Collection of Crop Statistics for Interior Lodgepole Pine Orchards

Final Report OTIP 0722
2010 Summary

Prepared for Michael Carlson

by

Joe Webber
ProSeed Consulting
425 Stewart Road
Salt Spring Island, BC
V8K 1Y6

250 537-8854
jewebber@telus.net

Executive Summary

Seed yields (filled seeds per cone) from north Okanagan (NO) orchards have not met expectations compared with seed yields routinely realized at Prince George (PG). This report summarizes the 2010 data collected for eight of the original 12 NO orchards, six new expansion NO orchards and two PG lodgepole pine seed orchards. It also provides a summary of annual statistics for cone and seed yields from eight of the original 12 orchards over the period of 2006 to 2010.

In previous years, higher seed yields per cone but fewer cones were observed at PG. However, in 2010, PG orchards produced similar number of cones per tree (287) compared to the eight NO (305) orchards (Figure 1) and six expansion (160) orchards (Figure 2). Figures 3 and 4 show that PG orchards also produced more seed per cone (20.6) than the eight older orchards (11.5) and six new orchards (8.3). Similar values were observed for the total number of seed per cone (Figures 5 and 6). Note that the number of cones per tree from KAL 230 has consistently been the highest over the five year period and seed yields similar to those observed in PG.

Figures 7 and 8 show the product of filled seed per cone and cone number. The number of seed per ramet between NO and PG was 3217 and 5902, respectively. If NO orchard 230 were excluded, the difference between NO and PG would be even greater. The mean number of seed per tree from the eight old (Figure 7) and six new (Figure 8) orchards was 4120 and 2186, respectively. Both PR T 338 and Tolko 339 produced over

3000 seed per tree which was similar to the mean number for all NO orchards (excluding KAL 230).

Bagging effects were also monitored in 2010 (Figures 9 and 10). On average, bagged cones produced about 5 seed per cone more than unbagged cones (15.9 versus 11.0 filled seed per cone). Over the five years observation, the loss of seed from unbagged cones ranged from about 2 to 5 filled seed per cone. The greatest loss of seed occurred at Kalamalka. There was no seed loss from unbagged cones at PG.

In 2010, an attempt to determine when seed losses from bagging occurred was repeated. In this trial, cones were exposed for a two week period beginning late April (See Table 1 for dates) and continuing through late August. Seed yields for each of the 9 exposure periods were then compared to seed yields from cones always protected (bags always on) and cones never protected (bags always off). Since it inferences on timing of seed losses can not be made from one year data, this experiment is intended to be repeated in 2011.

Figure 11 shows substantial seed losses late in the season (August). Seed losses were largest at KAL, less so at PRT and least at VSOC. Debate continues about the cause of this seed loss. One side of the argument suggest the losses are too large to be caused by insects alone. However, it is difficult to suggest a mechanism by which a fully formed embryo in July to disappears in August.

We continue to see about 10-15 fewer seed per cone from NO orchards compared to PG orchards. If bagging effect accounts for about 3-5 seed per cone, we still can not account for about 5-10 fewer seed per cone from NO orchards. The only way we can understand how embryos from post-dormant first year cones are lost in the second year cone is to complete comprehensive developmental studies.

Collection of Crop Statistics for Interior Lodgepole Pine Orchards

Final Report OTIP 0722
2010 Summary

Introduction

Basic seed orchard statistics have been standardized across selected north Okanagan and Prince George lodgepole pine seed orchards. Because provenance source, site, age, micro-climate, and management practices vary between orchard sites, standardizing the collection and analysis of crops statistics for each producing orchard will provide valuable base line data for comparing lodgepole pine seed orchard production across a variety of sites and for developing future orchard management practices to optimize production.

Methods

The original twelve orchards selected (2006) for this study were KAL 230 (NS/BV) and 307 (N); VSOC 218 (CP), 219(BV) and 222 (PG); PRT 308 (TO), 311 (TO) and 313 (N); Tolko 310 (TO-hi); and PGTIS 220 (PG), 223 (CP) and 228 (BV). This list did not include any of the younger, expansion orchards established beginning in 2000. These orchards are now 8-10 years old and beginning production. Because many of these orchards are of higher breeding values, some of the original orchards will be dropped and six expansion orchards included. The orchards to be dropped are VSOC 219 (BV) replaced with VSOC 234 (BV); PRT 313 (N) replaced with PRT 337 (N); and, Tolko 310 (TO-hi) replaced with Tolko 339 (TO-hi). New orchards to be included are KRSO 237 (PG): SSO 241 (CP) and MoFR (Bailey) 340 (EK). To keep the total number of orchards for the survey at 14, we excluded PGTIS 223 (CP) and kept PGTIS (220 (PG) and PGTIS 228 (BV). After consultation, PRT 308 was dropped and replaced with PRT 338. In summary, we drop 4 older orchards of lower BV and pick up 6 younger orchards of higher BV.

By comparing production in younger orchards to older established orchards, we can determine if younger more vigorous ramets affects seed yields. The same methods applied to the original orchards will be applied to the younger orchards. This includes selecting a single ramet (individual) from each of 15 clones (trees) and recording dates of both pollen and seed cone development (on younger orchards only). Seed cone numbers, will be estimated and cone yields for bagged and un-bagged cones determined. Each orchard site will be responsible for selecting the trees, recording receptivity dates, applying insect bags, estimating whole tree cone numbers, collecting cones, and shipping cones to Kalamalka Seed orchard site. Kalamalka will complete the cone analyses (dry cone weight, cone extractions, cone yields and x-ray analysis).

Phenology

Phenological dates for the periods of pollen shed and seed cone receptivity have been collected for 2006 to 2009 with the objective of providing a stronger estimate of seed yields based on variation of pollen load. However, pollen loads in the mature orchards are not limiting and sampling based on phenological variation does little to explain differences in seed yields. For 2010, phenological observations were not required for the eight older orchards but were provided for the six younger orchards.

Cone Numbers

All cones were collected from 15 single ramet clones and weighed. The weight of a 30 cone sub-sample was also determined and the number of cones per ramet calculated. This procedure accounts for the variation in cone size and allows more accurate estimates of seed production between clones and orchards. This procedure will also provide a stronger estimate of female gamete contribution for calculating GW.

Seed Yields

All cones were kiln dry for 8 hours, cone dry weights recorded and then shaken to release seed and then inspected to extract any remaining seed. All seed with a mature seed coat were counted and then x-rayed to determine the number of seed with a mature embryo. Yields were then expressed as total seed per cone (TSPC) and filled seed per cone (FSPC). Cone yields from bagged and unbagged cones were also compared.

Protocol

The following protocol standardizes the data requirements and methods for estimating annual orchard cone and seed production of lodgepole pine. It includes both young and older producing orchards in each of two locations, the north Okanagan (NO) and Prince George (PG).

Standardized protocol for estimating cone and seed production in lodgepole pine:

1. Select 15 clones from the orchard parent base with a collectable crop and with consideration of flowering phenology according to local knowledge from past surveys and experience.

2. Record clone number and ramet position and reproductive phenology class (E/M/L) and date selected (expansion orchards only).
3. April: insect bag 5 upper crown second-year cones in each of 2 bags. These samples will be used to determine annual insect bagging effects.
4. Pollination: record dates when: 1) 20% of the tree's pollen buds are shedding and 2) when 80% of the pollen buds have shed (expansion orchards only).
5. Receptivity: record dates when: 1) 20% of the first-year cones are receptive and 2) 80% of the first-year cones are past receptivity (expansion orchards only).
6. Cone Harvest: collect all second-year cones (except those insect bagged and the non-bagged cones collected in (8) below) from a sample tree, mix well and record weight (for a sample tree's production).
7. Cone Sampling: randomly select 30 second-year cones and record cone fresh weight, clone number, and position on a paper bag.
8. Bagging Effect: collect 5 insect-bagged second-year cones and 5 unbagged second-year cones from the same crown position as the bagged cones, place in separate paper bags and record clone number, position and treatment ("bagged" or "unbagged") on each bag.
9. The 30-cone sample bags (15) along with the insect-bagged and control unbagged (15 each) were shipped to Kalamalka Seed Orchards for processing.
10. Cone Mass: for each of the 30 conelots, record dry weights (dry weights after cone drying but before tumbling.
11. Cone Extraction: extract all seed (by cone tumbler) from all 30 conelots.
12. Bagging Effect: hand-extract insect bagged cones and control unbagged cones.
13. Total Seed per Cone: count all seed with a fully developed seed coat for each of the 30-cone conelots, insect-bagged cones and control unbagged cones. For the 30-cone conelots, total seed can be determined from the weight of a random sample of 300 seeds and the weight of all the seeds in the lot.
14. Filled Seed per Cone: determine all filled seed (by x-ray analysis) for each of the 30 conelots, insect bagged cones and control unbagged cones. For the 30-cone conelots, use the 300 seed sub-sample from step 13 above.
15. Seed Weight: record weight of 100-200 randomly selected filled seeds for each of the 30-cone conelots after the original total seedlot is cleaned thoroughly with a Dakota blower to remove all empty seeds (this data was not collected in 2009/10).

Timing of Bagging Effect: bags On/Off

Over the sampling period (2006-2010), bagging effects on seed yields have been measured. In an attempt to determine critical periods of seed loss, a series of exposure periods were determined in each of three orchards (KAL-307, PRT-311 and VSOC-219). Ten bags on each of 10 trees at each KAL, PRT and VSOC were put on April 23 at PRT and VSOC and April 21 at KAL. One bag was then taken off and exposed for a two week period (first bag put back on May 7 at PRT and VSOC and May 5 at KAL). This continued until late August (9 exposure periods). Cones were exposed for the two week period and compared to cones always bagged (treatment period 10) and cones never bagged (always exposed – treatment period 11).

Results

Phenology

Table 1 shows the range of dates for seed-cone receptivity and pollen shed for each of six expansion orchards added in 2010. Ranges of seed-cone receptivity and pollen shed dates of the original 12 orchards are available in the 2006 to 2009 sampling reports. These four years were sufficient to determine phenology differences from orchard to orchard and year to year. For 2010, the range of receptivity dates varied little between orchard sites near Vernon but was about 10-13 days later at Kettle River.

