					2	3	-	4	1	1	3	1	6	2	4				

Operational seed production

Pesticide treatment increase filled seed yield from 3% to 53% when measured as grams filled seeds per hectoliter of cones (Figure 1). When averaged across all orchards, Matador treatments increased yields by 24% and Delegate increased yields by 22% (Table 7). Yield increases for orchards producing for northern SPU (orchards 234, 236, 237, 238, 240, 241) averaged 24%, while those producing for southern SPU (337, 338, 339) averaged an increased yield of 12%.

Germination percentage and seed weights were measured by the Provincial Tree Seed Center using standard protocols for lodgepole pine. Germination was generally high for all lots and no significant differences were found between control blocks and blocks treated with either Matador or Delegate. Seed weight measured as seeds per gram (SPG) was also not significantly different between the treated and control blocks.

Table 7 Yield, germination percent, and weight of seed from Matador® treated and control blocks across four lodgepole pine seed orchards.

Orchard no.	Site	Pesticide	Hl cones	Grams filled seed	Grams seed / hl cones	Yield as % of control	Seed germ. %	Seeds / gram
234	VSOC	Matador	24.6	7,690	313	114	96	286
234	VSOC	Control	9.6	2,641	279		96	294
237	Kettle River	Matador	14.2	4,118	290	116	98	248
237	Kettle River	Control	21.4	5,335	249		95	248
240	Sorrento	Matador	16.5	3,805	231	153	95	250
240	Sorrento	Control	4.5	677	151		97	251
338	Grandview	Matador	90.2	33,504	372	114	96	258
338	Grandview	Control	26.0	8,476	326		92	284
339	Eaglerock	Matador	61.0	16,518	271	124	94	255
339	Eaglerock	Control	30.0	6,548	218		96	259
	Average	**Matador**			**295**	**124**	**95.8**	**259**
	Average	**Control**			**244**		**95.2**	**267**
236	VSOC	Delegate	23.0	6,256	272	108	96	311
236	VSOC	Control	20.2	5,075	251		97	288
238	Kettle River	Delegate	22.4	6,576	294	138	96	229
238	Kettle River	Control	5.6	1,190	213		94	247
241	Sorrento	Delegate	19.0	3,489	184	141	96	236
241	Sorrento	Control	6.8	877	130		95	239
337	Grandview	Delegate	17.1	5,655	331	119	96	256
337	Grandview	Control	13.8	3,823	277		97	254
338	Grandview	Delegate	27.2	9,083	334	103	95	263
338	Grandview	Control	26.0	8,476	326		92	284
	Average	**Delegate**			**283**	**122**	**96.0**	**259**
	Average	**Control**			**239**		**95.8**	**262**

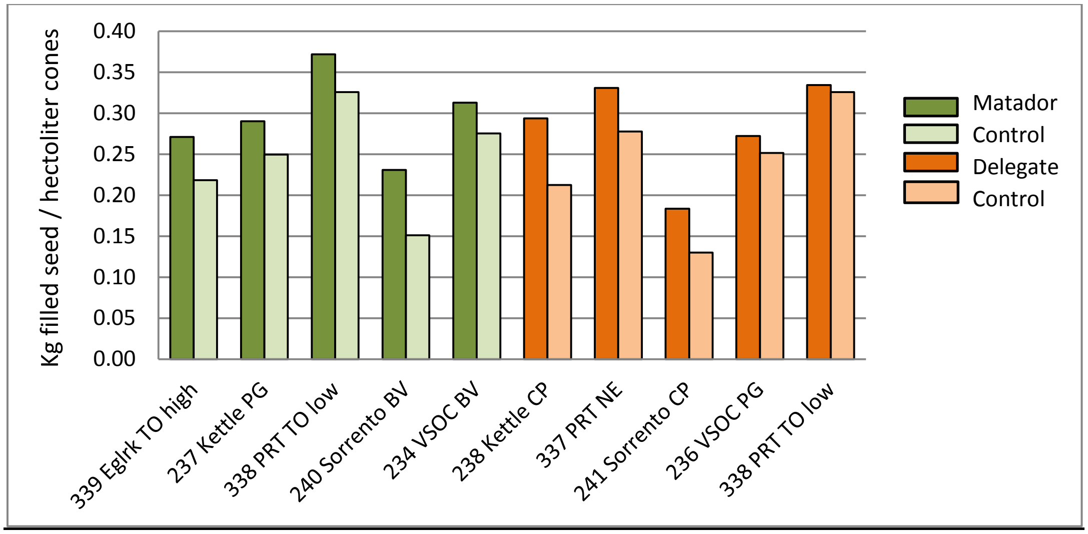

Figure 1 Operational seed yield in kilograms seed per hectoliter of cones by orchard and treatment type.

