Impact of Matador® on lodgepole pine filled seed production in southern interior BC seed orchards: 2014 trial

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Introduction

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. Many possible causes have been suggested and researched (Webber, 2014). This report summarizes the methods and results from four lodgepole pine seed orchards that applied the pesticide, Matador®, to control *Leptoglossus occidentalis* (Leptoglossus) populations during the 2014 cone production season.

Previous trials with Matador® (Strong, 2009-2013) showed promise for this pesticide to control Leptoglossus populations. Matador® is registered for use against similar insect pests such as the apple brown bug (*Halyomorpha halys*) and the tarnished plant bug (*Lynus lineolaris*). It is used on a wide variety of food crops, but it is not currently registered for use on lodgepole pine or other conifer seed orchards. Previous trials with lodgepole pine were done on a single-tree basis. For a highly mobile insect such as Leptoglossus, the very small experimental unit of a single tree is considered inadequate, as re-infestation of a treated tree from surrounding trees is expected soon after spraying. The trials reported here were implemented to test the use of Matador® on a larger area within each orchard, on the assumption that Leptoglossus is unable to readily re-infest the sprayed area within the time frame required for seed development.

Research done over several years, summarized by Webber (2014) consistently resulted in more filled seeds per cone (FSPC) when cones were protected with a screen bag to exclude insects relative to cones that were not protected from insects. Although not always definitive, these trials have suggested that Leptoglossus was impacting FSPC production. For comparison, the trials described here also included insect exclusion bags and controls.

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, and early July through to late August or early September when newly hatched nymphs begin to feed on developing seeds and mature to adults. It is believed 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 is thought to reduce the number of filled and viable seeds. As the product of a seed orchard is viable seed, both feeding periods will reduce filled-seed production by first reducing the total number of developing seeds, and by then reducing the number of filled seeds among those still developing after the first feeding period.

The trials reported here followed a common protocol and consist of three components:

- Operational-level treatment with Matador® of up to a 5 hectare spray block and a non-sprayed control, followed by operational cone collection and seed extraction.
- Insect exclusion bagging of cones on twenty parental clones in both the spray and control blocks. Bagged- and non-bagged-cone collections followed by seed extraction and counting seeds from individual cones.
- Collections of a random sample of cones prior to operational harvest (mid July), followed by seed extraction and counting seeds from individual cones.

These trials were undertaken by orchard owners on a collaborative basis. Funding was from the Ministry of Forests, Lands and Natural Resource Operations and the Forest Genetics Council of BC

through Land Based Investment Strategy funds, and from SelectSeed Ltd. Orchard owners collaborated on experimental design to ensure that the results from individual orchard trials would be comparable and could be analyzed as a single experiment.

Methods

Sites

Four orchards located on four different sites in south-central British Columbia collaborated on this trial (Table 1). Two sites (Grandview and Eaglerock) 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.

Table 1 Site location and climatic information for four lodgepole pine seed orchards where Matador® trials were implemented.

Orchard no.	Seed planning unit	Site	Latitude	Elev. (m)	Mean annual temp. (C)	Mean annual precip. (mm)	Mean summer precip. (mm)
339	Thompson Okanagan high elev.	Eaglerock	50°23'48	520	7.2	536	240
237	Prince George	Kettle River	49°12'60	636	6.7	453	185
338	Thompson Okanagan low elev.	Grandview	50°23'15	483	7.1	481	209
240	Bulkley Valley	Sorrento	50°52'08	521	6.8	585	248

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 sold by Sygenta Canada Ltd. It is currently registered for use on many pests, including the apple brown bug in apple orchards and the tarnished plant bug (*Lynus lineolaris*) 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.

Under Pest Management Regulatory Agency (PMRA) a pesticide registered for a similar pest may be used on a trial basis on an area of up to 5 hectares by a single site owner (Regulatory Requirements for Research on Pest Control Products – Appendix 1 – Page 3). As the orchards listed in Table 1 are all well over 5 hectares in size, a single approximately 5 hectare spray block was chosen, and the remainder of each orchard was left unsprayed as a control (Table 2).