Table 1: Range of receptivity and pollen shed dates for the 15 selected clones from each of six expansion orchards (2010).

		2010 Lodgepole Pine Seed Orchard Phenology Survey			
		20% Receptivity	80% Receptivity	20% Pollen Shed	80% Pollen Shed
Site	Orchard	Range	Range	Range	Range
BAL	340	na	na	na	na
KRSO	237	May 24-31	May 27-June 30	May 24-31	May 29-June 6
PRT	338	May 11-21	May 15-24	May 11-212	May 15-24
SSO	240	May 11-15	May 16-22	May 12-18	May 17-22
TOL	339	May 13-18	May 18-24	May 11-18	May 15-24
VSOC	234	May 07	May 16	May 12	May 19

Cone Numbers

Mean cone numbers (2010) per tree for north Okanagan (NO) orchards compared to Prince George (PG) was 245 (±14.8) versus 287 (±30.3), respectively. This is reversed from 2009 where the mean cone number per tree from NO was 274 and from PG 181. Note this comparison is not strictly comparable because sample size (N) was 158 for NO and 30 for PG. The comparison also includes the six new expansion orchards.

Figure 1 shows the 2010 mean (±standard error) number of cones from each of eight original NO and two PG orchards. Figure 2 shows the mean (2010) cone numbers per tree for the six new expansion orchards (no data was available for KRSO 237). Mean cone numbers per tree for the new, old and PG trees were 168, 305 (284 excluding KAL 230) and 287, respectively. Comparing the old orchards, only VSOC 218 did not meet or exceed PG cone production. KAL 230 continued to be the highest cone producer of all NO orchards (410 cones per tree) and with the exception of the two VSOC orchards, PG the lowest for the two locations. Of the new orchards (Figure 2), Tolko 339 produced the highest mean number of cones per tree (300) followed by PRT 338 (250). The other three orchards all produced 100 or fewer cones per tree.

Figure 1: Mean (±standard error) total number of seed cones per ramets from each of eight original NO and two PG orchards (2010).

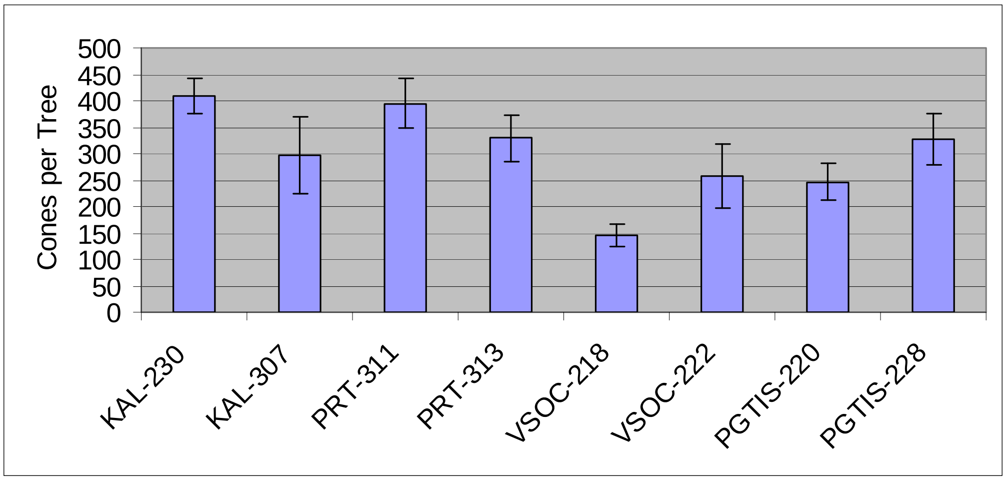
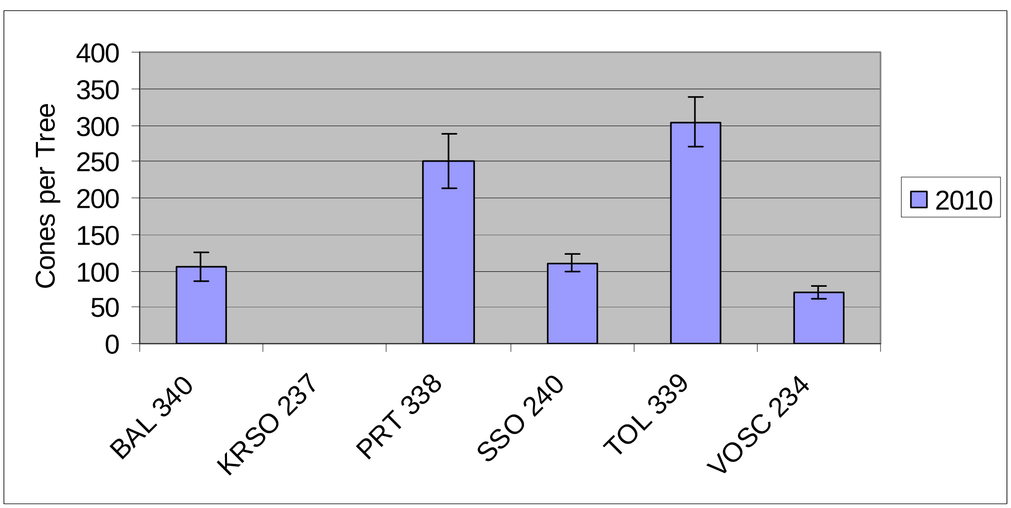
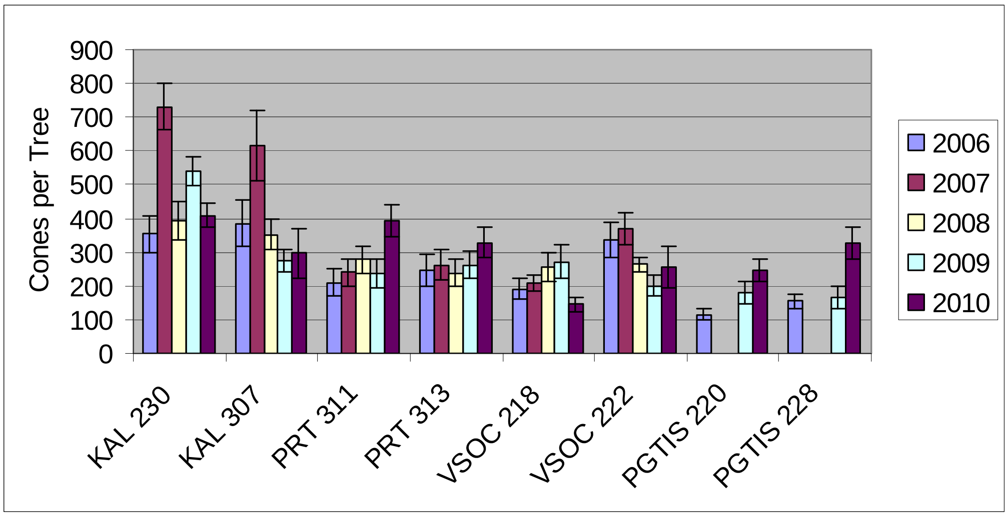


Figure 2: Mean (±standard error) total number of seed cones per ramets from each of six new expansion orchards (2010).



In general cone production in 2010 was about the same as 2009 with the notable exception of PRT 311 and 313 where cone production was the highest of all five sampling years (Figure 3). Prince George orchards also produced the highest cone numbers for the three years data were collected.

Figure 3: Mean (±standard error) total number of seed cones per ramet from each of eight original lodgepole pine seed orchards (2006 – 2010).



Figures 4 and 5 show the mean number (±standard error) of filled seed per cone (FSPC) extracted from the 30 cone sample for each of the original eight (Figure 4) and six new expansion orchards (Figure 5). A simple multiplication of cone number x filled seed per cone yields the number of seed per tree. Figures 6 and 7 show the number of seed per tree for the original eight (Figure 6) and six new expansion orchards (Figure 7). Figure 8 shows the same data for the original eight orchards for the period of 2006 to 2010.

Seeds per ramet for 2010 were lower than 2009 for all NO orchards with the exception of PRT 311 and 313. Comparing mean seeds per tree for the NO and PG orchards, PG produced 5901 (±850.1) where as the mean number of seed per tree from NO orchards was 3127 (±306.1). Again the two are not strictly comparable since the number of orchards/trees was substantially larger for the NO sample and the NO sample did include the younger orchards. However, PG production was nearly double that of NO orchards (even with KAL 230 included) on the basis of higher cone production and seed per cone production. In 2009, the mean number of seed per ramet between NO and PG was 4384(±422) and 5349(±598), respectively. If NO orchard 230 were excluded, the difference between NO and PG would be even greater.

Figure 4: Mean (±standard error) number of filled seed per cone (FSPC) from each of the original eight lodgepole pine seed orchards (2010).

