

A survey of percent-filled and empty seeds in *Juniperus* of the western United States**Robert P. Adams**Biology Department, Baylor University, Box 97388, Waco, TX
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ABSTRACT

The percent-filled empty seeds for 13 *Juniperus* species in the western United States was determined by X-ray analysis. The amount of variation in % filled seeds was remarkable, varying both by year and by location, ranging from 0.0 (*J. osteosperma*, Utah) to 79.0% (*J. osteosperma*, Sedona, AZ). Of interest is the variation from 2010 to 2011, with *J. osteosperma* (Utah) having 0.0 in 2010 and 0.4% in 2011. Yet, *J. osteosperma* (Sedona, AZ) had 79.0% filled in 2010, but only 7.2% filled in 2011. Interestingly, *J. deppeana* had a similar pattern: 38.2% filled in 2010 and 0.0 % filled in 2011. But, *J. arizonica*, collected nearby, had the same % filled in 2010 and 2011. Additional studies are needed to determine if *Juniperus* has a diurnal pattern in filled seeds as common in pinyon pine. Published on-line www.phytologia.org *Phytologia* 96(2): 47-57 (April 1, 2014). ISSN 030319430

KEY WORDS: *Juniperus arizonica*, *J. ashei*, *J. californica*, *J. coahuilensis*, *J. communis* var. *depressa*, *J. deppeana*, *J. grandis*, *J. monosperma*, *J. occidentalis*, *J. osteosperma*, *J. pinchotii*, *J. scopulorum*, *J. virginiana*, filled and empty seeds, X-ray analysis.

Juniperus is a very diverse group of taxa that are mostly dioecious (Adams, 2014). Ortiz, Arista and Talavera (1998) noted that the dioecious nature of *Juniperus* could lead to a lack of pollination. I (RPA) have noticed many cases in *Juniperus* where only the tree side facing prevailing winds produces seed cones. Ortiz, Arista and Talavera (1998) reported the incidence of filled seeds in three populations of *J. macrocarpa* Sibth. & Sm. [*J. oxycedrus* subsp. *macrocarpa* (Sibth. & Sm.) Ball.] ranged from 0.04% to 65.5%, with an average of 30.7% filled seeds. In 2 of the 3 populations, the modal group was 0.0% filled seeds. They also reported on 3 populations of *J. oxycedrus* L. and found that the incidence of filled seeds ranged from 0.0% to 95%, with an average of 30.35 filled seeds. In each of the 3 populations, 0.0% filled seeds was the mode.

Houle and Babeux (1994) examined 200 seed cones (300 - 500 seeds) from each of 5 populations of *J. communis* var. *depressa* Pursh. from subarctic Quebec and found that one population had only 4% of the seeds contained embryos, whereas the other 4 populations ranged from 40 - 60% filled seeds.

Garcia et al. (2000), in an excellent study, examined seed cones and seeds of *J. communis* from 31 populations in 7 regions throughout Europe into Siberia. Filled seeds varied: South Iberian Peninsula: 0 - 40%; Central Iberian peninsula: 2 - 12%; North Iberian peninsula: 2 - 35%; Alps: 36 - 60%; Great Britain: 10 - 40%; Saian Mtns., Siberia: 75 - 80%; Northern Scandinavia: 8 - 52%. Thus, their study found a large range of filled seeds from 0 to 80%.

Douaihy et al. (2013), in a comprehensive study of *J. excelsa* from Lebanon, reported that filled seeds varied from 5% (El Njass) to 42% (Qammoua).

In a study of cone characteristics of *J. cedrus* and *J. brevifolia* (Rumeu, et al., 2009) found that 41.5% filled seeds in *J. cedrus* (with 64.6% viable) and 87.1% filled seeds in *J. brevifolia* (with 4.7% viable). The percent filled seeds for *J. brevifolia* is the highest level reported for any juniper species. *Juniperus brevifolia* is endemic to the Azores and occupies mesic sites compared to drier sites for *J. cedrus* (endemic to Canary Islands).

Fuentes and Schupp (1998) examined the incidence of filled seeds in a semi-desert species, *J. osteosperma* from North America. They questioned whether the plain titmice (*Parus inornatus*), a seed-eating bird that feeds on the seed embryos of *J. osteosperma* might select seed cones that contain filled seeds versus those with empty seeds. Table 1 shows a comparison of paired trees (adjacent) that showed either high or no predation. They found the % filled seeds to be highly significantly different between high and no predation trees. Of interest is the fact that 11 of the 17 trees had 0 to 2% filled seeds.

