Impact of Surround®, Pounce®, and Matador® on lodgepole pine filled seed production in southern interior BC seed orchards: 2017 trial

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Summary

Pesticide trials to control *Leptoglossus occidentalis* (Lepto) populations were implemented in eight lodgepole pine seed orchards to compare filled seed production. Treatments used were Matador, Pounce, Matador in combination with Surround, and a non-treated control. Results show average and significant increased filled seeds per cone (FSPC) of 60%, 41%, and 81% respectively, relative to the non-treated control. Differences among the three pesticide treatments, however, are not statistically significant.

Observed on two of the four sites (four of the eight orchards) in this study was a large and significant reduction in total seeds per cone (TSPC), and an associated reduction in FSPC, that was likely due to a late first application of pesticides.

Pesticide treatments using Matador or Pounce to control Lepto are recommended for mid to late May and again in late June or early July. Surveys of Lepto populations during May should guide an initial pesticide treatment, with this first treatment being applied as soon as possible after Lepto are detected. Later season pesticide treatments are also recommended based on Lepto surveys and should normally take place in late June to early July.

Recommendations are made for further investigations into the efficacy of Pounce relative to Matador, as the results obtained here are somewhat inconclusive. It is also recommended that comparisons of Surround with Matador be undertaken to better understand whether Surround acts through a cooling effect or through a pesticide effect. Data from this study suggest that benefits from using Surround are primarily due to a pesticide effect.

Introduction

This is the third in a series of reports on cooperative projects that evaluated the impact of commercially-available pesticides on lodgepole pine seed production when used to control western conifer seed bug (Leptoglossus occidentalis) populations (referred to as "Lepto" through the remainder of this paper). This project builds on earlier projects reported by Woods et al. (2015), Woods and Strong (2016), and Giampa (2016 pers. communication). Specifically, this trial is designed to evaluate the efficacy of Surround in combination with Matador, and of Pounce, a permethrin-based pesticide, relative to Matador alone and to a non-treated control. Seed set (filled seeds per cone) is the primary variable of interest.

The production of filled seed in many 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, 2015) 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 82% to 200% for treated blocks relative to non-treated control blocks (Woods et al. 2015). A 2015 trial with both Matador and Delegate showed that both improved filled seed production relative to an untreated control, but the improvement was less dramatic than in the 2014 trial (14% to 53% for Matador and 3% to 41% for Delegate). The lower success rate in 2015 is thought to be due to lower Lepto populations than in 2014. The 2015 trial also showed that Lepto control prior to harvest reduces seed losses during August, a critical period during which cone harvest is taking place.

A trial implemented by Gary Giampa in 2015 tested the effect of Surround (a kaolin clay product used in agriculture) on filled seed production in a single orchard. A primary objective of this trial was to provide lodgepole pine trees planted in the warm conditions of the Okanagan valley with a cooling effect from the light-coloured clay covering foliage and reflecting some sunlight. Surround is also marketed as a pesticide, as the gritty clay particles can interfere with the exoskeleton function of some insects. The 2015 trial showed an increase in filled seed production of 22% relative to a non-treated control.

The importance of treatment timing

Previous work by Strong (2015) on the timing of Leptos emergence and feeding suggests two key periods for control; late May through June when overwintering Lepto 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 abundant evidence (Bates et al 2000, Strong 2006, Strong 2013, Woods et al. 2015) 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 (TSPC). The later feeding reduces the number of filled and viable seeds (FSPC) that develop in the immature seeds that remain following the first feeding. This later feeding appears to take place for a longer period than the first feeding. The 2014 trial results suggested that filled-seed losses were about equally caused by early- and late-season predation. The 2015 trials (Woods and Strong 2016) showed that a late July treatment of Matador or Delegate resulted in less seed loss during the critical August and early September period when cone harvest is taking place. The trials reported here attempted to implement pesticide treatments to reduce Lepto populations at the beginning of both the early and late feeding periods (approximately late May and early June).