Table 2 Orchard spray and control areas and number of ramets.

Orchard no.	Site	Spray-block area (ha)	Spray block no. ramets	Control-block area (ha)	Control block no. ramets
339	Eaglerock	4.2	1884	1.8	818
237	Kettle River	5.0	2382	4.8	2294
338	Grandview	4.3	2004	3.8	1793
240	Sorrento	3.4	1543	3.4	1543

Matador® was applied at or below the label rates specified for the tarnished plant bug on peach and nectarine orchards (Table 3). Dilution rates and the application rate used for the product-water mix were determined independently at each site with the goal of applying the solution to the point of run-off using the air-blast spray equipment available at each site. Applications were timed to control Leptoglossus populations at the beginning of each of the two feeding periods (late May and early July). Spray timing and rates differed between the sites, as orchard managers worked around other constraints, such as local weather, and used their judgment based on surveys. Product costs per hectare are shown in Table 3. Control blocks were not sprayed with Matador®, water, or any other pesticide. Orchard management in the spray and control blocks was otherwise identical across both blocks on each site.

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

Orchard no.	Site	Application dates	Application rate (ml product /ha)	Dilution rate in water (ml / 1000 L)	Liters solution applied per ha	Product cost per ha
339	Eaglerock	May 30	104	208	500	$25
339	Eaglerock	June 25	104	208	500	$25
237	Kettle River	June 4/5	92	69	1324	$22
237	Kettle River	July 1	71.4	79	908	$17
338	Grandview	May 15	104	103	1076	$25
338	Grandview	June 14	104	103	1076	$25
338	Grandview	July 21/22	104	103	1076	$25
240	Sorrento	June 2	104	175	570	$24
240	Sorrento	July 13	104	175	570	$24

Operational-level data collection

The purpose of the operational-level data collection was to compare the use of Matador® versus no spray at an operational level of management.

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 and shipped on September 13-14, 2014 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 2014) for the spray and control blocks in each orchard.

Orchard no.	Site	Spray-block collection dates	Control-block collection dates
339	Eaglerock	Aug. 13 - Aug. 28	July 29 - Aug. 8
237	Kettle River	Aug. 10 - 14	Aug. 14 - 19
338	Grandview	Aug. 15 - 22	Aug. 11 - 15
240	Sorrento	Aug 13 - 22	Aug 15 - 22

Insect-exclusion bag data collection

The purpose of the insect-exclusion bag data collection was to compare FSPC between bagged and non-bagged cones in both the spray and control blocks, with control of parental clones across treatments. In each orchard, one ramet with sufficient cones was chosen from each of 20 parental clones in both the spray and control blocks in each of the four orchards (Figure 1). The 20 parental clones used were different for each orchard, as each of the orchards contains genetic material for a unique seed zone and there is no parental-clone overlap between orchards. The purpose for using the same set of parental clones in spray and control blocks was to ensure a comprehensive sample of orchard parents and to reduce uncontrolled variation caused by the use of different orchard parents. There is no intent in this study to describe seed set for specific parental clones, and the sample size at the clonal level is too small to provide reliable data. Therefore, clonal effects on seed set are not discussed further.

Screen-mesh insect exclusion bags were put over branches containing up to seven cones on each selected ramet in the spray and control blocks for each orchard from April 25 to April 28, 2014. This resulted in 20 bags by 2 treatments by 4 orchards for a total of 160 bags. At the same time the insect exclusion bags were put on, five other cones on the same ramets and near the bags were marked with flagging tape for later collection. These cones were the non-bagged control.