Table 1. Percent filled seed cones from *J. osteosperma* trees suffering high levels of seed predation by titmice and matched trees with no predation. Numbers of seed cones examined in parenthesis. Note: *J. osteosperma* averages about 1 seed/cone (Adams 2014). (from Fuentes and Schupp, 1998).

Tree Pair #	High predation, % filled (#cones)	No predation, % filled (#cones)
1	11.81 (127)	2.04 (98)
2	4.13 (121)	0.00 (105)
3	17.33 (150)	5.36 (112)
4	16.30 (92)	16.15 (161)
5	4.43 (203)	0.74 (136)
6	14.81 (243)	0.00 (130)
7	3.33 (120)	1.08 (185)
8	4.30 (93)	3.61 (166)
9	3.23 (93)	0.00 (75)
10	7.84 (153)	0.00 (172)
11	3.18 (157)	7.44 (121)
12	12.65 (253)	3.24 (432)
13	15.45 (343)	0.44 (455)
14	3.78 (291)	1.38 (289)
15	0.40 (251)	0.00 (304)
16	16.50 (618)	0.35 (282)
17	<u>9.19 (272)</u>	<u>0.38 (526)</u>
Mean (std dev)	8.74 (5.83)	2.48 (4.12) p = 0.001 ***

Recently, we (Adams and Thornburg, 2011) reported on an unusual phenomenon that some *J. arizonica* male trees produced a few seed cones among their pollen cones. However, at the time, we did not know if the seed cones borne on male tree contained filled seeds. A few seeds were examined from nearby female trees of *J. arizonica* and found to contain no embryos (empty). Before damaging the seeds from the male trees by opening them, a survey of the seed literature revealed that the US Forest Service, National Seed Laboratory, Dry Branch, GA provides a non-destructive X-ray service to determine if seeds contain an embryo. However, a general survey was needed as background for the incidence of filled seeds in *J. arizonica* and this led to a more general survey of the incidence of filled vs. empty seeds for most of the *Juniperus* species of the western United States. The purpose of this paper is to report on the results of that survey.

MATERIAL AND METHODS

Plant specimens collected:

- J. arizonica*, Adams 12505-12509, 5 normal female trees, Cottonwood, AZ, 3 Nov 2010, Adams 13178-13182, 5 normal female trees, Cottonwood, AZ, 28 Nov 2011, Adams 12510-12516, 7 'male' trees with seed cones, Cottonwood, AZ, 3 Nov 2010,
- J. ashei*, Adams 12500-12504, Westlake Hills, Austin, TX, 30 Oct 2010,
- J. californica*, Adams 13249-13253, Bodfish, CA, 14 Mar 2012, Adams 13254-13258, Victorville, CA, 14 Mar 2012, Adams 13260-13264, Bagdad, AZ, 16 Mar 2012,
- J. coahuilensis*, Adams 12574-12578, Alpine, TX, 20 Dec 2010 (mostly ripe, pink),
- J. communis* var. *depressa*, Adams 12384-12387, 6 Aug 2010,
- J. deppeana* var. *deppeana*, Adams 12551-12555, 14 mi se Camp Verde, AZ, 34.489386° N, 111.624069° W, Nov 2010, Adams 1384-13187, 14 mi se Camp Verde, AZ, 34.489386° N, 111.624069° W, Nov 2010,
- J. grandis*, Adams 12318-12322, Onyx Summit, CA, 20 Jul 2010 (seed cones green, too early to be filled?), Adams 12527-12531, Onyx Summit, CA, 5 Nov 2010 (seed cones blue, ripe, soft),
- J. monosperma*, Adams 12569-12573, Lake Tanglewood, Palo Duro Canyon, TX, 17 Dec 2010 (very ripe),
- J. occidentalis*, Adams 12343-12345, sw of Susanville, CA, 23 Jul 2010 (too early to be filled?), Adams 12476-12480, Bend, OR, 10 Oct 2010 (seed cones blue, ripe, soft),
- J. osteosperma*, Adams 12408-12412, Big Cottonwood Canyon, Salt Lake City, UT, 4 Sep 2010 (too early to be filled?), Adams 13188-13192, Big Cottonwood Canyon, Salt Lake City, UT, 4 Dec 2011, Adams 12323-12327, Big Bear Basin, CA, 20 Jul 2010 (too early to be filled?), Adams 12546-12550, n of Sedona, AZ, 34.491521° N, 111.690468° W, Nov 2010, Adams 13174-13177, n of Sedona, AZ, 34.491521° N, 111.690468° W, Nov 2011,
- J. pinchotii*, Adams 12540-12544, 15 m s of Claude, TX (Palo Duro Canyon), 14 Nov 2010 (seed cones ripe, orange, pollen shed in Sep-Oct),
- J. scopulorum*, Adams 12561-12565, Cimarron Canyon, NM, 2 Dec 2010 (2 yr, ripe cones),
- J. virginiana*, Adams 121495-12499, Lockhart, TX 30 Oct 2010.