Questions addressed

The trials reported here were designed to specifically address the following questions:

Does Pounce increase seed set relative to no treatment, and is it as effective as Matador? The hypothesis for this question was stated in the working plan as: *there is no difference in the effectiveness of Matador and Pounce.*

Does Surround increase seed set beyond that achieved with Matador alone? If excessive heat is impacting seed set and if Surround is providing a cooling effect, then using Matador and Surround together are expected to have an additive effect and seed set should be higher than with using either alone. However, if Surround is increasing seed set due to its acting as an insecticide, then the use of Matador and Surround together are expected to have a similar impact on seed set as Matador alone. This assumes that Matador effectively eliminates Lepto following spraying, so there would be no Lepto remaining for Surround to impact. The hypothesis for this question was stated in the working plan as*: Surround effects are additive to Matador effects.*

Methods

Orchards

Eight orchards located on four sites in south-central British Columbia participated in this trial (Table 1). Two sites (Grandview, 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. Sorrento is in a somewhat cooler ecosystem, but Lepto has historically been a problem on the site. Kettle River is in a cooler ecosystem than Sorrento, and Lepto have been less of a problem than at the other three sites.

To address the key questions, the following treatments were used:

1. Control – no pesticide application
2. Matador
3. Pounce
4. Matador followed immediately with a treatment of Surround (Matador+Surround)

Each orchard was divided into from two to four blocks (Table 2). Smaller orchards were divided into only two or three blocks due to the need for a large block size to properly simulate whole-orchard treatment and to reduce the rate at which Lepto migrate back into a block following treatment. Block assignments to each orchard were structured to simplify spray applications, with consideration to the logistics of how a tractor-puller sprayer can be utilized and turned on the edges of each block.

Table 1 Site location and climatic information for the eight lodgepole pine seed orchards participating in the study.

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

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

Table 2. Number of ramets per treatment block.

			Number of ramets by treatment			
Orch #	**Location**	**SPU**	**#1 Control**	**#2 Matador**	**# 3 Pounce**	**#4 Matador + Surround**
237	Kettle River orchards	PG low	**896**	**536**	**2491**	**551**
238	Kettle River orchards	CP low	**492**	**572**	**1257**	**624**
337	PRT Armstrong	NE low	**-**	**436**	**555**	**-**
338	PRT Armstrong	TO low	**539**	**1201**	**2208**	**734**
240	Sorrento Nurseries	BV low	**-**	**686**	**1703**	**697**
241	Sorrento Nurseries	CP low	**609**	**907**	**483**	**-**
234	Vernon Seed Orch. Co.	BV low	**534**	**431**	**1453**	**449**
236	Vernon Seed Orch. Co.	BV low	**643**	**779**	**1996**	**789**
Totals			**3713**	**5548**	**12146**	**3844**

Pesticides and 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. This rate was used for these trials.

Pounce is a permethrin insecticide commonly used in agriculture. Other very similar permethrin products are Perm-Up and Ambush. Pounce is registered for use in seed orchards (Seeding Trees Reforestation Areas on the label) and for some conifers, including pine trees. Some restrictions apply. The application rate is 175 ml of product per ha applied as a ground spray. Pounce is a broad-spectrum insecticide with unknown control and residual effects on Lepto. It has a 12-hour re-entry period.

Surround is a kaolin clay product that forms a barrier to sunlight and thereby has a cooling effect that may reduce tree stress during hotter periods. In addition, the gritty clay particles are a deterrent to many insects. Because of this deterrent property, Surround is sometimes used as a method to control insect populations in agricultural crops.

Matador and Pounce were applied to label specifications on the dates shown in Table 3. Surround was applied at the rate of 25kg per hectare, as recommended by Gary Giampa and Mark French from Kalamalka Seed Orchards. All sites used an airblast tank sprayer pulled by a tractor. Nozzles were low and set to spray the pesticide mix up into the crowns of orchard trees. Tree heights are under 5 meters (with very few exceptions) and spray reached above the crowns and settled back onto the crowns.

A notable difference between how Surround was applied in this trial and how it was applied in trials done at Kalamalka is the nozzle heights for the sprayer. Kalamalka has a lift system that allows spray from nozzles set much higher, allowing spray directly onto the upper crown. It was noted that the amount of Surround visible on ramets at each site in this study was less than what was observed at the Bailey Road orchard. However, all orchard blocks treated in this trial had a clearly visible whitish hue from the Surround treatment. Likely due to the low height of the airblast sprayer nozzles, the lower crowns of the ramets treated in this trial appeared to have more Surround coverage than the upper crowns.

Table 3 Pesticide application dates by site.