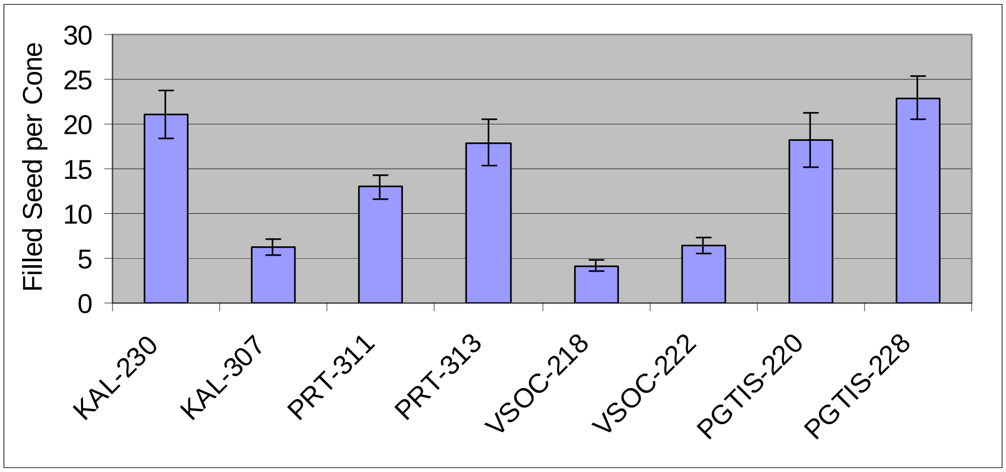
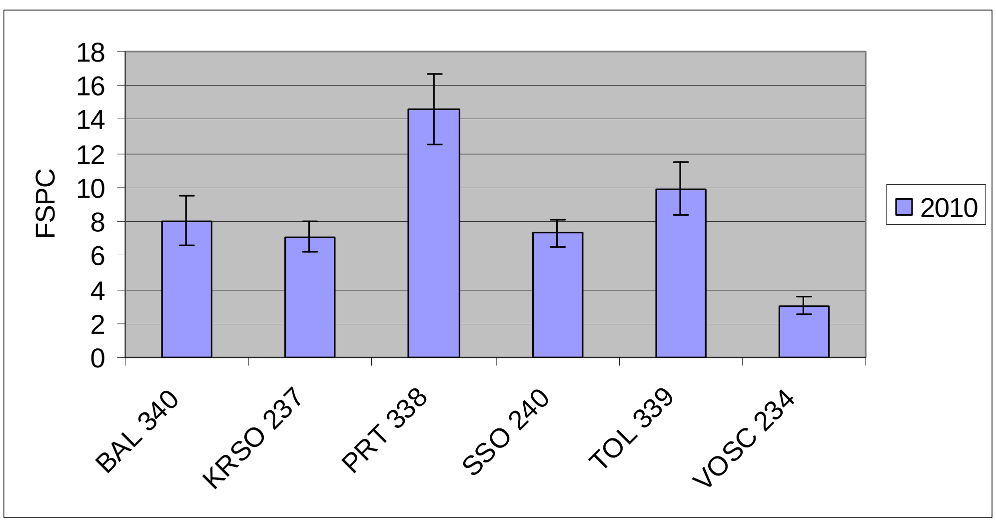


Figure 5: Mean (±standard error) number of filled seed per cone (FSPC) from each of six new expansion orchards (2010).



Note that KAL 230 seed yields (FSPC) in 2010 were about the same as PG orchards (Figure 4). However, total seed production per tree was about 3000 more seed because cones per tree from KAL 230 were greater (Figure 1). On average, the remaining NO orchards produced about half the seed number that the PG orchards produced. However, PRT orchards 311 and 313 were the highest producers from NO and approached those of PG (Figure 6). For the expansion orchards, PRT 338 produced the most seed followed by Tolko 339 (Figure 7). Again, this was based on higher cone numbers per tree (Tolko 339 was highest) and seed per cone (PRT 338 was highest).

Figure 6: Mean (±standard error) number of filled seed per tree from each of eight original lodgepole pine seed orchards (2010).

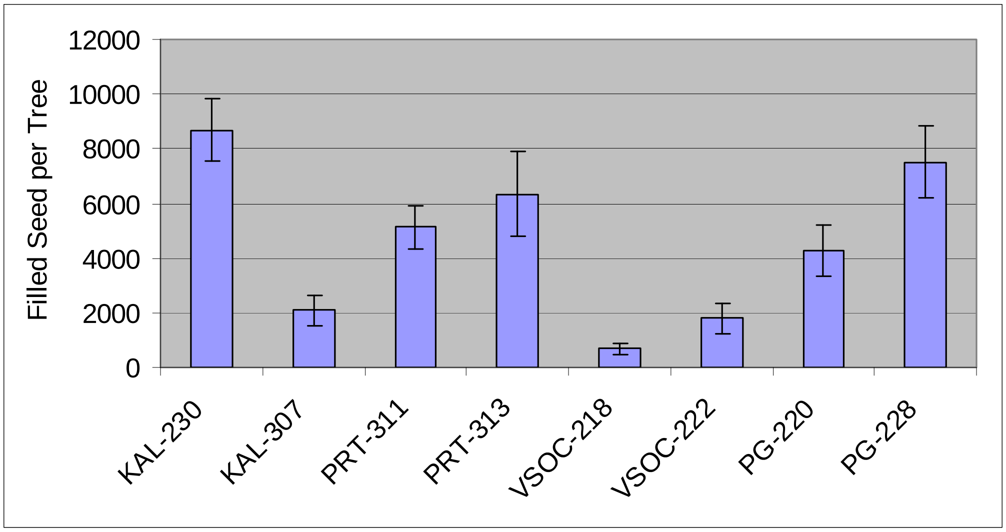


Figure 7: Mean (±standard error) number of seed per tree from each of the six new expansion orchards (2010). Note cone numbers per tree not available from KRSO 237.

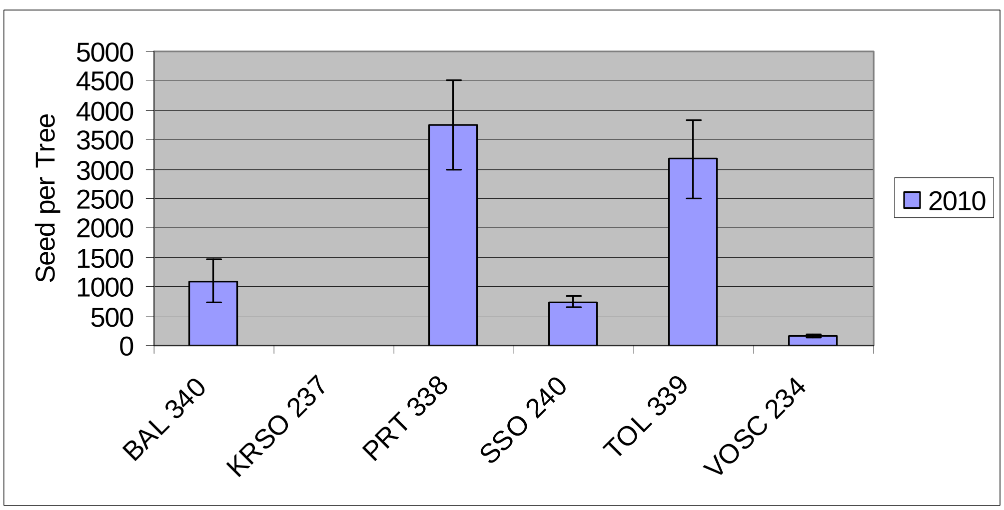
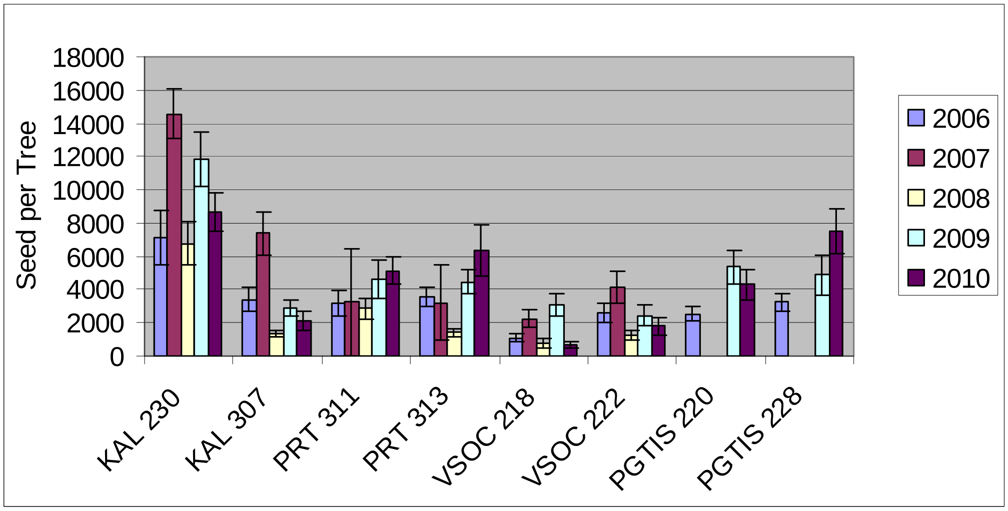


Figure 8: Mean (±standard error) number of seed per tree from each of the original eight lodgepole pine orchards (2006 – 2010).



Cone Dry Weight

Does cone size affect seed yields? Certainly PG dry cone mass (and seed yields) typically has been larger than the mean cone mass (and seed yields) from NO orchards but beyond that, any significant relationship between cone size and seed yields seems hard to establish. Mean cone dry weights from NO trees was 5.9 (±0.128) and 7.1(±0.345) from PG trees, similar to the previous years. Figure 9 and 10 show the mean cone dry weight for the 30 cone sample for the original eight and six new expansion orchards, respectively.

Figure 9: Mean (±standard error) cone dry weight for each of the eight original lodgepole pine orchards (2010).

