Western Larch Cones and Seeds--Current Intermountain Research Station Studies[1]

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Abstract.--In 1985, two studies involving western larch cone and seed production were begun. The first determines the influence of spacing on seed cone production of 30- to 32-year-old larch in western Montana. The second identifies factors limiting western larch cone production in forest stands of Idaho and Montana.

INTRODUCTION

The Intermountain Research Station's Silviculture Research Work Unit located in Bozeman and Missoula, Mont., began four western larch *(Larix occidentaZis)* cone and seed studies during the past 20 years. Two have been completed, two are underway. A brief review of results of two completed studies appear here; details are available in three publications cited. The remainder of this paper reports preliminary results of the two new, ongoing studies.

COMPLETED STUDIES

From 1964 through 1967, we studied the reliability of several factors for predicting western larch seed maturity on five larch growing at 4,000 feet on a north aspect near Missoula, Mont. (Shearer 1977). This study also determined if the period of cone collection (usually from late August through mid-September) could be extended. Embryo development (ratio of embryo length to seed cavity length) was complete in seeds from three study trees by early August and for two others by mid-August 1964. Specific gravity (about 0.75) and moisture content (about 25 percent) accurately predicted when cones would open. Although both indices decreased with advancing cone maturity, they did not give a clear indication of when cones were sufficiently mature to pick. Color is a poor indicator of cone maturity because of the wide range in cone colors within and among individual trees as cones mature. The study showed that cones on an individual tree open within a week, but cone opening among the trees varied considerably. Nearly all sound larch seed germinated when cone collection began by mid-August and cones were stored in well-ventilated areas for several weeks before seed extraction.

A second study began in 1980 at four locations in western Montana to determine the extent of damage to larch cones by western spruce budworm *(Choristoneura occidentalis)* and other insects. Shearer (1984) reported 3-year results. In 1980 and 1982, about two-thirds of the larch seeds were killed by insects. Cone production failed in 1981 because few, if any, ovulate buds formed in 1980. Second- and third-stage budworm larvae killed the small, developing larch cones soon after the ovulate buds opened. Occasionally, the budworm larvae ate seeds while randomly feeding within the developing larch cones, as described earlier by Fellin and Shearer (1968). A woolly aphid and a cone maggot caused heavy losses of cones and some loss of seed (Shearer 1984). A seed chalcid and a seedbug also killed a very few seed. Only 19 and 8 percent of the seeds were filled in 1980 and 1982. Empty and aborted seed made up 45 and 16 percent of the larch seed in 1980 and 1982. Larvae fed on filled, hollow, and aborted seed of mature cones, so the actual number of each were unknown.

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The second study also determined the number of cones that matured on larch trees within each of the four study areas from 1980 through 1983 (Shearer 1986). A good cone crop in 1980 accounted for 80 percent of all cones counted during the 4-year study. In 1980, cones matured on 85 percent of the larch in the 12- to 14-inch diameter class but only 38 percent matured on trees in the 4- to 6-inch diameter class. Cone production also was influenced by tree size. The average number of cones per tree in 1980 increased 27 times as the diameter classes increased from 4 to 6 inches to 12 to 14 inches. In years of fair or poor cone production the average number of cones per tree was about 15 times greater in the 12- to 14-inch diameter class than in the 4- to 6-inch diameter class. More than half of the larch in the 4- to 6-inch diameter class failed to mature any cones during the study; only 7 percent of the trees in the 12- to 14-inch diameter class failed to mature cones during the same period.

ONGOING STUDIES

In 1985, two additional studies began on western larch cone and seed production:

Study 1

Young, managed stands of western larch are gradually replacing the virgin forests that have dominated the Northern Rockies. Because of the importance of knowing the cone producing capabilities of young larch, this study, Cone Production on Immature Larch as Influenced by Spacing in Western Montana, is designed to identify the effects of stand density (spacing) on the frequency and amount of seed cone production. Initial results (spring 1985) are reported by Shearer and Schmidt (in press) and summarized in this paper.