Orchard no.	Site	1st application date	2nd application date
237	Kettle River	June 4-6	July 28
238	Kettle River	June 4-6	July 28
337	Grandview	May 19	June 29
338	Grandview	May 19	June 29
240	Sorrento	June 6, 7	July 13, 14
241	Sorrento	June 6, 7	July 13, 14
234	VSOC	June 6	July 14
236	VSOC	June 6	July 14

Cone and seed sampling

Within each treatment block, a central area was designated for cone sampling that was separated from the edge of the block by at least four orchard rows to reduce edge effects. A single sample of 80 cones was collected from each treatment block. Where possible, no more than two cones were collected from each orchard clone to ensure a broad and representative sample of parental clones. In some cases, cones were not found on 40 different clones, so the sample of 80 cones was made on fewer than 40 clones. In no instance were more than two cones sampled from a single ramet.

Eighty-cone samples from each treatment block in each orchard were bulked to a single sample and placed in appropriately-labelled paper bags. Cones from all samples 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 from each treatment sample was recorded (80 in all cases). Seeds were X-rayed to allow counts of the number of filled seeds among the formed seed that were extracted. For each of the 28 samples, 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 per cone (%FSPC = FSPC/TSPC).

Lepto surveys

Surveys for Lepto populations were conducted weekly on all sites using a timed 20-minute walk through each orchard or treatment block and recording the number of Lepto observed. Prior to the first spray, most sites did a single survey of the whole orchard. Following the first treatments, the 20-minute surveys were done weekly within each treatment block.

Data analysis

Means were calculated for TSPC, FSPC and, %FSPC by treatment and orchard. Statistical significance was tested with an analysis of variance using the following model:

Table Analysis of variance model to evaluate the relative effects and significance of treatments and orchards.

Variable	Df	SS	MS	F
Orchards	7	SSo	SSo/7	MSo/MSe
Treatments	3	SSt	Sst/3	MSt/MSe
Error	21	SSe	SSe/21	
Total	31	SStot		

Comparisons among treatments were done using a Holm correction test (stepdown Bonferroni).

Results and discussion

Lepto surveys

Lepto surveys were, in most cases, done by the same person on each site, but different people across sites. Observational skills will differ by surveyor, but these skill differences cannot be separated from site differences in Lepto numbers. Site managers attempted to conduct surveys during dry warm periods when Lepto are more active. However, weather differences occurred between weeks on each site, as well as between sites for a given week. These sources of error in Lepto counts can't be adjusted or properly evaluated among sites and must, therefore, be used only as a broad indicator of the actual Lepto populations at the time of a survey. Survey accuracy is considered to be adequate for the inference of general trends in Lepto populations before and after treatments.

Prior to the first treatments, some surveys were done at the whole-orchard level rather than by treatment block. Following the first treatments, all surveys were done by treatment block. No surveys were conducted following the collection of cone samples.

Table 5 Counts of Lepto by week, location, and treatment block. Prior to the first spray treatments, most sites conducted a single survey for the orchard rather than surveys by treatment block. All surveys were done with 20-minute visual walk-through. Dates of sample collections are shown. n/a indicates that no survey was conducted. Orange-filled cells indicate approximate spray dates.