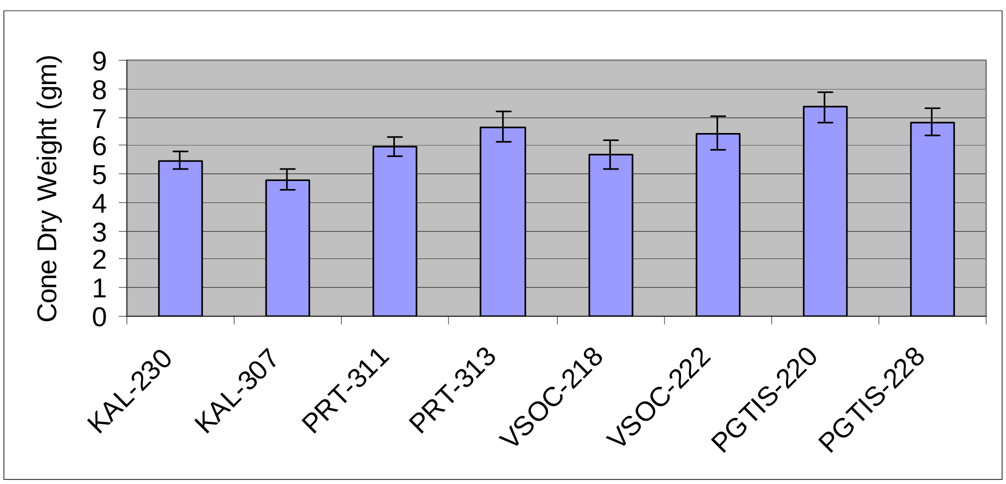
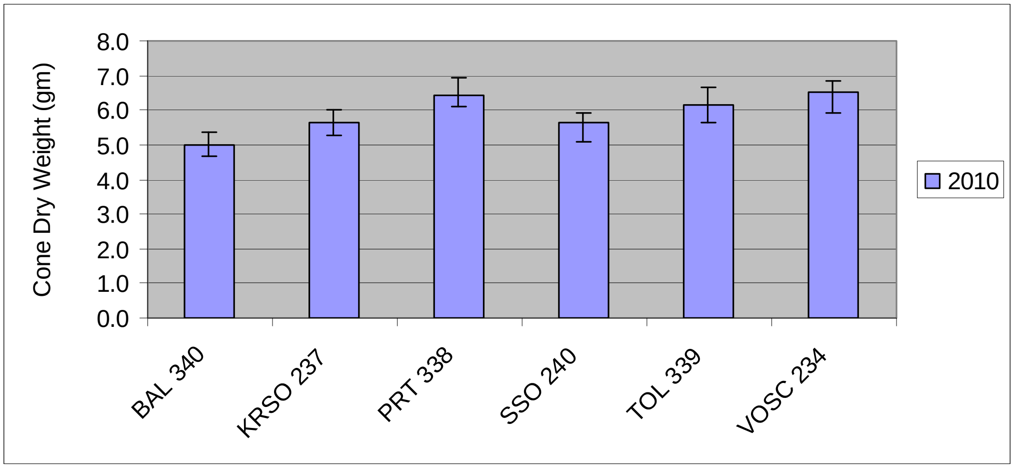
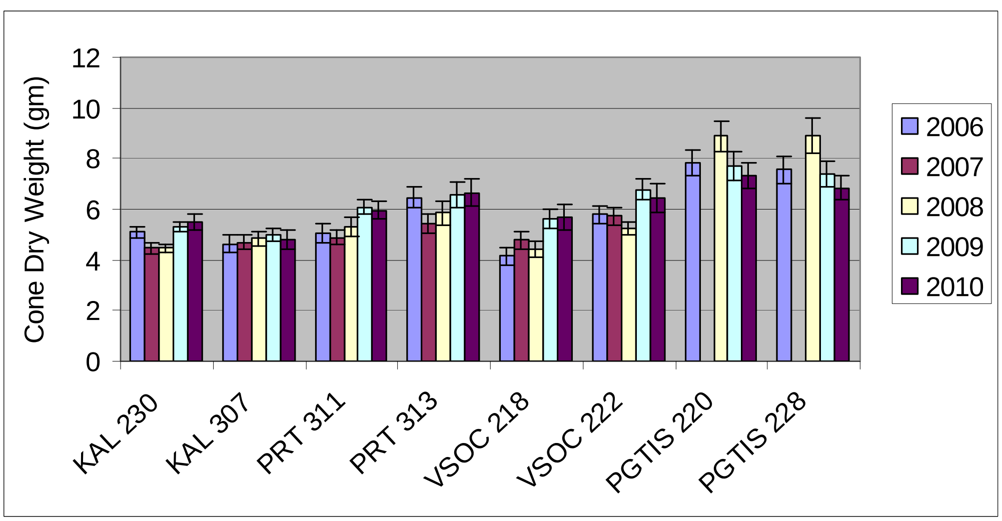


Figure 10: Mean (±standard error) cone dry weight for each of the six new expansion orchards (2010).



The highest cone dry weight for the eight original NO orchards was PRT 313 (6.7 gm) followed by VSOC 222 (6.4 gm). The lowest cone dry weight was KAL 307 (4.8 gm). The cone mass for both PRT 313 and VSOC 222 approached those from PG in 2010 (Figure 9). The cone dry weights for the six new expansion orchards (Figure 10) ranged from 5.0 (BAL 340) to 6.5 (VSOC 234). Mean cone dry weights for the original eight orchards over the five year period are shown in Figure 11. Note that cone dry weights in all PRT and VSOC orchards have shown a steady increase over the period 2006 – 2010 where as cone dry weight has remained about the same at KAL and has actually dropped at PGTIS.

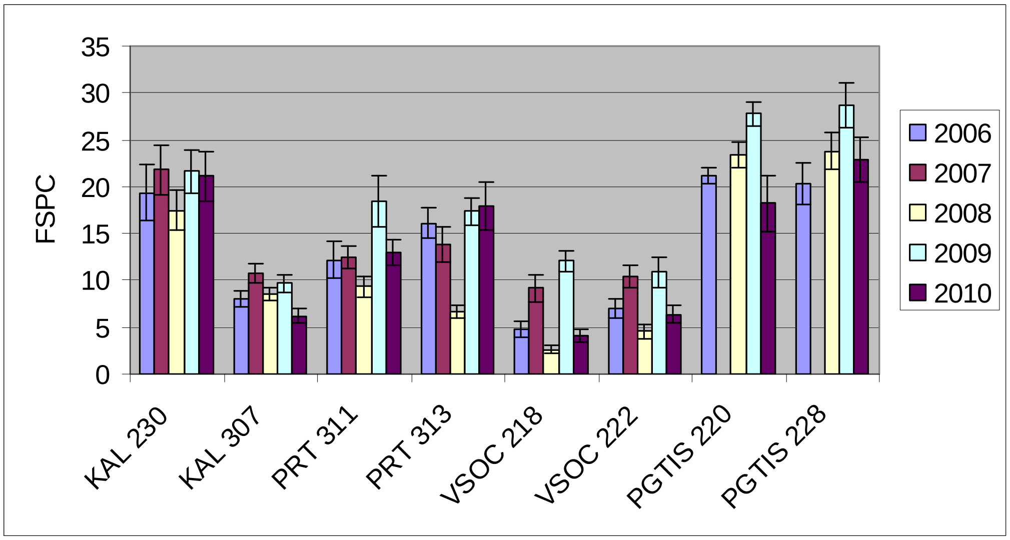
Figure 11: Mean cone dry weight (±standard error) for each of the eight original lodgepole pine orchards (2006 – 2010).



Seed Yields

Filled seed per cone values for the eight original and six new expansion orchards are shown in Figures 4 and 5. Figure 12 shows the mean filled seed per cone for the eight original orchards for the period of 2006 – 2010. For 2010, the mean filled seed per cone for NO orchards was 10.0 (±0.596) and 20.6 (±1.937) for PG orchards. Again the means are not strictly comparable since sample size from the NO orchards is so much larger. Also, the NO number is somewhat inflated because it includes KAL 230 whose mean FSPC was 21.1 (±2.679). Aside from 2009, PRT 311 and 313 have yielded the highest seeds per cone for all NO orchards (not including KAL 230).

Figure 12: Mean (±standard error) number of filled seed per cone (FSPC) from each of the original eight lodgepole pine seed orchards (2006 - 2010).



Figures 13 and 14 show the total seed per cone (TSPC) for the eight of the original orchards (Figure 13) and the six new expansion orchards (Figure 14). The mean TSPC for NO (KAL 230 data included) and PG was 21.7(±0.982) and 37.9(±2.440), respectively. The difference in 16 TSPC between NO and PG is important. We can account for some of the difference from bag effects (see next section) but there still remains about 10-12 TSPC that are lost in NO cones.

Figure 13: Mean (±standard error) total seed per cone (TSPC) for each of the eight original lodgepole pine orchards (2010).

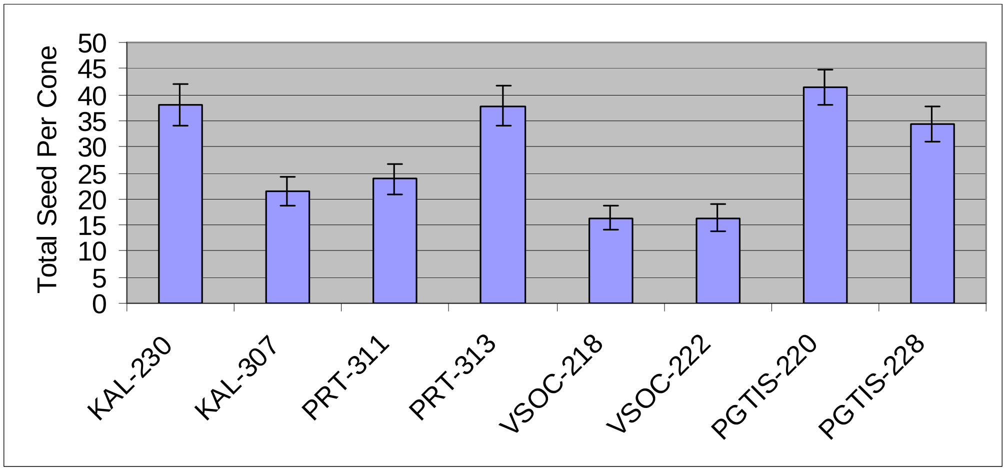
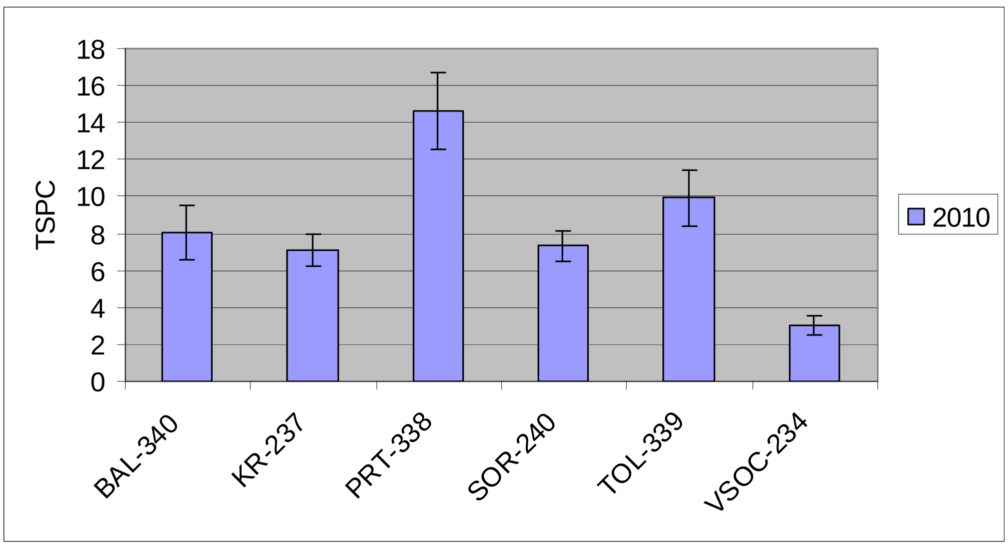