Value

Value, measured as dollars of seed produced per hectoliter of cones picked, increased $435 from applications of Matador and $370 from applications of Delegate. Pesticide application costs (chemical, labour, equipment) measured as $/hl cones or $ /kg seed vary a great deal among orchards due to different cone and seed yields. When averaged across all sites, spray costs averaged about $33 per hectoliter. Average costs per incremental kilogram of seed produced (estimated as extra seed yield in grams per hectoliter relative to control levels of seed yield) averaged $574 per kg. The benefit to cost ratio using a seed price of $8,300 per kg is about 15. Estimated overall potential value increase across all nine orchards used in these trials is estimated at $179,400 when estimated as the total seed yield and value had all areas of the orchard been sprayed relative to expected seed value had no spray treatments been applied. As Delegate application costs per hectare are higher than Matador costs, this benefit/cost ratio for Matador would exceed 15, on average.

Operational harvest timing effects

These results may have been influenced by the timing of operational harvest. It is well documented that seed set declines from mid July to late August (Weber, 2014). Operational constraints on crew organization during operational harvest do not always allow control of harvest timing. Therefore, spray and control blocks were generally harvested at different times. The probable impacts of operational harvest timing are discussed below for each orchard and are considered to have had a small and non-material impact on the overall results of this trial.

- The following orchards would have a bias towards higher seed yield in the control blocks relative to the spray blocks due to earlier harvest in the control blocks: 234 and 338 small bias; 339 larger bias.

- The following orchards would have a bias towards higher seed yield in the spray blocks relative to the control blocks due to earlier harvest in the spray blocks: 337 small bias; 236, 237, 238, and 240 moderate bias.

Harvest timing

Operational constraints of crew size, scheduling harvest from other orchards, and equipment such as picking ladders and lifts limit the ability of orchard managers to harvest lodgepole pine cones before substantial losses can result during the period immediately following cone maturity (typically late July to late August - the harvest period). The purpose of investigating the rate of filled seed losses during the harvest period in spray and control blocks was to evaluate the amount of management flexibility that might be provided if seed losses are reduced or eliminated.

Total formed seeds per cone (TSPC) was consistently higher by about two seeds in sprayed blocks compared to non-sprayed control blocks. Matador-treated blocks resulted in about 2.5 more TSPC and Delegate-treated blocks resulted in 0.9 more TSPC than control blocks. Changes in TSPC over the harvest period were minimal, with no clear pattern evident (Figure 2).

Filled seeds per cone (FSPC) was also consistently higher by about 2.9 seeds in sprayed blocks compared to non-sprayed blocks. Matador-treated blocks resulted in an average of 3.6 more FSPC gain relative to controls, while Delegate-treated blocks resulted in 2.2 more FSPC. The number of FSPC declined in control blocks during the harvest period. This decline was less evident in the spray blocks (Figure 2). Spray- and control-block differences in FSPC were small in mid July (about 1), but increased to nearly four FSPC by mid to late August. The results shown in Figure 2 are consistent with the operational collection data illustrated in Figure 1.

Individual orchards varied in the level of FSPC losses during the harvest period, but all orchards showed a decline. There was no pattern evident in TSPC and FSPC changes that related to different seed orchard populations (northern vs. southern) or to Lepto survey results.