Voucher specimens are deposited in the herbarium (BAYLU), Baylor University, Waco, TX.

X-ray analysis of the seeds was performed by the US Forest Service, National Seed Laboratory, Dry Branch, GA.

RESULTS AND DISCUSSION

The comparison between normal, female *J. arizonica* trees and the 7 'male' trees bearing a few seed cones (Table 2) shows the seeds from the normal, female trees ranged from 20 to 56% filled seeds in 2010 and 2011, with both years very similar in % filled seeds. The 7 'male' trees, with a few seed cones, varied from 0.0 (1) to 100.0% (2), but for larger numbers of seed (trees 1, 2, 10, 17), there was considerable filled seeds (42.8, 88.0, 29.4, 50.0%, Table 2). These seed from otherwise, 'male' (i.e. pollen producing) trees were just as likely filled (and presumably viable) as the normal, female trees seed.

Table 2. The % filled seeds from normal, female *J. arizonica* trees and 7 'male' trees bearing a few seed cones.

J. arizonica, 10 normal, female trees, Cottonwood, AZ, David Thornburg property.

coll. 3 Nov 2010	# cones	seeds/cone	#seeds X-rayed	% filled
12505	50	1.22	50	28
12506	50	1.00	50	30
12507	50	1.11	50	34
12508	50	1.14	50	56
12509	50	1.00	50	24
				avg = 34.4%
coll. 28 Nov 2011			#seeds X-rayed	% filled
13178			50	21
13179			50	39
13180			50	49
13181			50	20
13182			50	38
				avg = 33.4%

J. arizonica, 7 male trees, each with a few female cones, Cottonwood, AZ, David Thornburg property.

coll. 3 Nov 2010	# cones	seeds/cone	#seeds X-rayed	% filled
12510 tree 1	13	1.08	14	42.8*
12511 tree 2	50	1.04	50	88.0*
12512 tree 3	1	1.00	1	100.0
12513 tree 4	1	1.00	1	0.0
12514 tree 8	1	1.00	1	100.0
12515 tree 10	37	0.92	34	29.4*
12516 tree 17	30	1.00	30	50.0*
				avg. = 52.6% (for * trees)

Juniperus ashei is an abundant juniper in the Texas Edwards Plateau, ranging northward to n Arkansas and s Missouri (Adams, 2014). It has low to moderate % filled seeds at the Austin, TX population sampled, ranging from 14 to 38% (Table 3) in the 2010 sample.

Table 3. The % filled seeds for *J. ashei*.

J. ashei, Westlake Hills, Austin, TX, coll. 30 Oct 2010.

	# cones	seeds/cone	#seeds X-rayed	% filled
12500	47	1.06	50	38
12501	50	1.14	50	14
12502	32	1.56	50	26
12503	32	1.50	50	36
12504	50	1.28	50	22
				avg = 27.2%

The California juniper, *Juniperus californica*, has a large distribution in the margins of the California central valley from near Red Bluff, southward into Baja Mexico and east from s California to nw Arizona (Adams, 2014). Two populations in California showed a considerable number of filled seeds (38 to 78%, Table 4). The population from Bagdad, AZ had very high seed fill, ranging from 68 to 92% (Table 4).