Orch. #	Site	SPU	Treatment	April 24	May 1	May 8	May 15	May 22	May 29	June 5	June 12	June 19	June 26	July 4	July 10	July 17	July 24	July 31	Aug. 7
237	Kettle	PG	Control	n/a	0	0	0	0	0	1	0	0	0	0	1	0	0	n/a	Collect samples
237	Kettle	PG	Matador							0	0	0	0	0	3	0	0	n/a	
237	Kettle	PG	Matador + Surround							0	0	0	0	0	0	0	1	n/a	
237	Kettle	PG	Pounce							0	0	0	0	0	4	3	3	n/a	
238	Kettle	CP	Control	n/a	0	0	0	0	0	n/a	0	0	0	0	0	0	0	n/a	
238	Kettle	CP	Matador							n/a	0	0	0	0	2	0	0	n/a	
238	Kettle	CP	Matador + Surround							n/a	0	0	0	0	1	0	0	n/a	
238	Kettle	CP	Pounce							n/a	0	0	0	0	2	0	0	n/a	
337	Grndv.	NE	Matador	n/a	0	n/a	n/a	0	3	3	n/a	14	n/a	0	0	0	0	2	
337	Grndv.	NE	Pounce			n/a	n/a	1	3	3	n/a	13	n/a	0	0	0	0	1	
338	Grndv.	TO	Control	n/a	0	n/a	7	1	4	4	n/a	6	n/a	0	2	2	11	1	
338	Grndv.	TO	Matador			n/a		0	0	3	n/a	9	n/a	0	0	0	0	0	
338	Grndv.	TO	Matador + Surround			n/a		0	0	0	n/a	n/a	n/a	0	0	0	0	0	
338	Grndv.	TO	Pounce			n/a		3	8	9	n/a	20	n/a	0	1	1	0	3	
240	Sorrento	BV	Matador	n/a	0	0	0	n/a	5	2	0	0	2	3	2	0	0	Collect samples	
240	Sorrento	BV	Matador + Surround								0	0	1	1	0	0	0		
240	Sorrento	BV	Pounce								0	0	5	0	7	1	0		
241	Sorrento	CP	Control	n/a	0	0	0	n/a	3	0	3	3	7	2	5	10	2		
241	Sorrento	CP	Matador							0	0	0	1	2	2	0	0		
241	Sorrento	CP	Pounce							0	1	1	4	0	2	1	0		
234	VSOC	PG	Control	0	0	0	0	5	3	1	2	3	0	0	Sprayed - no survey	n/a	Collect samples		
234	VSOC	PG	Matador					5	6	0	0	0	0	0		n/a			
234	VSOC	PG	Matador + Surround					5	10	0	0	0	0	1		n/a			
234	VSOC	PG	Pounce					12	6	0	0	2	1	0		n/a			
236	VSOC	PG	Control	0	0	0	0	12	9	2	2	0	0	0		n/a			
236	VSOC	PG	Matador					18	7	0	0	0	0	0		n/a			
236	VSOC	PG	Matador + Surround					10	8	0	0	0	0	0		n/a			
236	VSOC	PG	Pounce					8	4	0	0	2	0	0		n/a			

Total seeds per cone

Seeds that were successfully pollinated the previous year will expand to fully formed seeds in the early spring period if no events, such as insect predation, stop development (Owens, 2006). Therefore, TSPC is a measure of the number of pollinated seeds that were healthy and still had the potential to become filled seeds at the time seed coat development and formation is complete in approximately late May to mid-June. TSPC includes both filled seeds which have complete embryo and megagametophyte development (FSPC), and non-viable empty seeds that were pollinated and healthy until an abortion-causing event during the spring. In a 2014 study (Woods et al. 2015) about half of the total loss in FSPC to Lepto predation was attributed to early feeding that eliminated potential seeds before a seed coat fully formed (i.e. reduced TSPC). The remaining loss of FSPC were due to later-season predation that reduced the number of filled seeds among the already formed seeds.

TSPC treatment means are shown in Table 6. Based on an ANOVA these differences are not significantly different ($p>0.22$). Orchard effects are significant, however ($p<0.04$). Review of Lepto survey data and knowledge of the sites and phenological stages suggests that the initial pesticide-treatment timing at Grandview was early enough to control high Lepto populations before substantial feeding of over-wintering Lepto. At Kettle, almost no Lepto were observed through most of the summer, so it's likely that the first treatment had little effect on TSPC. At VSOC, Lepto survey counts were high for at least two weeks prior to the first spray application. At Sorrento, surveys were not applied in a consistent manner, but it is likely that Lepto populations were reasonably high for at least two weeks prior to the first treatment. Orchard mean TSPC for VSOC and Sorrento orchards ("late" treatment) are much lower than for Grandview and Kettle orchards ("early" treatment). These differences among early- and late-treatment sites are significant (p<0.001) and account for a confounding of orchard differences in TSPC with pesticide treatment differences in the mixed-model ANOVA used because most of the reduction to TSPC at VSOC and Sorrento likely took place before the first treatment. In addition, due to small orchard size and some treatments not being applied (missing cells in Table 6), the sample size for the comparison of the control treatment with the three pesticide treatments on a site with Lepto pressure is reduced to a single sample (orchard 338).

Table 6 TSPC by orchard and treatment. Based on ANOVA across all sites, differences between treatments are not significant (P>0.05). Blank cells indicate no data.