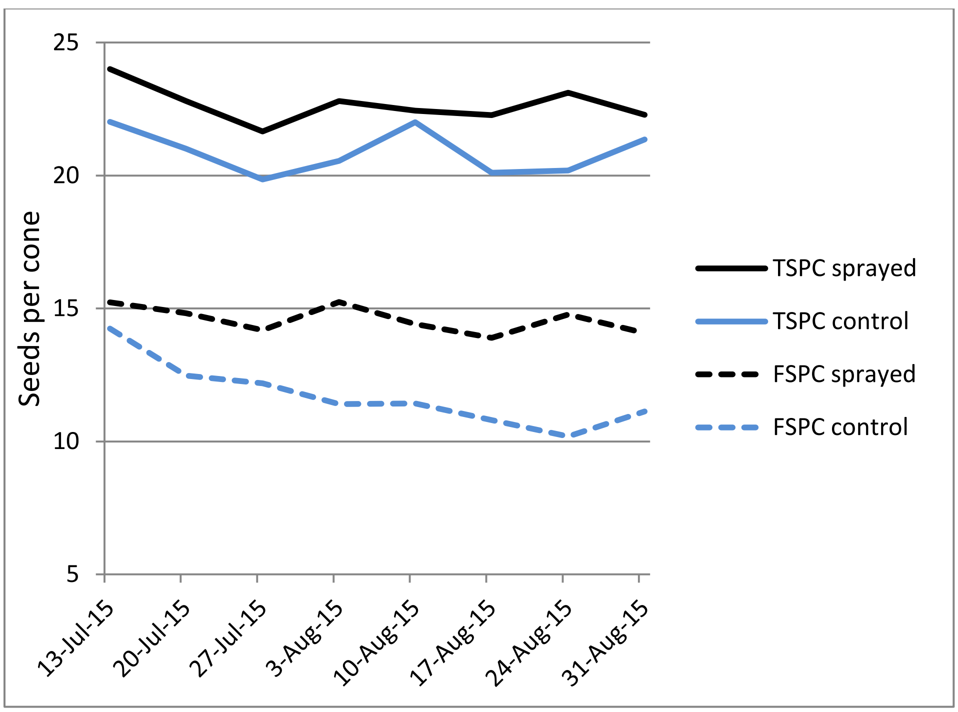

Figure 2 Average number of total formed seeds (TSPC) and filled seeds per cone (FSPC) in sprayed (Matador and Delegate treated combined) blocks relative to non-sprayed control blocks at weekly intervals from mid July to late August.

As TSPC and FSPC are correlated, some of the cone-to-cone differences in TSPC and FSPC are eliminated in the statistic percent filled seeds per cone (the ratio of FSPC/TSPC expressed as a percentage). Using this statistic (Figure 3), sprayed blocks show small and inconsistent declines in the % FSPC over the harvest period, while control blocks show a drop of about 15% for Matador and 10% for Delegate treatments.

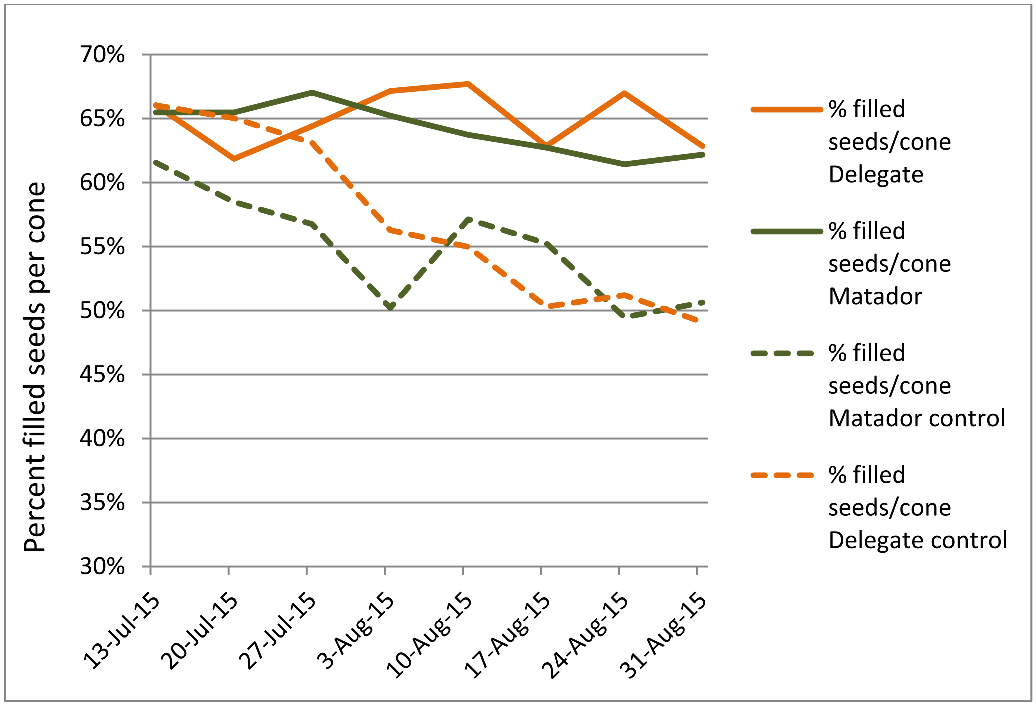

Figure 3 Average percent filled seeds by treatment type (Matador or Delegate) relative to control blocks at weekly intervals from mid July to late August.