Study 2

Western larch has produced few mature cones for many years within much of the panhandle of Idaho and in some nearby Montana stands, even when excellent cone crops occurred elsewhere in western Montana. Reasons for the lack of cone production are unknown. This study, Larch Cone and Seed Potential in Northern Idaho and Western Montana--Magnitude and Causes of Cone and Seed Failure, will identify the major factors reducing larch cone and seed potential in northern Idaho and in adjacent western Montana. Early results (1985 through early July 1986) are summarized here from a paper by Shearer and Theroux (in press).

STUDY AREAS AND METHODS

Only brief descriptions of study areas and types of data collected are presented. In-depth descriptions are contained in the study plans; short descriptions are given in the "in press" publications cited.

Study 1

Study 1 was superimposed on long-term research plots designed to evaluate the effects of spacing on the growth of young western larch. Four sets of plots were established in western Montana: two at Coram Experimental Forest near Glacier National Park; one at Cottonwood Lakes near Seeley Lake, about 93 miles south of Coram; and one at Pinkham Creek near Eureka, about 93 miles northwest of Coram. Elevations at the Coram plots averaged 3,820 feet, at Cottonwood 5,300 feet, and at Pinkham 4,870 feet. Site indices at 50 years were about 59 at Coram, 52 at Cottonwood, and 69 at Pinkham. In 1985, the average heights and ages of the sample trees were:

Coram 1 - 46 feet, 32 years
Coram 2 - 43 feet, 32 years
Cottonwood - 30 feet, 30 years
Pinkham - 43 feet, 30 years

Four densities were selected to study cone production at all four locations. An additional two densities were selected at the two Coram locations, resulting in 20 plots used to measure cone production. Densities and spacings were:

Locations	Densities: Trees per acre	Densities: Average spacing (feet)
Coram 1 and 2 only (unthinned plots)	∿15,000	∿2.0
All locations	1,740	6.5
All locations	680	8.0
All locations	360	11.0
All locations	200	15.0
Coram 1 and 2 only	110	20.0

Cone production is being monitored on the 10 tallest trees per plot. Binocular counts of cones in May and late August each year are made from one point for each tree.

Study 2

Study 2 identifies (1) frequency and amount of potential cone production, (2) cone development, and (3) factors reducing cones and seeds. Nine study areas were selected in northern Idaho, ranging from near New Meadows

In the south to near Bonners Ferry in the north. Two sites were chosen in western Montana, one near St. Regis and the other close to Libby. All areas are within larch forests originating after wildfires earlier this century. At each study area, 10 opengrowing dominant larch were selected that met three selection criteria: (1) crown length at least 40 percent of the total tree height, (2) accessible for climbing, and (3) evidence of prior cone production. Potential cone production and actual number of mature cones were determined on the five sample trees that were judged (from binocular counts) to have the greatest cone potential. Cone development and condition were determined at each visit for cones marked on two trees of each study area. Factors reducing cone and seed production were identified at each visit to the study areas by examining the marked cones and other evidence found in the trees. Unmarked cones were collected at each visit and dissected later to determine damage to cones and seeds.

RESULTS

The results shown here are preliminary because they represent only 1 or 2 years' data from each 5-year study.

Study 1

Although seed cone production in young western larch began several years ago, most trees had relatively few if any developing cones at the time of the first measurement in May 1985. The maximum was 65 on a tree in the 15-foot average spacing.

All seed cones were produced on ascending branches or on the 1981 to 1984 terminal leaders, except, within the 20-foot average spacing plots at Coram. There, half the trees produced cones on both ascending and horizontal branches. Most seed cones at all locations were produced within the upper third of the crown. Of the trees with cones, 76 percent had cones only in the upper third of the crown, 19 percent had cones in the upper two-thirds of the crown, and 5 percent produced cones only in the central third of the crown.

In 1985, more trees produced cones at both of the moderately productive sites at Coram and at the more productive site at Pinkham than at the less productive Cottonwood site (table 1). About 19 percent of all sample trees produced cones in 1985, ranging from 0 and 2.5 percent in the unthinned and 6.5-foot spacing plots to 30 and 50 percent in the 15- and 20-foot spacing plots. These early results show that trees designated for seed production must be open grown and full crowned to produce large numbers of cones.