Orchard	Treatment	Bagged	Not bagged
Orchard 1	Sprayed	20	20
	Not sprayed	20	20
Orchard 2	Sprayed	20	20
	Not sprayed	20	20
Orchard 3	Sprayed	20	20
	Not sprayed	20	20
Orchard 4	Sprayed	20	20
	Not sprayed	20	20
	Total	160	160

Figure 1 Graphic of treatments for bagged/not bagged and sprayed/not sprayed treatments on ramets from the same 20 parental clones within each orchard.

Cones contained within insect exclusion bags and cones flagged as controls were collected from all treatments and orchards from August 4th to 7th. For each orchard, cones from each clone/spray/bag treatment combination were placed in paper bags and appropriately labeled. This resulted in a total of 80 bags per orchard, each containing from two to seven cones. Not all collections resulted in the target of five cones due to some cone loss during the summer.

Cones from all orchards 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 320 samples in Figure 1, 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).

Early random cone collections

Between July 13th and 17th samples of from 20 to 36 cones were collected in both the spray and control blocks at each site. Cones were sampled in a non-biased way, with no clonal control, by walking through the orchard and picking 1 cone from each of from 20 to 36 ramets. Cones were held in paper bags. Cone drying, seed extraction, and counting followed the same protocol described above tor the insect-exclusion bag trial.

Leptoglossus surveys

Surveys of Leptoglossus occurrence were conducted from time to time at each site. Methods varied among sites, but in all surveys cones were observed and counted during a walk through each orchard. As Leptoglossus are difficult to find and the ability to find them can vary with weather and observer acuity, these surveys are considered to provide only a rough guideline of actual Leptoglossus density.

Data analysis

Operational collections and early random cone collections: Data were analyzed with a paired 2-sample T-test.

Insect exclusion bag collections: A mixed-model randomized-block split-plot ANOVA with four factors was used. Factors were orchard (random), clones within orchard (random), spray (fixed), and bag (fixed). Only factors spray, bag, and the spray*bag interaction were tested.

Results and discussion

Leptoglossus surveys

Walk-through surveys of Leptoglossus occurrence provided rough guidance on population density, however, these data are not sufficiently reliable to allow correlation with seed statistics. These data do, however, suggest that Matador® treatment successfully reduced Leptoglossus populations in spray blocks.

Survey average observed number of Leptoglossus across all sites before spraying, including surveys done three or more weeks after a spray treatment, was 2.5 for spray blocks and 3.0 for control blocks, with a range from 0 to 9. The observed number within three weeks after a spray treatment averaged 0.2 (range 0 to 2) in spray blocks and 3.6 (range 0 to 13) in control blocks.

Operational-level data

Filled seed yield in grams per hectoliter of cones from Matador® treated blocks ranged from 182% to 300% more than from non-treated control blocks, across the four orchards (Table 5, Figure 2). Seed weight, and seed germination were not significantly different between the treated and control blocks ($p > 0.1$). Yield differences between treated and control blocks were highly significant ($p = 0.004$). No significant differences or obvious patterns for differences in seed weight and seed germination were observed, suggesting that these statistics were not affected by the application of Matador®.

These results may have been influenced by harvest timing (Table 4) at all sites. It is well documented (Webber, 2014) that seed set declines from mid July to late August. Therefore, the following are the likely impacts of differences in harvest timing:

- Sorrento - harvest of the control block was after harvest of the spray block. This would result in a reduction of FSPC relative to the spray block and likely exaggerated the effect of Matador® treatment.

- Eaglerock - harvest of the control block preceded harvest of the spray block, likely reducing the actual effect of Matador® treatment.
- Grandview and Kettle River - spray and control block harvest took place at the same time or close to the same time. Therefore, there is no meaningful impact of harvest timing is expected.

Table 5 Yield, germination percent, and weight of seed from Matador® treated and control blocks across four lodgepole pine seed orchards.