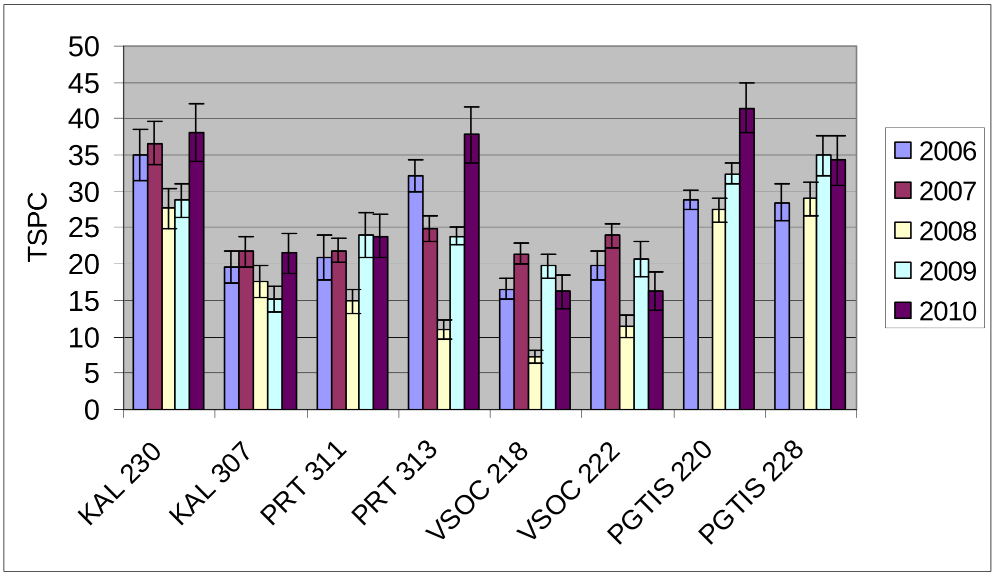
Figure 14: Mean (±standard error) total seed per cone (TSPC) for each of the six new expansion orchards (2010).



Again, KAL: 230 had the highest number of TSPC (38.0) but PRT 313 was as high (37.8). This is the first time in the five years sampling that a NO orchard produced the same number of TSPC as KAL 230 and the two PG orchards. However, FSPC (Figure 4) from PRT orchard 313 was less than half (17.9). What then happened to the remaining 20 potential seed per cone?

Total seed per cone values for the six new expansion orchards is shown in Figure 14. All orchards produced less than 15 TSPC. We may suspect limiting pollen supply in young orchards but even PRT 338 and VSOC 234 showed very low values and these orchards are adjacent to mature orchards where pollen production is high.

Figure 15: Mean (±standard error) total seed per cone (TSPC) for each of the eight original lodgepole pine orchards (2006 - 2010).



With the exception of 2008 and 2010 and excluding KAL 230, the remaining NO orchards produced about 20 TSPC over the five years. An important question remains. What happened to the 15 fewer TSPC from NO orchards compared to PG? Since recent work by Patrick von Aderkas suggests that the number of fertile ovules in the post dormant first-year cone is about the same for both NO and PG trees, the lose in TSPC must then occur in the developing second year cone.

Similar data is shown for filled seed per cone (FSPC) in Figure 12. The mean FSPC for PG was 20.6 compared to the mean value across all NO orchards of 10.0, a difference of about 11 FSPC between the two locations. It is also interesting to note that the difference between mean TSPC and FSPC at the two locations (NO and PG). About 17 fewer FSPC than TSPC occurred at PG whereas only 11 fewer FSPC than TSPC were found at the NO orchards. If values for KAL 230 are excluded, then the difference between TSPC and FSPC for NO orchards is about 15. This suggests that the factors affecting a total seed becoming a filled seed may be similar at the two locations. However, we still can not account for the approximately 10-15 fewer TSPC from NO orchards. This suggests the loss may occur before a seed coat is formed.

Seed Yields and Cone Size

Figure 16 shows the mean number of filled seed per gram of dry cone weight based on the 30 cone sample from each of the eight original orchards. Figure 17 shows the same values for the six new expansion orchards. KAL 230 again had the highest number of seed per gram cone dry weight (about 3.8) followed by PRT 313 which was about the same as the mean for the two PG orchards (about 3). Of the NO orchards (excluding KAL 230), PRT had the highest number of seed per gram cone dry weight and this trend continued over the period of 2006-2010 (Figure 18).

Figure 16: Mean (±standard error) number of filled seed per gram cone dry weight for each of the eight original lodgepole pine orchards (2010).

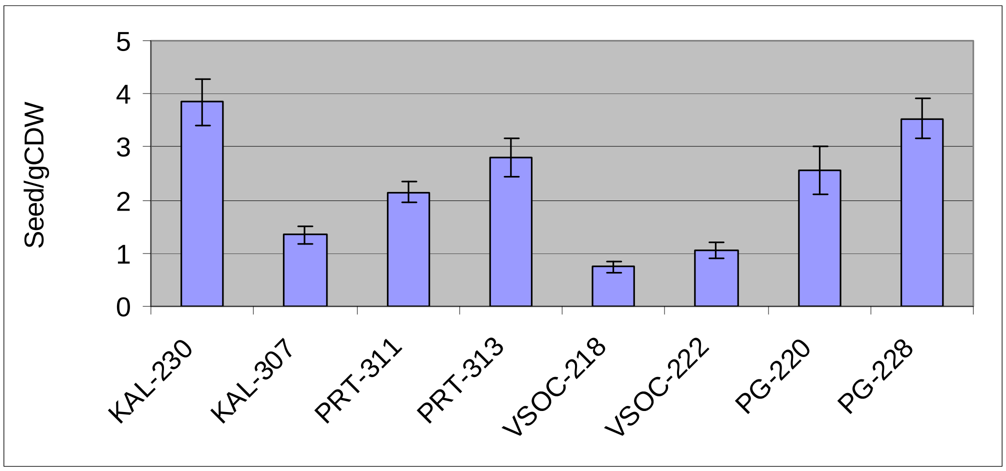


Figure 17 shows the number of seed per gram cone dry weight for the six new expansion orchards. PRT had the highest number (2.3) and VSOC 234 the lowest (0.5). The remaining NO orchard all had about 1.5 seed per gram cone dry weight. Across all NO orchards the value was 1.7(±0.096) and for the two PG orchards 3.0(±0.301).

If we compare the cone dry weights and FSPC for KAL 230, PRT 313 and PG 220 in 2010, the corresponding values are 5.5, 6.5 and 7.3 gm CDW and the corresponding FSPC are 21.1, 17.9 and 18.2. KAL 230 had the smallest cones but the highest yields whereas PRT and PG had higher cone dry weights but fewer seed per cone.

Obviously, the trend between cone size and seed yields is not a strong one. Figure 19 shows a trend line for filled seed per cone plotted against cone dry weight for the original eight orchards using data collected from 2006 to 2010. The r^2 value for this trend line is 0.3889 suggesting that 39% of the variation between cone size and seed yields is explained by cone size. The remaining 61% of the variation must be explained by other factors.

Figure 17: Mean (±standard error) number of filled seed per gram cone dry weight for each of the six new expansion orchards (2010).

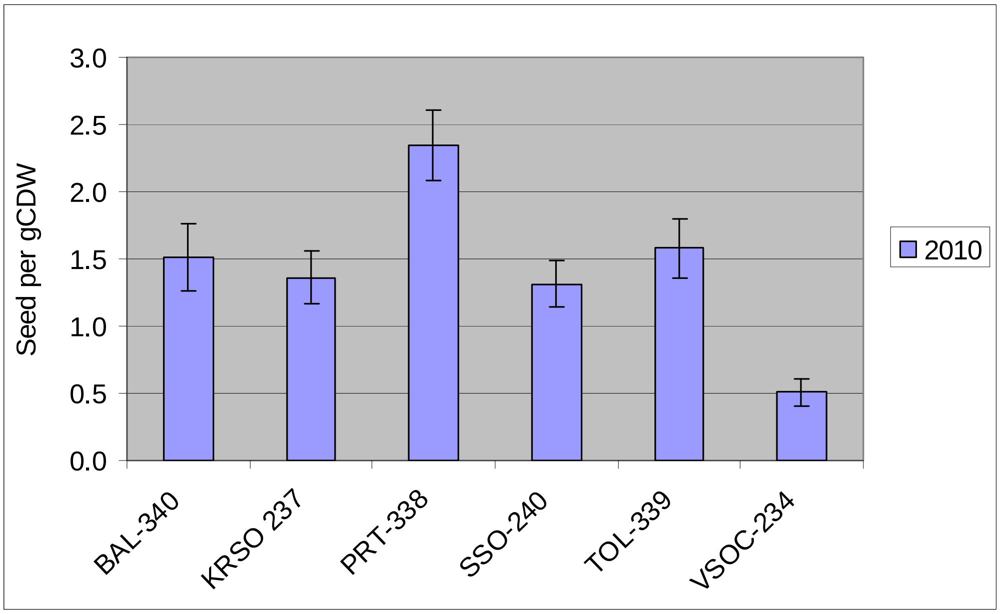


Figure 18: Mean number of filled seed per gram cone dry weight (±standard error) for each of the eight original lodgepole pine orchards (2006 - 2010).