Table 1.--Percent of trees in May 1985 that had new developing seed cones by location and average spacing. Sample size: 10 trees per location and spacing. Adapted from Shearer and Schmidt (in press)

	Spacing (feet)					
Location	20	15	11	8	6.5	Unthinned
Coram 1	40	60	10	10	0	0
Coram 2	60	0	30	30	0	0
Cottonwood	[1]--	20	10	0	0	[1]--
Pinkham	[1]--	40	20	30	10	[1]--

[1]No plot established.

Wider spacing of trees produced more seed cones (table 2). No cones were found on any of the unthinned-plot trees. Only one of the 40 sample trees in the 6.5-foot spacing produced cones--it had 18--for an average of 0.4 per sample tree. The number of developing

Table 2.--Average number and standard deviation (t) of new developing seed cones per tree in May 1985 by location and average spacing. Sample size: 10 trees per location and spacing. Adapted from Shearer and Schmidt (in press)

	Spacing (feet)					
Location	20	15	11	8	6.5	Unthinned
Coram 1	6± 9	10±21	2± 8	1±2	0	0
Coram 2	13±18	0	6±10	4±8	0	0
Cottonwood	[1]-----	<1± 1	1± 4	0	0	[1]--
Pinkham	[1]-----	8±17	<1± 1	1±2	2±6	[1]--
Average	[2]10±14	5±14	2± 6	1±6	<1±3	[2]0

[1]No plot established.
[2]Coram average only.

seed cones per tree averaged 9.5 in the 20-foot spacing, 23 times greater than in the 6.5-foot spacing.

Study 2

In 1985 and 1986, cones potential (developing cones) occurred at all study sites and on nearly all study trees. There was a broad range in cone potential among these trees, both within and among stands (table 3). The four study areas with the greatest cone potential in 1985 also had the best potential in 1986.

Buds of larch seed cones open much before those of other conifer species, often when snow still covers the ground. In 1985 and 1986, seed cone buds opened in late March to early April within the four study areas between 2,500 and 3,900 feet elevation. The ovulate buds probably opened by mid-April at the five sites between 4,500 and 4,800 feet elevation, and by late April at the two study areas at 5,000 and 5,800 feet elevation. Approximate dates for bud opening are given because snow blocks most of the roads, preventing early access to the study sites.

Cone elongation quickly followed bud opening and was complete or nearly complete by early July. Cone maturity occurred in August after the embryos were fully developed within the seeds, as described previously by Shearer (1977).

Insects and frost killed nearly all potential cones in 1985 and 1986. Even the few cones that matured usually contained seeds that were damaged by insects. As a result, almost no viable larch seed was dispersed on our study areas in northern Idaho in 1985 and even fewer are expected in 1986.

After the ovulate buds opened, frost killed all or most of the developing seed cones at all but the lower elevation sites. Although we are unsure of the threshold temperature that freezes and kills young cones, temperatures as low as 25 °F in 1986 did not kill or visibly damage the young cones at the low-elevation Twin study area. All other sites, where frost was a problem, had lower minimum temperatures (as low as 17 °F).

Periodic cone collections from areas with surviving cones showed that insect damage began by late April. In 1985, a woolly aphid (probably a species of *Adelges* was found on cones at Meadow, Standard, and Twin, but not at Twelve Mile or Beacon. None were found in 1986. In 1985 and in 1986, one or more cone maggot larvae (probably a species of *Hylema* fed within many cones that survived the frost. An unidentified scale midge was found on many cones in late June, 1985.