			Treatment				
Orchard	**Site**	**SPU**	**Control**	**Matador**	**Pounce**	**Matador + Surround**	**Orchard mean**
337	Grandview	NE low		21.0	19.7		20.3
338	Grandview	TO low	16.6	22.9	17.3	26.3	20.8
237	Kettle	PG	26.4	25.7	26.6	27.8	26.6
238	Kettle	CP	15.5	29.9	22.8	20.3	22.2
234	VSOC	BV	11.3	13.6	13.7	11.3	12.5
236	VSOC	PG	12.4	11.5	14.7	12.1	12.7
240	Sorrento	BV		9.4	7.1	9.8	8.8
241	Sorrento	CP	7.0	6.5	7.3		6.9
Treatment mean			14.9	17.6	16.1	17.9	
Percent increase over control				18%	9%	21%	

Filled seeds per cone

Filled seeds result when a potential seed successfully completes fertilization, followed by embryo and megagametophyte development that is uninterrupted to the time of seed maturity and sampling. Filled-seed counts in these trials are based on X-ray photographs, and are assumed to correlate strongly with actual viable seed production.

FSPC results by orchard and treatment are shown in Table 7. Based on ANOVA, these results show highly significant (p<0.01) treatment and orchard effects. All pesticide treatments result in a significant (P<0.05) increase in FSPC relative to the non-treated control blocks. Differences among pesticide treatments are not significant (P>0.6). Both the Matador and the Matador+Surround treatments resulted in greater FSPC than the Pounce treatment, as well a more favorable probability that they are significantly better than the control. However, based on these data there are no strong indicators that any differences exist among the three pesticide treatments used.

Table 7 FSPC by orchard and treatment. Probabilities that treatments are different from the control are based on ANOVA and multiple comparisons using a Holm correction. Blank cells indicate no data.

			Treatment				
Orchard	Site	SPU	Control	Matador	Pounce	Matador + Surround	Orchard mean
337	Grandview	NE low		8.3	6.7		7.5
338	Grandview	TO low	3.7	11.6	8.0	12.1	8.9
237	Kettle	PG	10.9	14.3	12.3	18.5	14.0
238	Kettle	CP	6.7	15.8	13.8	12.4	12.2
234	VSOC	BV	6.3	7.5	8.4	6.7	7.2
236	VSOC	PG	3.7	5.1	7.7	6.2	5.7
240	Sorrento	BV		4.9	2.2	4.1	3.7
241	Sorrento	CP	1.8	3.0	2.9		2.6
Treatment mean			5.5	8.8	7.7	10.0	
Percent increase over control				60%	41%	81%	
Probability of difference from control				0.007	0.044	0.007	

Percent filled seeds per cone

The percentage of FSPC relative to TSPC (%FSPC) is a good measure of seed losses during the late summer in seeds that were successfully fertilized and remained healthy long enough to develop a formed seed coat. Based on ANOVA of %FSPC data, treatment effects were highly significant ($P<0.001$).

Table 8 %FSPC by orchard and treatment. Probabilities that treatments are different from the control are based on ANOVA and multiple comparisons using a Holm correction. Blank cells indicate no data.

			Treatment				
Orchard	Site	SPU	Control	Matador	Pounce	Matador + Surround	Orchard mean
337	Grandview	NE low		40%	34%		37%
338	Grandview	TO low	22%	51%	46%	46%	41%
237	Kettle	PG	41%	56%	46%	67%	53%
238	Kettle	CP	43%	53%	61%	61%	54%
234	VSOC	BV	55%	55%	61%	59%	58%
236	VSOC	PG	30%	45%	52%	51%	44%
240	Sorrento	BV		52%	30%	42%	41%
241	Sorrento	CP	26%	46%	39%		37%
Treatment mean			36%	50%	46%	54%	
Percent increase over control				37%	28%	49%	
Probability of difference from control				0.002	0.011	0.001	

As with FSPC, multiple comparisons using a Holm correction shows a highly significant difference ($P<0.002$) between the non-treated control and both the Matador and the Matador+Surround treatment. The difference between the Control and the Pounce treatment is also significant ($P<0.02$), but less favorable. Differences among the three pesticide treatments are not significant ($P>0.39$).

Discussion

These trials show that the control of Lepto populations increases filled seed production in lodgepole pine and support the results from previous trials undertaken in 2014 and 2015. The first hypothesis these trials set out to test (there is no difference in the effectiveness of Matador and Pounce) is accepted, as no significant differences were noted in the FSPC production between the two pesticides. However, the lower overall FSPC and %FSPC result obtained for Pounce relative to the other treatments and the lower level of significance for differences between the Pounce and control treatments are indicators that Matador may be more effective than Pounce. If Pounce is less effective than Matador, the experimental design used did not clearly demonstrate this. Further investigation is warranted to further test the relative efficacy of these two pesticides.