Table 4. The % filled seeds for *J. californica*.*J. californica*, Bodfish, CA, coll. 14 Mar 2012

	# cones	seeds/cone	# w 2 seeds	# w 3 seeds	#seeds X-rayed	% filled	
13249	43	1.16	7	0	50	54.0	
13250	43	1.16	7	0	50	60.0	
13251	34	1.47	16	0	50	52.0	
13252	50	1.00	0	0	50	54.0	
13253	45	1.11	5	0	50	72.0	avg = 58.4%

J. californica, Victorville, CA, coll. 14 Mar 2012

	# cones	seeds/cone	# w 2 seeds	# w 3 seeds	#seeds X-rayed	% filled	
13254	40	1.25	10	0	50	64.0	
13255	24	1.63	7	8	50	68.0	
13256	29	1.52	8	7	50	38.0	
13257	27	1.56	7	8	50	68.0	
13258	25	1.72	11	7	50	78.0	avg = 63.2%

J. californica, Bagdad, AZ, coll. 16 Mar 2012

	# cones	seeds/cone	# w 2 seeds	w # 3 seeds	#seeds X-rayed	% filled	
13260	50	1.00	0	0	50	92.0	
13261	50	1.00	0	0	50	68.0	
13262	48	1.04	2	0	50	80.0	
13263	43	1.16	7	0	50	80.0	
13264	48	1.04	2	0	50	68.0	avg = 77.6%

Juniperus coahuilensis is an usual juniper with unique, pink-colored seed cones. It is common in northern Mexico, but is uncommon in the United States, found only in the trans-Pecos Texas area (Adams, 2014). As the case in all juniper species, the seed cones are prone to insect attack and the laying of eggs in the young seed cone. The samples of *J. coahuilensis* contained one tree in which all the seed cones examined (~250) were damaged by insects. The other four trees seed cones had filled seeds ranging from 10.9 to 51% (Table 5).

Table 5. The % filled seeds for *J. coahuilensis*.*J. coahuilensis*, Alpine, TX, 20 Dec. 2010, most fruit ripe, very few greenish

	# cones	seeds/cone	#seeds X-rayed	% filled	
12574	50	1.00	49	51.0	
12575	50	1.00	46	34.8	
12576*	49	1.02	0*	0.0*	
12577	50	1.00	46	10.9	
12578	50	1.00	44	18.2	avg = 22.8%

* all seeds damaged by insects. Some larvae were still inside seeds.

The common juniper, *Juniperus communis*, is a Pan-Arctic species found at northerly latitudes. *Juniperus communis* var. *depressa* is confined to North America (Adams, 2014). The population near Winnipeg, Manitoba, Canada had low seed fill (8.3 - 16%, Table 6). This is not too dissimilar from the results of Houle and Babeux (1994) who found the incidence of filled seeds in 5 populations of *J. communis* var. *depressa* were 4, 40, 53, 57, and 60%.

Table 6. The % filled for *J. communis* var. *depressa*

J. communis var. *depressa*, Winnipeg, Canada, coll. 6 Aug 2010

	# cones	seeds/cone	#seeds X-rayed	% filled
12384	50	1.98	50	16.0
12385	50	2.32	50	12.0
12386	--	--	60	8.3
12387	--	--	50	10.0
				avg = 11.6%

The alligator bark juniper, *Juniperus deppeana*, has large, woody seed cones with 2 - 4 seeds/cone. It very common in Arizona and New Mexico (Adams, 2014). Our first samples were collected in Nov., 2010 and had filled seeds ranging from 20.8 to 48.1% (Table 7). However, seeds were collected from trees at the same population in Nov., 2011 and no (0.0) filled seeds were produced that year. Conifers are well known to produce large seed crops in alternative years (cf. pinyon pine). This may be the case in *J. deppeana* or 2010 may have been a bad year for filled seeds.

Table 7. The % filled seeds for *J. deppeana*

J. deppeana, ca 14 air miles SE of Camp Verde, Az along Hwy 260, ex David Thornburg coll. **Nov 2010**.

	# cones	seeds/cone	#seeds X-rayed	% filled
12551	20	2.30	46	21.7
12552	17	3.06	53	48.1
12553	12	4.17	45	40.0
12554	20	2.55	53	60.4
12555	21	2.38	48	20.8
				avg = 38.2%

J. deppeana, **re-collection**, ca 14 air miles SE of Camp Verde, Az along Hwy 260 ex David Thornburg, coll. **28 Nov 2011**.