In 1985, frost killed all cones at four of nine study areas, killed from 40 to 71 percent of the cones at three other sites, and caused no losses at the two lowest elevation sites (table 4). All of the cones at Twin were killed by insects, about 90 percent by woolly aphid, and 10 percent by cone maggot larvae. In 1986, no woolly aphids were observed on the developing cones. At Meadow in 1985, 44 and 47 percent of the cones were killed by woolly aphids and cone maggots,

Table 3.--Average number of cones per tree estimated soon after bud opening in 1985 and 1986 on 11 study areas. From Shearer and Theroux (in press)

Study area	1985				1986			
	Cones	Sx	Range	n	Cones	Sx	Range	n
	(No.)				(No.)			
Meadow	1,220	354	416-2,288	5	2,879	905	892-6,137	5
Standard	199	70	1- 432	5	24	9	3- 58	5
Twin	656	197	304-1,232	5	56	28	9- 160	5
Twelve Mile	267	110	42- 563	5	287	168	76- 957	5
Beacon	828	113	471-1,082	5	1,354	400	36-4,039	10
Cairn	[1]--				322	122	2- 688	10
Brushy Fork	[1]--				284	164	0-1,722	10
Savage	163	143	0- 736	5	111	100	0- 512	5
Ericson	981	351	121-1,937	5	1,527	343	553-2,383	5
Peter	1,270	494	366-2,795	5	1,181	357	178-2,275	5
Brush Mountain	318	180	75-1,029	5	485	228	81-1,316	5

[1]Not established, no data collected.

Table 4.--Percent cone survival and mortality by cause. From Shearer and Theroux (in press)

Location	1985			1986		
		Mortality			Mortality	
	Survival	Frost	Insects	Survival	Frost	Insects
Meadow	12	0	88	0	100	0
Standard	2	40	58	0	[1]100	0
Twin	0	0	100	[2]--	0	[2]--
Twelve Mile	10	63	27	0	100	0
Beacon	16	71	13	0	100	0
Other[3]	0	100	0	0	100	0

[1]Two nonplot trees had a few cones that survived the frost.
[2]Data not complete on July 7, 1986.
[3]Savage, Ericson, Peter, and Brush Mountain in 1985 and 1986; Cairn and Brushy Fork 1986 only.

the remaining 9 percent by unidentified insects. At the other three locations, the cone maggot caused most of the insect-caused mortality.

Frost killed all cones on 10 of the 11 sites in 1986, although a few cones survived on two trees at Standard (not on the study plots) (table 4). For the second year no cones were killed by frost at Twin. No insect data are available at this time.

Less than 10 percent of the seed extracted from cones collected at four sites in 1985 were sound (table 5). The average number of sound (potentially viable) seed per tree ranged from about 32 at Standard to 1,466 per tree at Meadow. Insects damaged 26 to 55 percent of the potential seed at the four locations. Empty and abnormal (often aborted) seeds made up 38 to 65 percent of the potential seed on these areas.

Table 5.--Estimated number of seeds produced per tree at four study areas in 1985 and the percent of filled, damaged, and other nonviable seed. From Shearer and Theroux (in press)

Location	Estimated seeds per tree	Filled	Insect damaged	Other nonviable
	(No.)	*-Percent-*		
Meadow	20,950	7	55	38
Standard	355	9	26	65
Twelve Mile	3,442	8	46	46
Beacon	13,520	3	35	62

A sample of 100 mature cones from the four study areas in 1985 averaged only 9.4 sound of 104.5 potential seeds (table 6). Insects damaged or destroyed 43.4 of these seeds, 40.1 were hollow, 9.3 were abnormal, 2.3 had malformed embryos. The cone maggot most frequently caused damage within cones, followed by the woolly aphid and the scale midge. Feeding by cone maggot larvae left spiral tunnels around the axes. The condition of the seed (sound, hollow, etc.) before damage was obscured by this feeding. An examination of only undamaged cones and of cones damaged only by cone maggot, by woolly aphid, or by scale midge, gave a better understanding of the impact of each insect on viable seed.