Orchard no.	Site	Treatment	Hl cones	Grams filled seed	Grams seed / hl cones	Yield as % of control	Seed germ. %	Seeds / gram
339	Eaglerock	Matador®	35.0	4,824	138	182%	96	220
339	Eaglerock	Control	15.8	1,193	76		91	222
237	Kettle River	Matador®	19.2	4,728	246	199%	94	235
237	Kettle River	Control	22.8	2,819	124		97	242
338	Grandview	Matador®	37.5	10,730	286	186%	98	225
338	Grandview	Control	21.8	3,343	154		96	246
240	Sorrento	Matador®	12.1	1,638	135	300%	96	277
240	Sorrento	Control	8.4	378	45		94	278

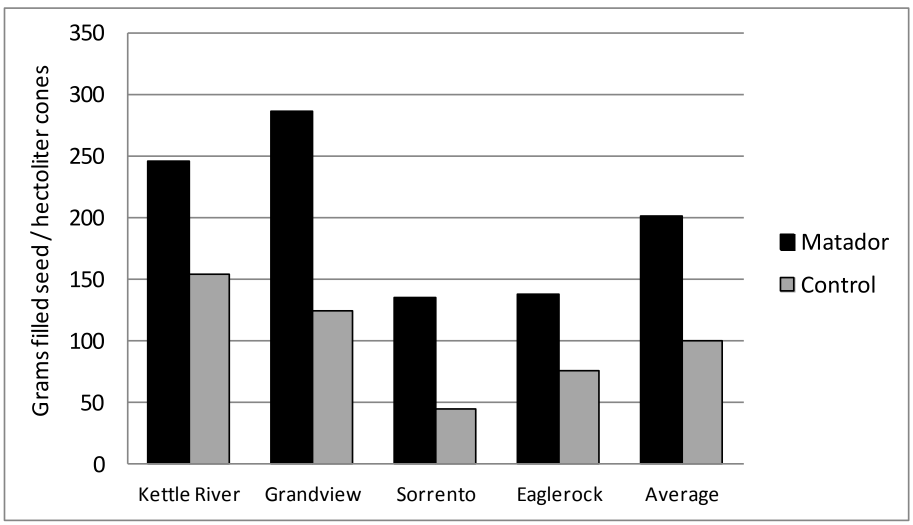

Figure 2. Operational yield of seed by orchard for Matador® treated and control blocks.

Insect-exclusion bag data

a. Whole-model analysis

Insect-exclusion bags provided a significant or highly significant increase in filled seeds per cone (FSPC), total seeds per cone (TSPC), and percent filled seeds (%FS) (FSPC/TSPC) over non-bagged cones (Table 6). These data show that seed set is reduced in unprotected cones; likely due to reduced seed predation by *Leptoglosus*.

Spraying resulted in a nearly-significant increase in FSPC, a non-significant increase in TSPC, and a significant increase in %FS. FSPC and TSPC are highly variable among clones; %FS helps remove the clonal variability, making it the more useful variable to consider in this case. This shows that despite large variation from tree to tree, we were able to determine that spraying with Matador was valuable for improving seedset.

The spray * bag interaction measures whether the bag effect changes between the sprayed and non-sprayed areas. Bagging increases seedset in non-sprayed areas; if spraying is effective, then bagging should not increase seedset in sprayed areas. Thus an interaction indicates that seed-set gains from bagging differ between sprayed and non-sprayed areas. This was the case for %FS, though tree-to-tree variation was so large that no interaction was detected in FSPC or TSPC.

Table 6. P-values of the ANOVA for insect-exclusion bag data.

Response	FSPC	TSPC	%FS
Spray	.0850 °	.106	.0332 *
Bag	.0104 *	.0154 *	.00699 **
Spray * Bag interaction	.321	.733	.0463 *

b. Analysis for the effect of Spraying in Non-bagged cones, and bagging in non-sprayed cones.