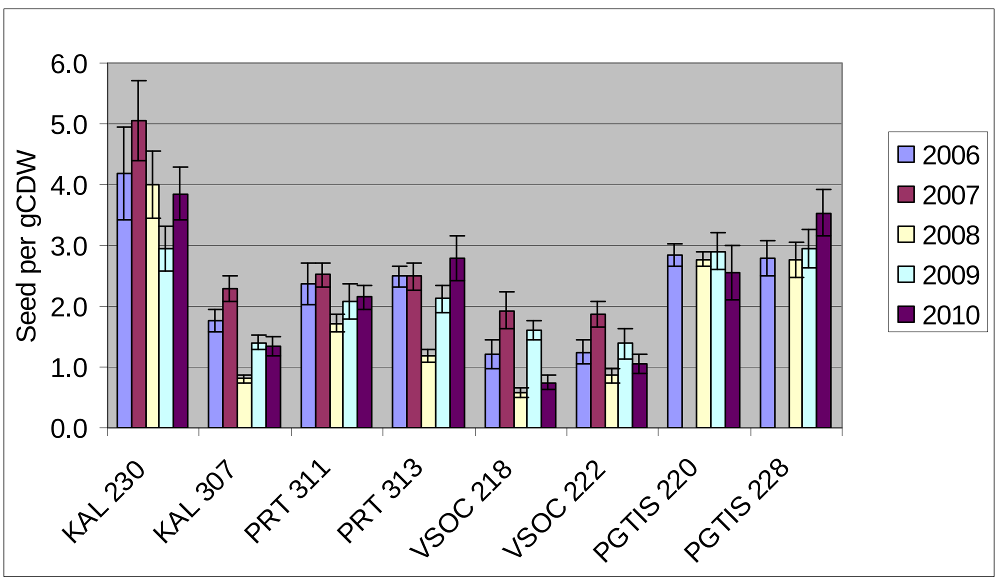
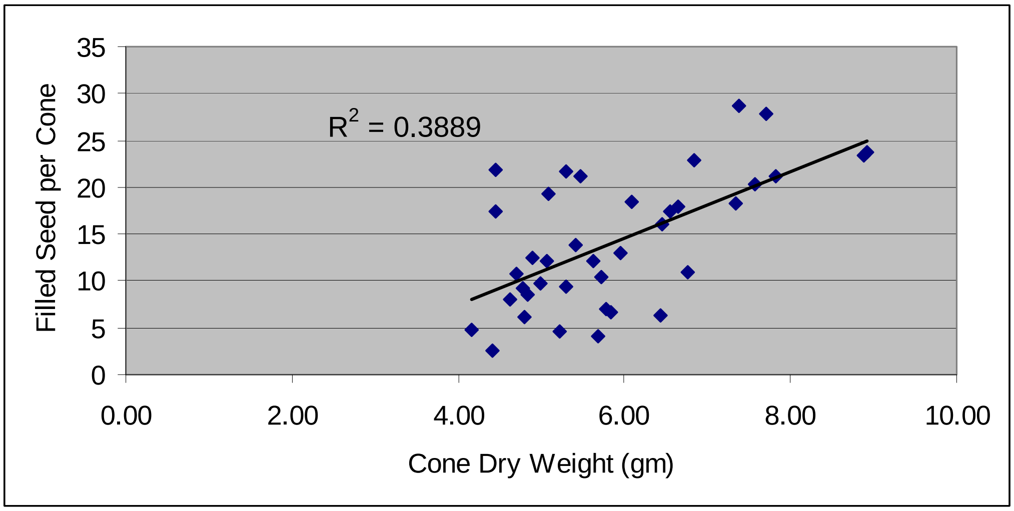


Figure 19: Trend line for cone size (cone dry weight) plotted against filled seed per cone for data collected from the eight original orchards (2006 – 2010).



Bagging Effects: Sampling Trees

Figures 20, 21 and 22 show the cone dry weight, TSPC and FSPC values for bagged and unbagged cones (2010), respectively. There was no bagging effect on cone dry weight for NO orchards and bagged cones from PG were slightly smaller (likely not significant).

Figure 20: Mean (±standard error) cone dry weight for Bagged and noBag cones from 12 North Okanagan and two Prince George orchard sites (2010).

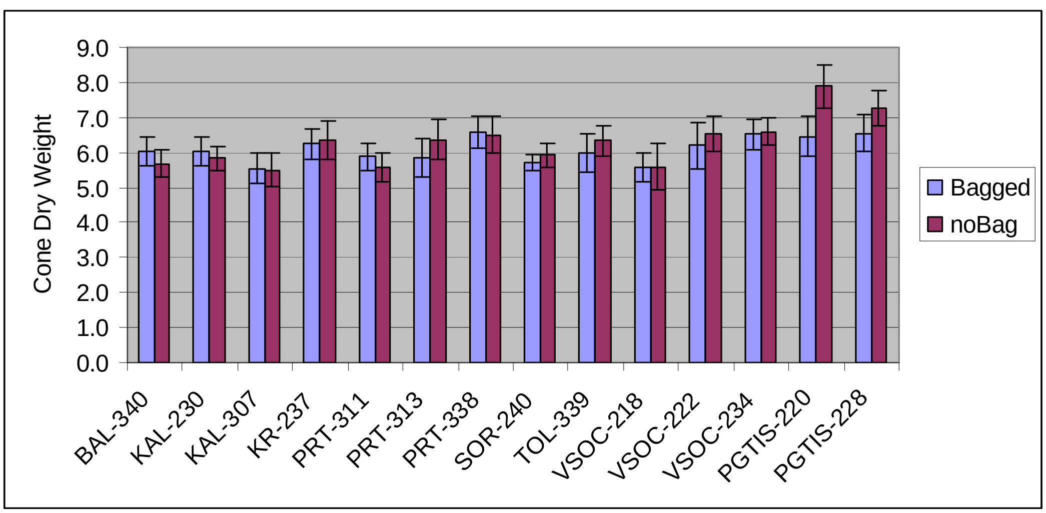


Figure 21: Mean (±standard error) total seed per cone (TSPC) for Bagged and noBag cones from 12 North Okanagan and two Prince George orchard sites (2010).

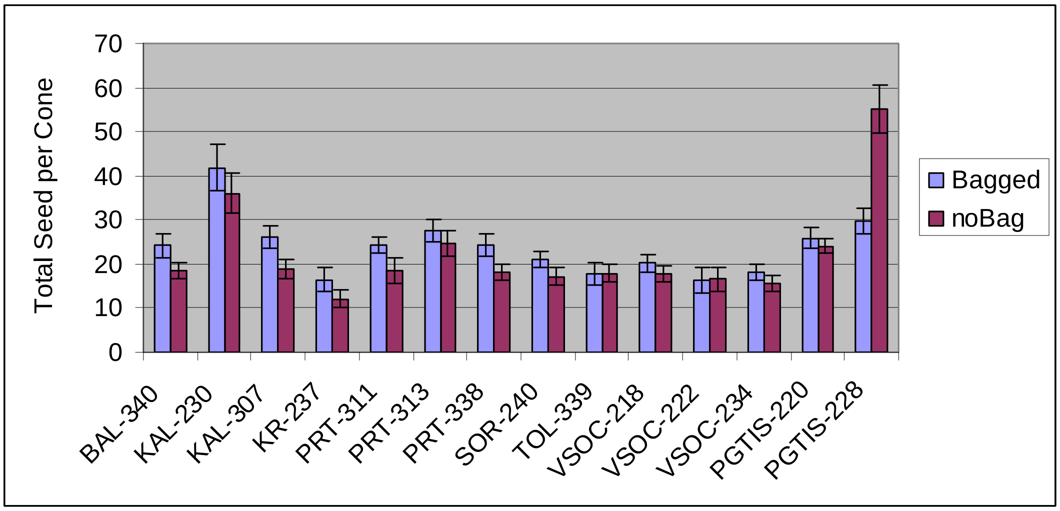
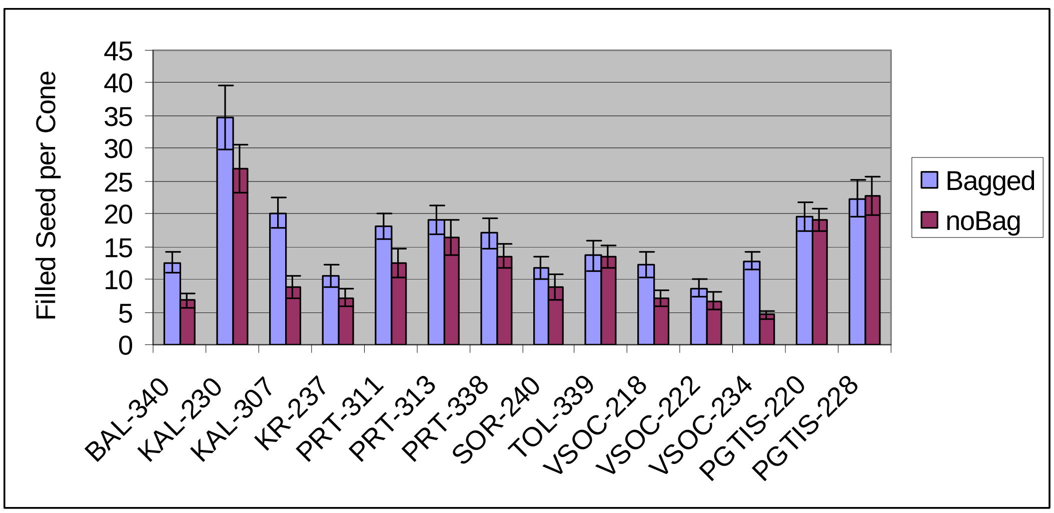


Figure 22: Mean (±standard error) filled seed per cone (FSPC) for Bagged and noBag cones from 12 North Okanagan and two Prince George orchard sites (2010).



Both TSPC and FSPC values were lower in unprotected cones from NO with mean differences of 3.8 and 4.9 (2010), respectively. Values for TSPC from bagged and unbagged cones from PG were about the same for one orchard and the value for the second (PG-228) is suspect. There were no differences in FSPC from either the PG orchards.

Figures 23 and 24 show the differences in TSPC and FSPC from insect-bagged and unbagged cones for the eight original NO and two PG orchards for the period of 2006-2010.

Figure 23: Mean (±standard error) total seed per cone (TSPC) difference between insect-bagged cones and unbagged cones from eight North Okanagan and two Prince George orchard sites (2006 – 2010).