Early versus late season seed losses

Strong (2015) demonstrated two periods during which Lepto appear to be feeding on Pli. Overwintering adult populations begin feeding in May (early season) and newly hatched nymphs begin feeding in larger numbers in early July through to September (late season). Woods et al. (2015) showed that filled seed losses can be attributed to early season and late season losses in approximately equal amounts. Early-season losses result in fewer TSPC, likely due to predation on unfertilized ovules or on very recently fertilized developing seeds. These predation events do not allow formed seed development, reducing TSPC. Late season predation impacts filled seeds, but does not change TSPC, as seed coats are already formed by early July and the number of formed seeds is not impacted by Lepto predation.

Data from this trial resulted in an average of 1.7 more TSPC in cones sampled in treated blocks relative to cones sampled in control blocks as part of the harvest-timing trial. It is assumed that each of these lost seeds could have formed a filled seed with equal probability to other seeds. Therefore, using the average percent FSPC for spray-treated blocks of 65%, approximately 1.1 FSPC are lost due to early season predation. In mid July, cones from spray blocks contain about 1.4 more FSPC than cones from control blocks. This suggests that only about 0.3 FSPC are lost to late-season predation by mid July. By late August about 3.8 FSPC had been lost, suggesting that late season predation accounted for an additional loss of 2.4 FSPC, or about 20% of the total crop.

These early and late season loss estimates are consistent with operational differences in seed yield observed in this study.

Discussion

The results of the trials reported here further support the hypothesis that seed predation from Lepto is a significant cause of poor seed set in lodgepole pine orchards in the southern interior. Both Matador and Delegate appear to be nearly equally effective at controlling Lepto predation, resulting in operational filled seed production increases relative to non-treated control areas of 24% for Matador and 22% for Delegate in these trials.

Filled seed gains result from controlling Lepto populations at two different feeding periods; May and early June when overwintering populations are feeding on non- or recently-fertilized ovules, and July-August when newly hatched nymphs begin feeding on maturing seeds. Early-season feeding reduces TSPC. As a percentage of these seeds would have been capable of becoming filled seeds, the number of filled seeds is subsequently reduced. In this study, early-season predation accounted for about a 10% loss of filled seeds. Late-season predation results in increasing losses from early July to late August as more and more seeds are impacted by feeding. By late August, this feeding accounted for an additional 20% loss of filled seeds in non-treated areas.

Results from this study support the conclusions of Woods et al. (2014), however, anecdotal observations of Lepto populations in 2014 suggest that they were much higher than in 2015. Weekly Lepto counts done as part of this study indicated small populations on some sites and only moderate populations on other sites. These smaller populations were reflected in the smaller difference between treated and control blocks in operational seed yield. In the 2014 study Matador treatment approximately doubled filled seed production, whereas in this study Matador treatments increased filled seed production in the same four orchards by only 27%. Even so, the value of the increased seed yields substantially exceeded the cost of treatments. A benefit to cost ratio of 85 was estimated.

The fact that a 23% increase in seed production was achieved despite what was in some orchards nearly undetectable levels of Leptoglossus illustrates two things. First, the Lepto monitoring system is inadequate. Leptoglossus hide well, and a visual monitoring system is inefficient. Unfortunately we have no alternative at present. Second, because of this, a spray threshold of a single observed Leptoglossus is appropriate. In fact, several orchards this year illustrated that sprays timed by calendar, without finding any Leptoglossus, were economically justified. Though it is difficult to recommend applying pesticides when no pests can be found, our inefficient monitoring system suggests that sprays timed by calendar are warranted until such time as we have better detection methods for Lepto.

The results from this study show that Lepto control with Matador or Delegate will substantially reduce seed losses during the critical period of cone harvest. This has the benefit of allowing managers to delay harvest to ensure seeds are mature and to extend the harvest period, providing for more flexibility with crew organization and scheduling.

Recommendations

- To control Lepto populations, Matador should be applied at the rate of about 100 milliliters per hectare using an airblast sprayer set to deliver a solution to the point of run-off.
- Applications of Matador should be applied about May 15th and June 25th in North Okanagan orchards, May 22nd and July 1st at Kettle River. A third application should be

considered if Leptoglossus are observed in spray blocks after July 1st or if harvest is extended or delayed beyond the first week of August.

- An URMULE for Delegate should be pursued to provide a second effective treatment that can be alternated with Matador to reduce the impact on non-target insect species.
- Twenty-minute Lepto counts should be conducted at least weekly to evaluate Lepto populations. If any Lepto are observed, an extended walk-through survey should be done to guide spraying decisions (note that Lepto are difficult to find and the observation any should be taken as an warning that more may be on the site).

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