The complete analysis measures the effect of sprays on all bagged and non-bagged cones. This analysis does not represent our true interests, which is whether spraying increases seedset in non-bagged cones, or whether bagging increases seedset in non-sprayed cones. To test this, we subsetted the data to contain only non-bagged data, on which we then tested the spray effect, and another subset that contained only non-srpayed data, on which we tested the bag effect. The significance levels reported below are from this analysis.

Total Seeds per Cone:

For non-bagged cones, Matador® spraying increased TSPC by an average of 41% relative to the nonsprayed cones (P=0.059, Table 6). The significance is very close to 0.05, suggesting that spraying is responsible for the increase in TSPC. Bagged cones in the non-sprayed part of the orchards averaged 47% more TSPC (P= 0.0186), suggesting that the spray treatment was nearly as effective as the bagging treatment at increasing the number of formed seeds. These results were consistent across orchards, but the high differences at the Sorrento orchard may increase the average gains above what would normally be expected. The mean TSPC gain from Matador® treatment for the other three orchards is 20%.

Table 7 Total seeds per cone (TSPC) by orchard and treatment. Percent gains from spraying and bagging are relative to the not-sprayed and not-bagged control treatment.

Orchard	Treatment	Bagged	Not bagged	Gain from spraying	Gain from bagging
Kettle River	Not sprayed	16.7	14.8	6%	13%
	Sprayed	16.1	15.7		
Grandview	Not sprayed	20.4	16.9	32%	21%
	Sprayed	21.7	22.3		
Sorrento	Not sprayed	10.8	5.3	104%	103%
	Sprayed	18.4	10.9		
Eaglerock	Not sprayed	13.3	8.9	22%	49%
	Sprayed	15.6	10.9		
Average		16.6	13.2	41% (P=0.059°)	47% (P= 0.0186*)

Filled Seeds per Cone:

FSPC was also higher in Matador® treated blocks. Cones with no insect-exclusion bags had an average of about 1.5 times more FSPC relative to the Control (P=0.0179, Table 7). Bagging increased FSPC by 175% in the control block (P=0.0059). These results were again relatively consistent across orchards, although the scale of FSPC gains varied from a low of 51% to a high of 448%. Gains in FSPC excluding the Sorrento orchard are 57%. Results support those for operational gains in seed yield per hectoliter of cones (Figure 2), including those for the Sorrento orchard where the Control block was harvested after the spray block.

Table 8. Filled seeds per cone (FSPC) by orchard and treatment. Percent gains from spraying and bagging are relative to the not-sprayed and not-bagged control treatment.

Orchard	Treatment	Bagged	Not bagged	Gain from spraying	Gain from bagging
Kettle River	Not sprayed	12.3	7.8	32%	59%
	Sprayed	10.3	10.3		
Grandview	Not sprayed	13.8	9.2	60%	51%
	Sprayed	13.4	14.7		
Sorrento	Not sprayed	5.6	1.0	417%	448%
	Sprayed	12.1	5.3		
Eaglerock	Not sprayed	7.4	3.0	78%	144%
	Sprayed	9.7	5.4		
Average		10.6	7.1	147% (P=0.0179)	175% (P=0.0059)