	# seeds X-rayed	% filled
13183	50	0.0
13184	50	0.0
13185	50	0.0
13186	50	0.0
13187	50	0.0
		avg = 0.0%

The grand juniper, *Juniperus grandis*, was previously recognized as *J. occidentalis* var. *australis*. However, recent DNA sequencing data supports its recognition as a distinct species (Adams, 2014). Two sets of seed cone samples were collected from a population at Onyx Summit, San Bernardino Mtns., CA on 20 Jul 2010 and 5 Nov 2010. Because the seed cones were smaller and green in the 20 Jul samples, it was suspected that collecting later, when the seed cones were mature, would yield seeds easier to score. The 20 Jul seeds ranged from 4.8 to 25.0% filled, whereas the 5 Nov seeds ranged from 6.0 to 24.0% filled (Table 8). So it does not appear that using younger seeds made any difference in the ability to utilize X-ray analyses to determine filled and empty seeds.

Table 8. The % filled seeds for *J. grandis* collect at Onyx Summit, CA
J. grandis, Onyx Summit, CA coll. 20 Jul 2010 (too early?), cones green, hard

	# cones	# w 2 seeds	#seeds X-rayed	% filled	
12318	--	--	88	25.0	
12319	--	--	85	22.3	
12320	--	--	71	5.6	
12321	--	--	73	11.0	
12322	--	--	84	4.8	avg = 13.7%

J. grandis, Onyx Summit, CA, re-collection, coll. 5 Nov 2010, fruit blue, ripe, soft!

	# cones	seeds/cone	#seeds X-rayed	% filled	
12527	26	1.92	50	6.0	
12528	35	1.43	50	20.0	
12529	35	1.43	50	24.0	
12530	28	1.78	50	20.0	
12531	30	1.57	50	8.0	avg = 15.6%

The one-seeded juniper, *J. monosperma*, grows from west Texas into New Mexico, Colorado, and northern Arizona (Adams, 2014). A population on the rim of Palo Duro Canyon, TX was sampled. The seeds ranged from 20.0 to 77.6% filled. The 77.6% value seems unusual (Table 9).

Table 9. The % filled seeds for *J. monosperma*.

J. monosperma, Lake Tanglewood, TX Dec. 17, 2010, very ripe

	# cones	seeds/cone	#seeds X-rayed	% filled	
12569	46	1.09	48	27.0	
12570	49	1.02	43	25.6	
12571	48	1.04	49	77.6	
12572	49	1.02	47	34.0	
12573	50	1.00	50	20.0	avg = 36.8%

The western juniper, *J. occidentalis*, is the dominant juniper (and tree) in much of eastern Oregon (Adams, 2014). Seeds from 2 populations were collected in 2010. The Bend, OR seeds ranged from 0.0 to 12.0% filled (Table 10), whereas seed of two trees from SW of Susanville, CA had 0.0 and 11.8% filled.

Table 10. The % filled seeds for *J. occidentalis*.

J. occidentalis, Bend, OR, Collected (Mark Corbet) 10 Oct 2010, ripe, blue, soft, resinous

	# cones	seeds/cone	#seeds X-rayed	% filled	
12476	29	1.72	50	0.0	
12477	36	1.38	50	0.0	
12478	30	1.67	50	4.0	
12479	40	1.25	50	12.0	
12480	39	1.28	50	12.0	avg = 5.6%

J. occidentalis, sw of Susanville, CA collected 23 Jul 2010 (too early?)

	# cones	# w 2 seeds	seeds/cone	#seeds X-rayed	% filled	
12343	67	0	1.00	67	0.0	
12345	50	18	1.36	68	11.8	avg = 5.9%

The Utah juniper, *J. osteosperma*, is the dominant tree in many parts of Utah and Nevada and extends into northern Arizona, southern California, and western New Mexico (Adams, 2014). Seeds were collected from a small population (50 - 100 trees) growing at the mouth of the Big Cottonwood Canyon, SLC, Utah in 2010 and 2011. No filled seeds were found in 2010 and only 1 seed (in 50, = 2%) was found in 2011 (Table 11). This is an extreme situation. Seeds from a population north of Sedona, AZ were collected in 2010 and 2011. In 2010, filled seeds ranged from 54.4 to 95.5% (Table 11), compared to 2.0 to 16.0% the next year (2011, Table 11). This change from 2010 to 2011 is similar to that found for *J. deppeana* (Table 7) from nearby Camp Verde, AZ. One population was sampled from Big Bear Basin, San Bernardino Mtns., CA in 2010. Four trees were very uniform ranging from 61.5 to 66.7% filled seeds, whereas one individual (Table 11) had no filled seeds. This reinforces the idea of collecting from several tree sources to obtain viable seeds for germination.