The second hypothesis (Surround effects are additive to Matador) is rejected, as no significant differences were found in FSPC production following an additional treatment with Surround in a Matador-sprayed block, relative to treatment with Matador alone. As discussed previously, Surround may impact filled-seed production through a cooling effect that could result in less stress, or through a pesticide effect due to the gritty kaolin clay particles impacting insects. As there was no significant improvement in filled seed production when Surround was used after Matador relative to using Matador alone, it is likely that previously observed modest improvements in filled seed production at Kalamalka in 2015 (22%) was due more to a pesticide effect than to cooling. However, this assertion should be further tested, as the applications of Surround in the trials reported here likely resulted in a less complete coverage of the product on foliage than was achieved in the Kalamalka trial. Also, it is likely that most of the orchards in this trial are under less physiological stress than the orchard used for the 2015 Kalamalka trial.

Data here support conclusions of Strong (2015) and Woods et al. (2015) that about half of the loss in filled seed is due to Lepto predation by over-wintering adults feeding on developing seeds from about mid-May to mid-June. Losses during this period reduce TSPC and the number of viable seeds in a cone that can develop during the late spring and early summer. The remaining losses appear to take place from mid-July through to late September (Woods and Strong 2016). For operational control of Lepto feeding, a first pesticide spray in mid-to-late-May to reduce over-wintering Lepto populations is likely the most critical treatment as it has a large impact on the potential number of seeds available for development through the remainder of the spring and summer. Furthermore, if uncontrolled, these adults give rise to progeny that consume seeds later in the summer. A second spray in late-June to mid-July can be undertaken based on observed Lepto populations. Quick harvest beginning about the last week of July or the first week of August will help avoid Lepto predation from developing nymphs and adults during the August and September feeding period.

Recommendations

1. Trials to further compare the efficacy of Pounce relative to Matador are warranted.
2. Comparison of Matador with Surround on more stressful sites such as Bailey Road, Kalamalka, and VSOC would help to determine if Surround is improving seed set because of cooling and associated stress reduction or because of a pesticide effect. These trials should include blocks with Matador, Surround, and Matador+Surround.
3. Pesticide treatments to control Lepto should be applied in mid to late May on north Okanagan sites and as soon as possible after surveys detect any Lepto.

4. Summer pesticide treatments to control Lepto should be applied based on surveys.
5. Early and quick cone harvest should be carried out beginning in late July or the first week in August, as is the current practice on most sites.

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References

Bates, S.L., J.H. Borden, A.R. Kermode and R.G. Bennett. 2000. Impact of *Leptoglossus occidentalis* (*Hemiptera: Coreidae*) on Douglas-fir seed production. Journal of Economic Entomology 95:1444-1451.

Strong, W.B. 2006. Seasonal changes in seed reduction in lodgepole pine cones caused by feeding of *Leptoglossus occidentalis* (*Hemiptera: Coreidae*). The Canadian Entomologist 138:888-896.

Strong, W.B. 2015. Lodgepole pine seedset increase by mesh bagging is due to exclusion of *Leptoglossus occidentalis* (*Hemiptera: Coreidae*). Journal of the Entomological Society of British Columbia 112:3-18.

Strong, W.B. 2009-2013. Forest Genetics Council Pest Management TAC reports 2009-2013, http://www.fgcouncil.bc.ca/ptac-area.html

Strong, W.B. 2015. Thermocouples, iButtons, and Lepto-cams: understanding the low Pli seedset problem. TIC Talk, Feb 2015, pp 13-18, http://www.fgcouncil.bc.ca/TICtalk2015_Vol12_Feb18_2015.pdf)

Owens, J. N 2006. The reproductive biology of lodgepole pine. Forest Genetics Council of BC Extension Note 07. 62pp. http://www.fgcouncil.bc.ca/ExtNote7-Final-web.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA - High-Resolution Spatial Climate Data for Western North America. Journal of Applied Meteorology and Climatology, 51(1), 16:29.

Woods, J., Strong, W., and Carlson, M. 2015. Matador® impacts on lodgepole pine filled seed production in southern interior BC seed orchards. Unpublished technical report. pp 13. See http://www.fgcouncil.bc.ca/doc-10-technicalreports.html

Woods, J. and Strong, W. 2016. Impact of Matador® and Delegate® on lodgepole pine filled seed production in southern interior BC seed orchards: 2015 trial. Pp 12. See http://www.fgcouncil.bc.ca/doc-10-technicalreports.html