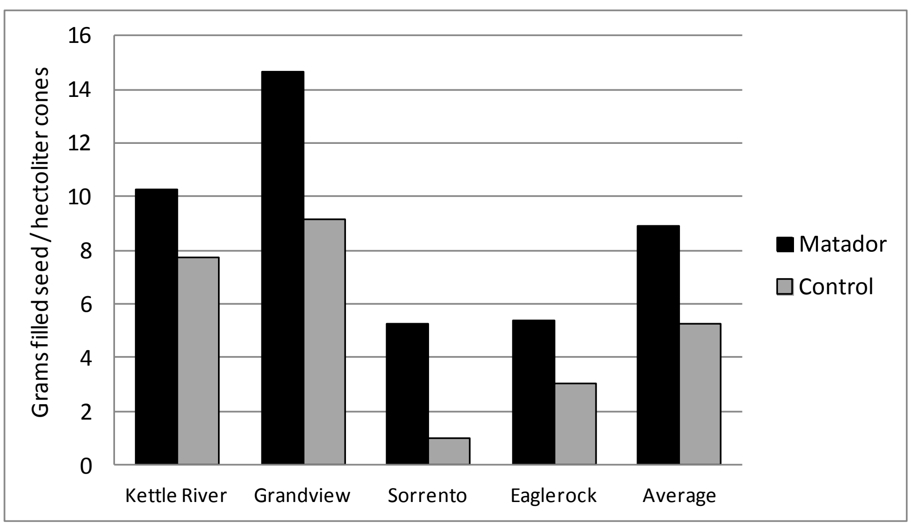

Figure 3. Average FSPC for Matador® treated blocks and control blocks across four orchards.

Percent Filled Seed

Percent filled seed is the ratio of FSPC divided by TSPC expressed as a percentage. It is a useful indicator of the proportion of fertilized seeds that developed to become filled seeds at the time of harvest. Spraying of non-bagged cones increased the average percent filled seed by 61% across all orchards relative to the Control, with a range from 21% to 153% (P= 0.0126, Table 8). Bagging increased the percent filled seeds by an average of 75% relative to the Control, with a range from

25% to 169% (P=0.0243), suggesting that the spray treatments applied in these trials was somewhat less effective than insect exclusion bags at increasing filled seed production. Large differences between orchards were found, however, with the largest gains from spraying and from bagging occurring at the Sorrento orchard site, where overall yield in the non-treated control was lowest.

Table 9 Percent filled seeds per cone relative to total seeds per cone by orchard and treatment. Gains from spraying and bagging are relative to the not-sprayed and not-bagged control treatment.

Orchard	Treatment	Bagged	Not bagged	Gain from spraying	Gain from bagging
Kettle River	Not sprayed	74%	53%	24%	40%
	Sprayed	64%	65%		
Grandview	Not sprayed	68%	54%	21%	25%
	Sprayed	61%	66%		
Sorrento	Not sprayed	51%	19%	153%	169%
	Sprayed	65%	48%		
Eaglerock	Not sprayed	56%	34%	47%	64%
	Sprayed	62%	50%		
Average		63%	53%	61% (P=0.0126)	75% (P=0.0243)

Fertilization of ovules takes place during late June to early July of the same year that cones would normally be harvested (Owens 2006). The development of a formed seed is dependent upon a successful fertilization event. Therefore, TSPC is a measure of successfully fertilized ovules and any reductions in TSPC are an indicator of the loss of ovules or an interruption of the fertilization event prior to late June or early July. Reductions in TSPC in the Control treatments relative to both the spray or bagging treatments is likely the result of early-season predation of ovules by Leptoglossus that have overwintered.

Gains in FSPC with Matador® treatment result from both a gain in TSPC and a gain in seeds that could potentially develop and remain filled following fertilization. Assuming that every fertilized and formed seed has equal potential to become a filled seed following fertilization, then the percent FSPC times the gain in TSPC with a treatment relative to the Control, is a measure of the early-season gain of potentially filled seeds. Late season gain is the gain not accounted for by early-season gain (Figure 4). When expressed as a percentage relative to FSPC for the Control treatment, these gains in FSPC are assumed to measure the gain from controlling early and late seed predation. Averaged across the four orchards, the Matador® spray treatment resulted in an early season FSPC gain of 40% and a late season gain of 29% relative to the Control.