Table 11. The % filled seeds for *J. osteosperma*..

J. osteosperma, Big Cottonwood Canyon, SLC, UT coll. **4 Sep 2010** (too early?)

	# cones	# w 2 seeds	seeds/cone	#seeds X-rayed	% filled	
12408	90	0	1.00	90	0.0	
12409	102	1	1.01	103	0.0	
12410	101	0	1.00	101	0.0	
12411	102	0	1.00	102	0.0	
12412	100	6	1.06	106	0.0	avg = 0.0%

J. osteosperma, Big Cottonwood Canyon, SLC, UT coll. **4 Dec 2011** ex Andy Hornbaker

	# cones	# w 2 seeds	seeds/cone	#seeds X-rayed	% filled	
13188	50	0	1.00	50	2.0	
13189	50	0	1.00	50	0.0	
13190	50	0	1.00	50	0.0	
13191	50	0	1.00	50	0.0	
13192	50	0	1.00	50	0.0	avg = 0.4%

J. osteosperma, Sedona, AZ, coll. **Nov 2010** ex David Thornburg

	# cones		seeds/cone	#seeds X-rayed	% filled	
12546	50		1.00	49	89.8	
12547	49		1.02	48	85.4	
12548	49		1.02	44	95.5	
12549	47		1.06	48	54.2	
12550	47		1.06	50	70.0	avg = 79.0%

J. osteosperma, Sedona, AZ, coll. **Nov 2011** ex David Thornburg

				#seeds X-rayed	% filled	
13173				50	4.0	
13174				50	2.0	
13175				50	7.0	
13176				50	16.0	
13177				50	6.8	avg = 7.2%

J. osteosperma, Big Bear Basin, CA, coll. **20 Jul 2010**

	# cones	# w 2 seeds	seeds/cone	#seeds X-rayed	% filled	
12323	50	2	1.04	52	61.5	
12324	50	12	1.24	62	64.6	
12325	50	0	1.00	50	64	
12326	52	2	1.04	54	66.7	
12327	45	0	1.00	45	0.00	avg = 51.4%

Recall that Fuentes and Schupp (1998) examined the incidence of filled seeds in a semi-arid species, *J. osteosperma* from Utah (Table 1, above). Their 34 trees varied from 0.0 to 16.5% filled seeds (avg. = 5.61%). So it is interesting that the Sedona, AZ, 2011 samples display a range of variation similar to their Utah samples.

The redberry juniper, *J. pinchotii*, grows in southwest Oklahoma and west Texas, and thence into northern Mexico (Adams, 2014). Samples from a population on the north side of Palo Duro Canyon, TX had very low seed fill in 2010 (0.0 to 8.0%, Table 12). Warren (2001) examined 5000 seeds per population and found 17% filled in Palo Duro Canyon (and 9.5 to 18.1% filled in 3 other locations, Table 12). It is very likely that samples from our population, in a different year might, have been quite different in % filled seeds.

Table 12. The % filled seeds for *J. pinchotii* from Palo Duro Canyon and from Warren (2001) for four populations.

J. pinchotii, Palo Duro Canyon, 15 m s of Claude, Tx, fruit ripe, coll. 14 Nov 2010.

	# cones	seeds/cone	#seeds X-rayed	% filled	
12540	47	1.06	50	0.0	
12541	46	1.09	50	8.0	
12542	50	1.00	50	6.0	
12543	48	1.04	50	0.0	
12544	29	1.72	50	0.0	avg = 2.8%
<i>J. pinchotii</i> , from Warren (2001)			# seeds	% filled	
Palo Duro Canyon			5000	17.0	
Justiceburg, TX			5000	9.5	
San Angelo, TX			5000	18.1	
Guadalupe (Salt Flat, TX)			5000	9.9	avg = 13.6%

The Rocky Mountain juniper, *J. scopulorum*, is very widely distributed in the Rocky Mountains of western North America (Adams, 2014). Analysis of seeds from Cimarron Canyon, NM revealed seeds filled ranged from 25.5 to 79.5% (Table 13).