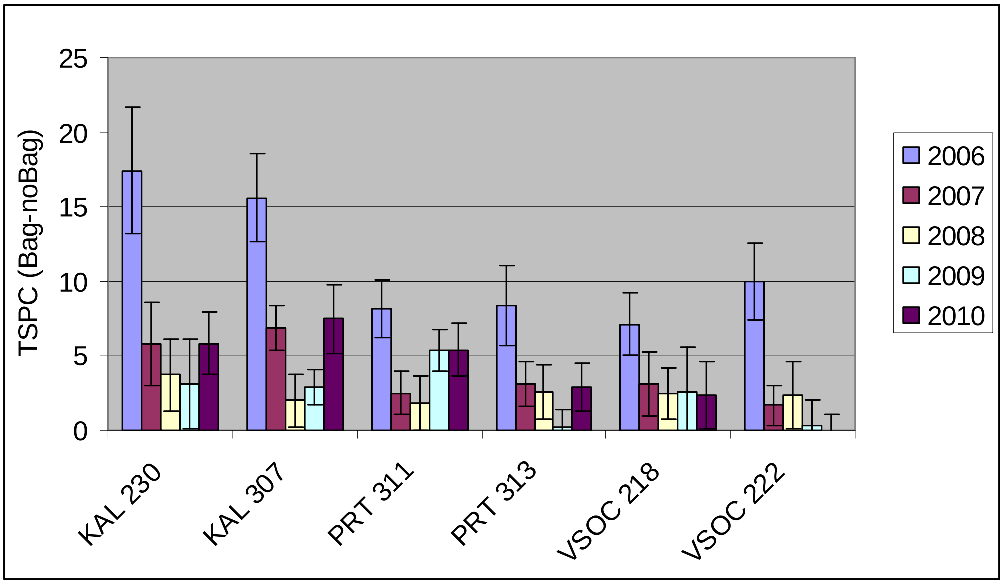
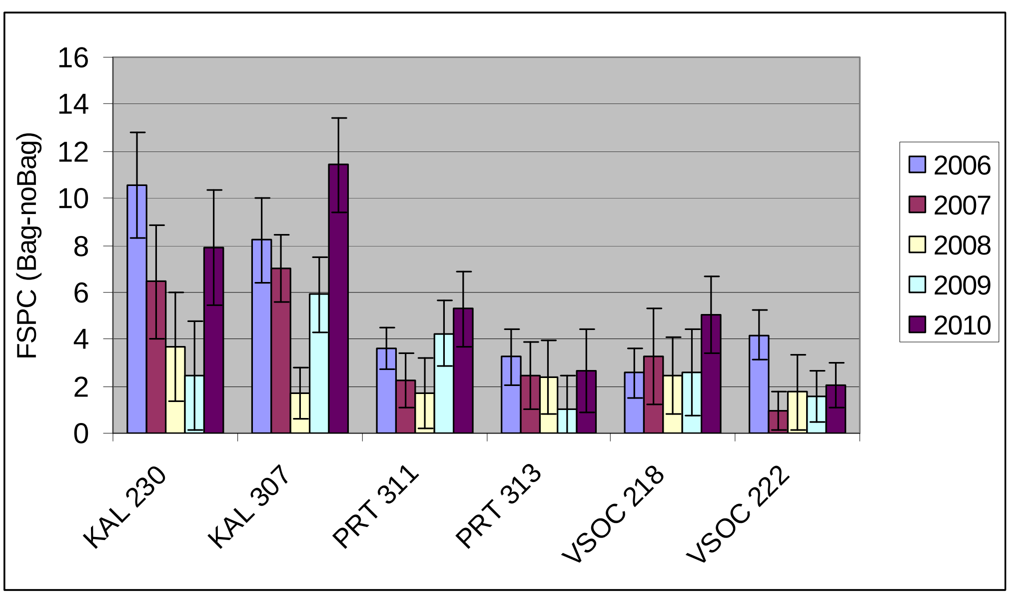


Figure 24: Mean (±standard error) filled seed per cone (FSPC) difference between insect-bagged cones and unbagged cones from eight North Okanagan and two Prince George orchard sites (2006 – 2010).



Prince George orchards showed little if any effect due to bagging. For the eight original NO orchards, the difference in TSPC and FSPC has shown a weak decline in differences (loss) over the period of 2006 to 2009. However, in 2010, there was a substantial increase in seed loss (both TSPC and FSPC) in both Kalamalka orchards. Losses at the PRT and VSOC orchards were similar to 2009. However, note the magnitude of the error bars is high making comparisons between small differences (2-3) less meaningful. We have consistently attributed the difference in bagged and unbagged yields to insect predation (leptoglossus). While concern has been raised that this difference is not an insect effect, there is no other compelling reason being offered to explain the differences observed. Since insect predation does occur, it then becomes a discussion of magnitude. We do not suggest that low seed set from NO orchards is solely caused by insect predation but it is an important factor.

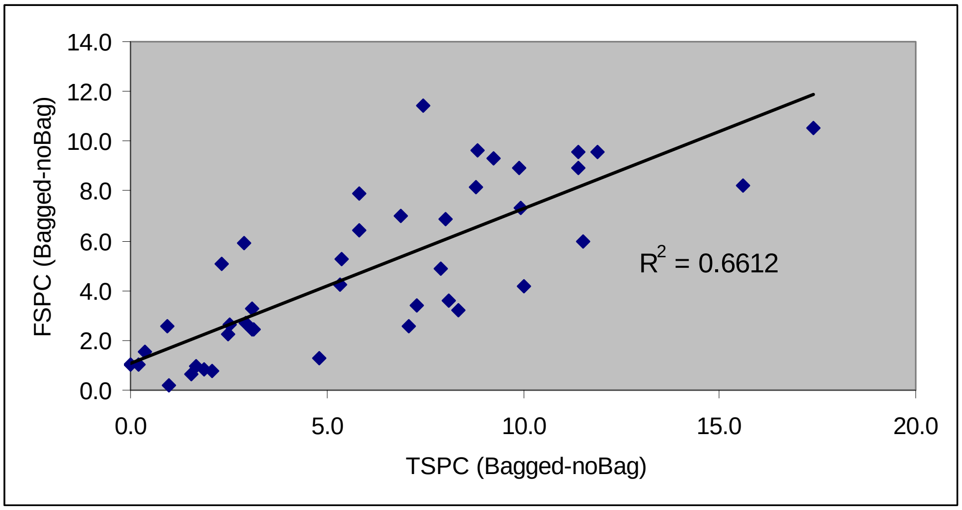
The relationship between the difference in TSPC and FSPC from bagged and unbagged cones is shown in Figure 25. This trend line explains about 66% (r^2=0.6612) of the variation between TSPC and FSPC seed losses. This is an important observation because TSPC and FSPC are linked and may indicate when seed loss occurs (i.e., before or after the seed coat is formed).

In general, when TSPC increases or decreases, FSPC changes in a similar way. This suggests that bagging affects both TSPC and FSPC in a similar way. Since there is a strong relationship between the difference (loss) in TSPC and FSPC, we may suggest that most of the seed loss (70%) due to bagging may occur after the seed coat is formed.

We may account for some of the lower TSPC and FSPC from NO orchards due to bagging effects but there still is a large number of both TSPC and FSPC not accounted for. We know from work by Patrick von Aderkas (UVic) that about 40 TSPC are expected from the post dormant first-year cone. Assuming that about 80% of these ovules develop, then we should expect about 30-32 TSPC. Assuming 80% of these developed ovules could form a fully developed seed, then we should expect yields about 20-24 FSPC.

In general, we can expect bagging effects to account for about 4-6 FSPC loss. Over the five year sampling period, an average of about 10 FSPC were observed across for all NO orchards. This leaves about 10-12 FSPC which can not be accounted for. This suggests some failure (physiological or morphological) of the developing second year seed cone (likely before fertilization occurs in June).

Figure 25: Trend line for total seed per cone (TSPC) and filed seed per cone (FSPC) differences between insect-bagged and unbagged seed cones from North Okanagan and Prince George orchards (2006 – 2010).



Bagging Effects – Bags On/Off Trial

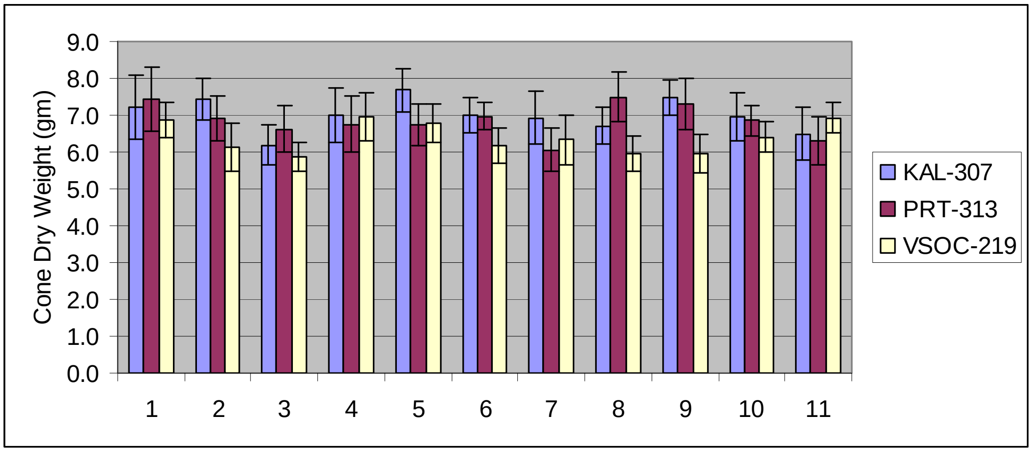
In an attempt to determine when bagging effects occur, cones were exposed for a two week period beginning mid April and continuing through August, 2010. Table 2 shows the nine periods of exposure in addition to a bag control which was always on (period 10) and a noBag control which was never bagged (period 11). Note for one of the three orchards monitored (KAL 307) the date of exposure began 2 days earlier.

Table 2: Dates of exposure periods for a Bag On/Off field trial (2010).

Period	Date
1	April 21/23 - May 5/7
2	May 5/7 - May 19/21
3	May 19/21 - June 2/4
4	June 2/4 - June 16/18
5	June 16/18 - June 30/July 2
6	June 30/July2 - July 14/16
7	July 14/16 - July 28/30
8	July 28/30 - August 11/13
9	August 11/13 - August 25/27
10	Always On
11	Always Off

Figure 26, 27 and 28 show the cone dry weights, TSPC and FSPC, respectively for each of the eleven exposure periods.

Figure 26: Mean (±standard error) cone dry weights for eleven exposure periods from a Bag On/Off field trial in each of three NO orchards (2010).



Cone dry weights did vary over the eleven exposure periods but the magnitude of the error bars suggests these were not significant. There were no differences in cone dry weight for cones protected all the time (period 10) and exposed all the time (period 11). However, for TSPC (Figure 27) and FSPC (Figure 28), seed yields did drop substantially for cones exposed all the time, especially for KAL-307 and to a lesser extend for PRT-313 and VSOC-219.