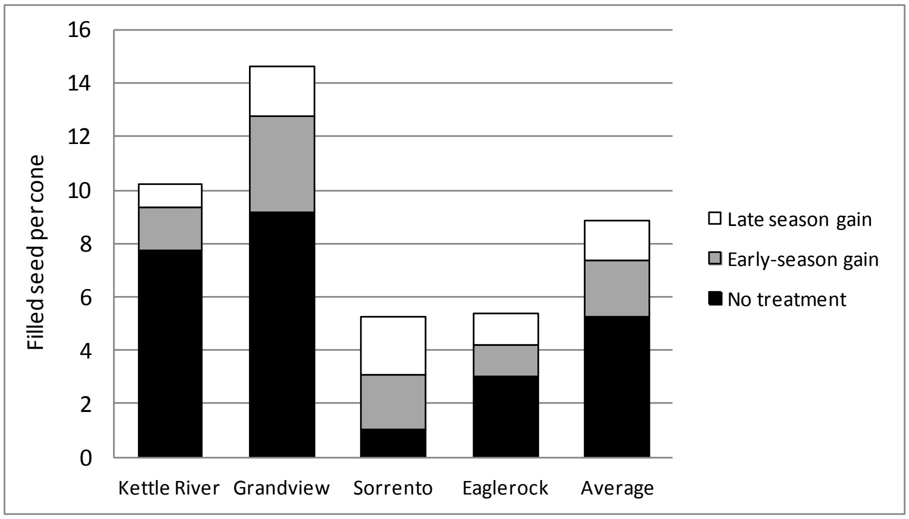

Figure 4. Estimated early-and late-season gains in FSPC relative to FSPC with no treatment, by orchard.

Early random cone collections

Mid-July cone collections were made to compare TSPC and FSPC with collections made later in the summer. Mid-July is before expected seed maturity and is near the beginning of the Leptoglossus summer feeding period (Strong 2015). Comparing data from mid-July collections with data from early August collection from the insect-exclusion-bag trial show little change in TSPC in the sprayed blocks over this period (Figure 5). Non-sprayed blocks, however, showed both a decline in TSPC and FSPC in July, and a further decline in both TSPC and FSPC by early August based on collections from the Control blocks of the insect-exclusion-bag trial. Comparison of July data for the spray and non-sprayed blocks shows reduced TSPC, as would be expected due to early-season Leptoglossus feeding. The decline in FSPC is largely explained by TSPC decline, suggesting that late summer Leptoglossus feeding had not yet substantially reduced filled seeds. This is consistent with earlier studies (Webber, 2014).) that have showed a steady decline in FSPC beginning in mid July and continuing through August.

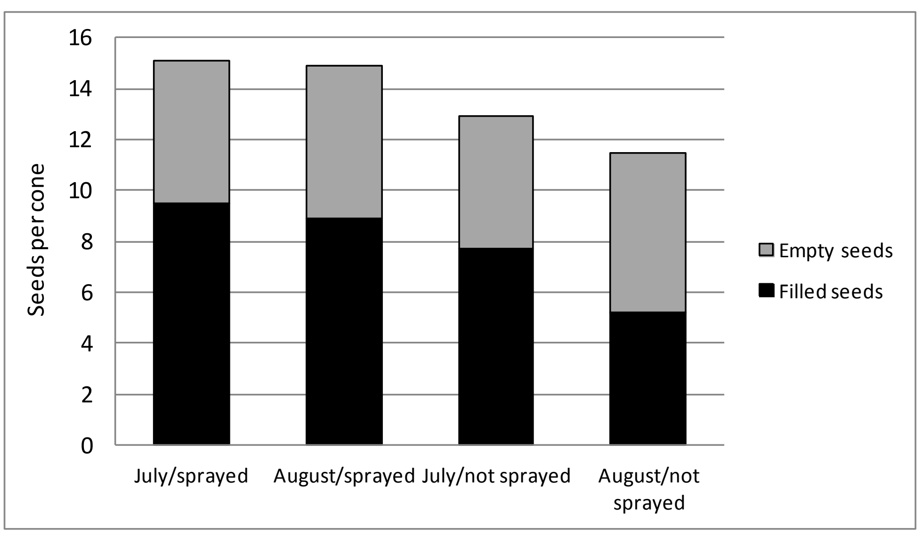

Figure 5 Average filled and empty seeds per cone for mid-July and early-August cone collections in Matador spray blocks and non-sprayed control blocks, across four orchards. Empty seeds equals TSPC - FSPC.