Table 13. The % filled seeds for *J. scopulorum*.

J. scopulorum, Cimarron Canyon, NM, 2 Dec 2010, lots of 2yr ripe cones

	# cones	seeds/cone	#seeds X-rayed	% filled	
12561	42	1.19	47	42.6	
12562	45	1.11	47	40.4	
12563	37	1.35	48	29.2	
12564	40	1.25	47	25.5	
12565	47	1.06	44	79.5	avg = 43.4%

Juniperus virginiana, eastern red cedar, is a sister species to *J. scopulorum*. It grows from the eastern part of the Great Plains to the Atlantic ocean (Adams, 2014). Normally, it has lots of filled seeds and high viability. However, the Lockhart population sampled had lots of % filled seeds, ranging from 0.0 to 4.0% (Table 14). It may be that filled seeds are low in this population, or more likely, 2010 was a poor year for filled seed production. It is surprising to find such a low percent filled seeds in *J. virginiana*.

Table 14. The % filled seeds for *J. virginiana*..
J. virginiana, Lockhart, TX coll. 30 Oct 2010.

	# cones	seeds/cone	#seeds X-rayed	% filled	
12495	42	1.19	50	2.0	
12496	39	1.28	50	0.0	
12497	39	1.31	51	0.0	
12498	38	1.32	50	4.0	
12499	30	1.70	51	0.0	avg = 1.2%

The amount of variation in % filled seeds is remarkable, varying both by year and by location. The % filled seeds for 13 *Juniperus* species from the US and Canada are shown in Table 15. These values range from 0.0 (*J. osteosperma*, Utah) to 79.0% (*J. osteosperma*, Sedona, AZ). Of interest is the variation from 2010 to 2011, with *J. osteosperma* (Utah) having 0.0 in 2010 and 0.4% in 2011. Yet, *J. osteosperma* (Sedona, AZ) had 79.0% filled in 2010, but only 7.2% filled in 2011. Interestingly, *J. deppeana* had a similar pattern: 38.2% filled in 2010 and 0.0 % filled in 2011. But, *J. arizonica*, collected nearby, had the same % filled in 2010 and 2011 (Table 15).

Additional studies are needed to determine if *Juniperus* has a diurnal pattern in filled seeds as common in pinyon pine.

Table 15. Comparison of % filled seeds for 13 *Juniperus* species in North America.

Species, location	% filled (year)
<i>J. arizonica</i> , Cottonwood, AZ	34.4 (2010), 33.4 (2011)
<i>J. ashei</i> , Westlake Hills, Austin, TX	27.2 (2010)
<i>J. californica</i> , Bodfish, CA	58.4 (2012)
<i>J. californica</i> , Victorville, CA	63.2 (2012)
<i>J. californica</i> , Bagdad, AZ	77.6 (2012)
<i>J. coahuilensis</i> , Alpine, TX	22.8 (2010)
<i>J. communis</i> var. <i>depressa</i> , Winnipeg, Can.	11.6 (2010)
<i>J. deppeana</i> , 14 miles SE Camp Verde, AZ	38.2 (2010), 0.0 (2011)
<i>J. grandis</i> , Onyx Summit, CA	13.7 (7/2010) 15.6 (11/2010)
<i>J. monosperma</i> , Lake Tanglewood, TX	36.8 (2010)
<i>J. occidentalis</i> , Bend, OR	5.6 (2010)
<i>J. occidentalis</i> , sw of Susanville, CA	5.9 (2010)
<i>J. osteosperma</i> , Big Cottonwood Canyon, UT	0.0 (2010), 0.4 (2011)
<i>J. osteosperma</i> , Sedona, AZ	79.0 (2010), 7.2 (2011)
<i>J. osteosperma</i> , Big Bear Basin, CA	51.4 (2010)
<i>J. pinchotii</i> , Palo Duro Canyon	2.8 (2010)
<i>J. pinchotii</i> , from Warren (2001)	
Palo Duro Canyon	17.0
Justiceburg, TX	9.5
San Angelo, TX	18.1
Guadalupe (Salt Flat, TX)	9.9
<i>J. scopulorum</i> , Cimarron Canyon, NM	43.4 (2010)
<i>J. virginiana</i> , Lockhart, TX	1.2 (2010)

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