Figure 27: Mean (±standard error) total seed per cone (TSPC) for eleven exposure periods from a Bag On/Off field trial in each of three NO orchards (2010).

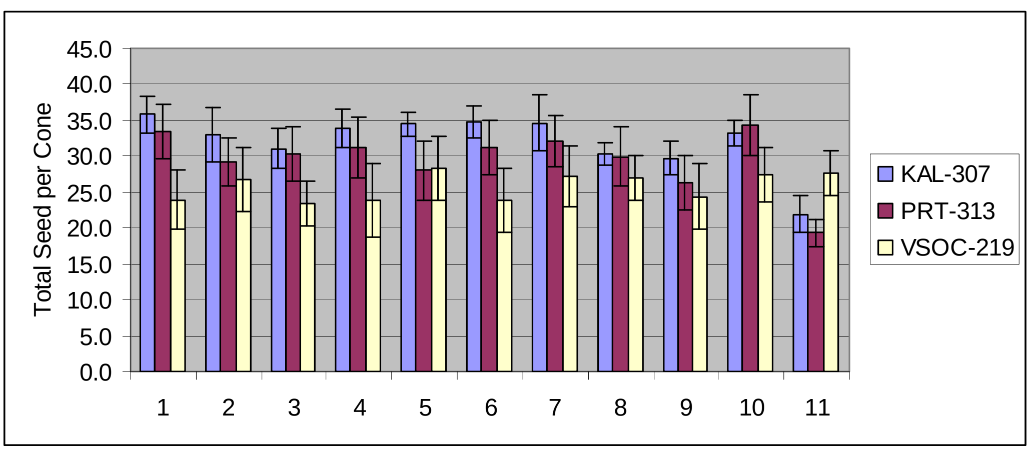
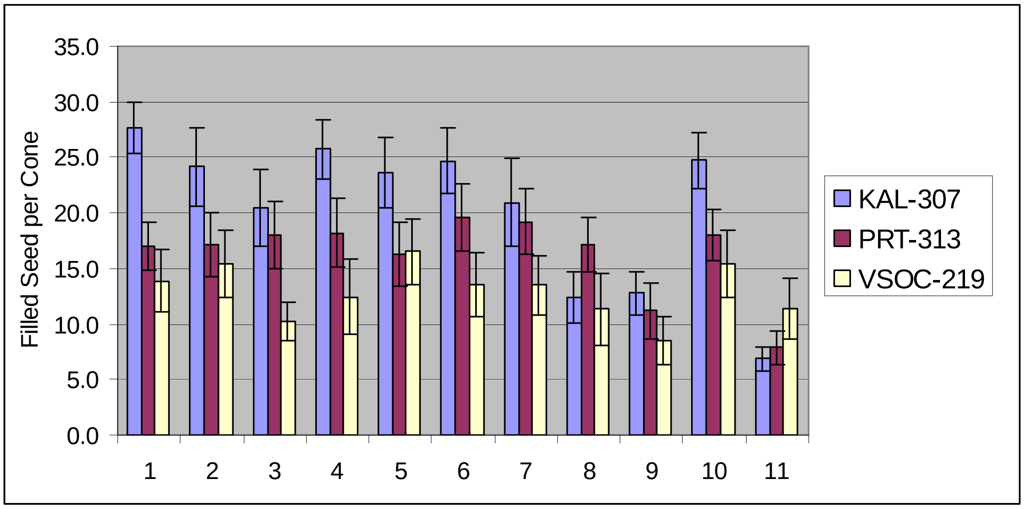


Figure 28: Mean (±standard error) filled seed per cone (FSPC) for eleven exposure periods from a Bag On/Off field trial in each of three NO orchards (2010).



All orchards showed a drop in FSPC for the last two exposure periods (late July and the four weeks of August exposure). Again, the effect (see Table 3) was greatest at Kalamalka (72% drop), less at PRT (56% drop), and least at VSOC (26(±standard error) % drop). Since insect populations are typically higher at Kalamalka, we may infer these differences in seed loss between orchards are due to differential insect predation.

Table 3: Mean filled seed per cone (FSPC) losses from cones bagged during the entire BagOn/Off trial and those exposed during the entire time (2010).

	CDW			TSPC			FSPC		
	KAL	PRT	VSOC	KAL	PRT	VSOC	KAL	PRT	VSOC
Always On	7.0	6.9	6.4	33.3	34.3	27.4	24.7	18.0	15.4
Always Off	6.5	6.3	6.9	21.9	19.3	27.7	6.9	7.9	11.4
Difference	0.5	0.5	-0.5	11.3	15.0	-0.3	17.9	10.1	4.0

It is interesting to note that seed losses at KAL 307 were17.9 FSPC from this trial (Table 3) and 11.4 FSPC from the sampling trees (Figure 24). At PRT, the loss from the Bag On/Off trial (Table 3) was about 8 FSPC but from the sampling data, the loss was only 2.7 seed (Figure 24). Since cones from the sampling trial were harvested earlier, they were not exposed as long as those cones harvested in late August. In the author's opinion, this indicates longer feeding time for insect predation.

Dr. Ward Strong provided a statistical analysis of this data (see email dated December 12, 2010) and summary as follows: “As expected, all the KAL data are highly significant; the two periods when bags were off in August took big hits in seedset. Somehow seeds are being emptied during that time. VSOC and PRT data have variable significance, hovering around the 0.05 level, which is a reasonable assurance that something's going on. But when you look at the multiple-range tests, you see that virtually all the significance is due to one treatment: never bagged. Pretty much all the other treatments are not significant. So although it looks like the same trend exists at PRT and VSOC as at KAL (August exposure empties seeds), this is actually a very weak trend, more plausibly explained by random chance than by a treatment effect.”

The conclusion that significant seed loss occurs at KAL in the month of August is strong but less so at PRT and VSOC. While interesting, this data can not support the inference that seed loss due to bagging occurs in August every year. This field trial should be repeated with the same design (although not necessarily the same orchards) to determine if environmental conditions of another year produce the same (or different) results.

Conclusions

The purpose of collecting lodgepole pine orchard statistics is to standardize the methods to estimate cone and seed production in all lodgepole pine seed orchards. The method to estimate cones per tree (based on cone weight) made comparisons between orchard sites and individual orchards more meaningful. This is also true for estimates of cone analyses (FSPC, TSPC and cone dry weight) for general orchard production (30-cone sample) and insect-bag effects.

In general, we expect Prince George orchards to produce fewer seed cones but higher seed yields. Likewise, experience has shown that north Okanagan orchards produce more cones but fewer seed. This did occur for 2006 and 2009 where cone and seed yield comparisons were made. However, in 2010, Prince George orchards produced both more cones and seed yields. This made seed production from Prince George orchards (5901 seed per tree) almost twice as much compared to the north Okanagan orchards (3127 seed per tree). This comparison includes the younger orchards and KAL 230 as well. Mean seed per tree for the NO (excluding KAL 230), PG, and the new expansion orchards was 3210, 5902 and 1783, respectively.

Overall production of filled seed per cone from Okanagan orchards lags behind that of Prince George. Okanagan orchards have about 10-15 fewer TSPC and FSPC compared to Prince George orchards. Over the five years observation, seed losses from the insect-bag affect have ranged from as low as 2 (2009) to a high of 10 (2006) and on average the loss has bee around 5 TSPC and FSPC. Certainly there is considerable variation between orchards but highest losses have consistently occurred at Kalamalka.

There is no consistent trend towards increasing or decreasing seed yields for the original orchards over the sampling period. In fact seed yields have remained fairly consistent for each orchard. Variation in the seed yields per tree from year to year is more affected by cone production than cone yields.

There still remains the question whether bagging effects are caused by insect damage (*Leptoglossus*) or some other unknown mechanism. In the author's opinion, the bag affect (i.e., more seed from bagged cones) is caused by insect damage. This is based the difficulty in rationalizing how an insect bag could affect second-year cone development. We know the total seed potential (number of fully developed seed coats) in lodgepole pine is 30-40 and the number of actual seed produced is about 20-25 (based on PG results). Assuming insect damage accounts for about 5 FSPC, we still have to account for about 10 FSPC. What effect between Prince George and the north Okanagan could account for this loss?

Does cone size provide a clue? PG cone dry weights are about 2-3 grams heavier than NO cones and the number of seed per gram cone dry weight from PG orchards is larger (about 1 seed per gram cone dry weight). The highest number of seed per gram cone dry weight was recorded at KAL 230 but the values from all PRT orchards (see Figure 18) have increased over time. The lowest values of seed per gram cone dry weight were observed at KAL 307 and the three VSOC orchards.

It is difficult to compare cone yields as a function of cone dry weight because we expect cone dry weight to vary by orchard seed planning units (SPU). In 2006 and 2009, we were able to compare three Prince George orchards (220-PG, 223-CP and 228-BV) with three VSOC orchards from the same provenance source (222-PG, 218-CP and 219-BV). Yields per cone mass were about double for PG orchards while cone mass alone from VSOC orchards was about 25% less than PG orchards. It appears from this data that the cone dry weight alone does not account for seed yield differences between PG and NO.

The trend line for FSPC as a function of cone dry weight is also not strong (see Figure 19).

However, increasing cone mass does, in general, indicate higher tree vigour. Associated with higher tree vigour is the ability to produce both more cones and seed yields per cone. For PRT orchards, cone numbers have remained about the same over the five years but cone dry weight, and FSPC have risen steadily and remain the highest of all north Okanagan orchards (excluding KAL 230). The steady rise in cone mass and seed yields from PRT orchards is encouraging. It is also encouraging to seed the high cone dry weight from two new expansion orchards (PRT-338 and Tolko-339). Assuming orchard pollen production will increase as these orchards mature; can we expect to see seed yields rise also? We expect so but there remains the question that affects all NO orchard (except KAL 230). Is the chronic low seed yield from NO orchards related to the environment of the north Okanagan?

This report does not include comparisons between orchard age and management practices such as insect control and SMP. It also does not account for different management practices that improve crown vigour (fertilizer, irrigation and crown pruning). If PRT yields continue to rise relative to other north Okanagan orchards, it may be prudent to review previous orchard management practices at PRT.