Discussion

Data from the trials reported here support the hypothesis that seed predation is the cause of poor seed set in lodgepole pine orchards in the southern interior. The timing of TSPC and FSPC reduction are consistent with the feeding and reproductive timing for Leptoglossus. We conclude, therefore, that Leptoglossus feeding is the primary cause of FSPC loss observed in non-treated cones in these trials.

The use of Madador® to control Leptoglossus was successful. As an orchard management technique, pest control with Matador® is both highly effective and relatively inexpensive. The timing of applications used here was based on earlier Leptoglossus feeding trials (Strong 2015), however, the efficacy of applications appears to have varied among the orchards participating in these trials. Based on degree-day data collected by the Ministry of Forests, Lands and Natural Resource Operations (J. Corrigan, personal communication), and on observed lodgepole pine reproductive phenology, the Kettle River site builds heat sums slower than the other three sites. Assuming that Leptoglossus development is correlated with heat sums, it is probable that the optimal spray timing for Kettle River is later than the other sites. The treatment success for gains due to reduced early feeding were relatively more successful for Kettle River and Grandview, where the first spray applications appears to have been done early enough to control feeding by overwintering Leptoglossus adults. At Sorrento and Eaglerock, the first spray application may have been too late to fully control early feeding.

At the Sorrento site the spray and bagging treatments had a large impact on filled seed production, however, the production was still much lower than the other sites. This may be due to several factors, including poor pollination the previous year, poor early control of Leptoglossus, or unknown factors. It is well known that northern orchard populations of lodgepole pine produce less seed in North Okanagan orchards than do southern orchard populations. The Sorrento orchard produces for the Bulkley Valley area in west-central BC, whereas the Grandview and Eaglerock orchards produce for the Thompson Okanagan area. Kettle River also contains a northern population (Prince George zone), but the Kettle River site is somewhat cooler and has a better production history than Sorrento.

Where most successfully applied (Grandview and Kettle River), treatment with Matador® in about mid May, followed by a second treatment in late June, increased operational seed yields measured as grams seed per hectoliter of cones, to the levels achieved during some of the best seed production years and well into the range needed to make these operations financially viable and meeting long-term objectives.

Harvest timing is a concern with lodgepole pine due to the heavy seed losses experienced beginning in mid July and accelerating through August. With effective Leptoglossus control, the urgency to harvest as early as possible may be reduced. This trial did not focus on harvest timing, but further work to understand how quickly Leptoglossus return to a treated orchard in late summer and begin seed predation would assist orchard managers with decisions regarding harvest timing.

Recommendations

As these trials were conducted for only a single year, it is recommended that the application of Matador® using the techniques described below is repeated for at least another year. It is not recommended that the insect-exclusion component of this trial be repeated, as the outcome here was definitive and it was clearly shown that the Matador® application was nearly as effective as insect exclusion bags at increasing seed set. It is also recommended that other pesticides that are relatively safe, inexpensive, and expected to be effective against Leptoglossus should be tested.

The following specific recommendations are made:

- Individual lodgepole pine orchard owners should conduct an operational-scale spray trial using Matador®, with an control block, in the same orchard. Operational collections should be extracted separately at the TSC for comparison as was done in 2014.
- 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 should be applied about May 15th and June 25th in North Okanagan orchards, May 22nd and July 1st at Kettle River. A third application may be warranted if Leptoglossus are observed in spray blocks after July 1st.
- An experiment should be designed to investigate seed set decline from mid July to late August in Matador® -treated orchards to assist with harvest-timing decisions.
- Other pesticides with promise against Leptoglossus should be tried using a similar operational-level design.

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