Table 6.--Analysis of 100 mature western larch cones from Meadow, Standard, Twelve Mile, and Beacon study areas. Data shown as average number and range and $\bar{S}x$ of seeds per cone and percent germination of total and potentially sound seed. From Shearer and Theroux (in press)

Condition	Average and range	Sx
Damaged	43.4 (0-131)	3.8
Empty	40.1 (2-105)	2.4
Abnormal	9.3 (0- 67)	0.9
Malformed embryo	2.3 (0- 22)	0.4
Potentially viable	9.4 (0- 56)	1.2
Total	104.5 (52-158)	2.1
Germinated seed	7.9 (0- 56)	1.1
percent of total	7.6	
percent of potentially viable	84.2	

Cones without insects had no damaged seeds (table 7). Cones that were infested only by cone maggot larvae, however, averaged 85 (79 percent) damaged seeds; cones with only woolly aphids averaged 33 (33 percent) damaged seeds, and cones with only scale midges averaged 17 (17 percent) damaged seeds (table 7). Undamaged cones had about 14 (16 percent) seeds that were abnormal or the embryos were malformed; those with cone maggots had 5 (5 percent); those with woolly aphids 11 (11 percent); and those with scale midges 18 (18 percent). Cones with no insects had 21 (24 percent) potentially viable seed contrasting to 2 (2 percent), 5 (5 percent), and 14 (14 percent) for cones infested only by cone maggots, only by woolly aphids, and only by scale midges, respectively.

SUMMARY

In 1985, the number of seed cones generally increased as average spacing increased. Cone production was so low in 1986 that no pattern was evident. Unthinned trees had neither new nor old seed cones in 1985. The least productive site produced the fewest seed and pollen cones, while the more productive sites produced the most cones.

Frost caused the greatest reduction in cone potential by killing all cones within four of the nine stands examined in 1985 and within nine of the 11 stands examined in 1986. One stand escaped frost-caused cone mortality both years. A cone maggot caused heavy cone mortality at the five sites least affected by frost in 1985 and was present in cones collected in 1986. A woolly aphid caused some cone mortality in 1985 but none in 1986. A cone maggot, a woolly aphid, and a scale midge caused seed mortality in mature cones in 1985. Results from 1986 were not available. In 1985, cones with no insect damage averaged 24 percent sound seed, compared to 2, 5, and 13 percent sound seed in cones damaged only by a cone maggot, woolly aphid, or scale midge, respectively.

CONTINUING RESEARCH

At least three more field seasons will be devoted to documenting cone production for both studies and causes of cone mortality in study 2. About 1989, when the fieldwork on these studies may terminate, we will begin to determine the effects of cultural treatments on cone production of western larch. This effort will interest managers of seed production areas and seed orchards. In addition, the current studies will identify other factors we should study in greater depth.

Results from our studies will help predict where natural regeneration of larch should succeed and where artificial means are necessary to ensure maintaining the species it in forest stands.

Table 7.--Analysis of mature western larch cones by cause of damage. Data shown as average number and range and standard error of the mean (Sx) of seeds per cone and percent germination of total and potentially sound seed. From Shearer and Theroux (in press)

	Cause of damage											
	Undamaged n=11			Woolly aphids n=7			Cone maggots n=26			Scale midges n=32		
Condition	Avg.		Sx	Avg.		Sx	Avg.		Sx	Avg.		Sx
Damaged	0	(0)	0	33	(3- 99)	14	85	(53-131)	4	17	(0- 99)	4
Empty	52	(22- 78)	5	51	(17- 87)	10	16	(2- 46)	2	53	(17-105)	3
Abnormal	12	(2- 20)	2	9	(5- 16)	2	4	(0- 12)	1	14	(2- 67)	2
Malformed embryo	2	(0- 11)	1	2	(0- 5)	1	1	(0- 2)	T	4	(0- 22)	1
Potentially viable	21	(2- 56)	5	5	(0- 15)	2	2	(0- 11)	1	14	(0- 47)	2
Total	87	(52-112)	7	100	(82-130)	7	108	(68-144)	4	102	(58-158)	4
Germinated seed	20	(2- 56)	5	5	(0- 15)	2	2	(0- 10)	1	13	(0- 47)	2
percent of total	23			5			2			13		
percent of potentially viable	96			100			85			90		

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