SEXUAL CHANGE IN *JUNIPERUS ARIZONICA*: FACULTATIVE MONECIOUS?

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ABSTRACT

A two year study of the incidence of female cones on otherwise male trees of *Juniperus arizonica* revealed that about 5-10% of the trees had a few female cones interspersed with the male cones. Literature reports on sex change in Juniperus are reviewed. *Phytologia 93(1): 43-50 (April 1, 2011).*

KEY WORDS: *Juniperus arizonica,* monecious, dioecious, female cones, sexual expression.

Vasek (1966), in a seminal study of the junipers of the western United States, tagged individual trees of *J. occidentalis* subsp. *australis* Vasek (now *J. grandis* R. P. Adams) and *J. osteosperma* (Torr.) Little and recorded their sexual expression for up to five years. Table 1 shows the results of his study. Although *J. o.* subsp. *australis* was reported as 90-95% dioecious (Vasek, table 4, 1966), some of the trees changed from male cones to producing both male and female cones (MBMBM, OMMB, MMMB, table 1) and some trees changed from female to none (FFFO, FOOO, table 1), but none changed from male to female or from female to male.

Juniperus osteosperma is about 85-90% monecious (Vasek, table 4). A few trees changed from female to both (FBBBB, FBBB, FBB, FFBB, table 1) and some changed from male to both (MBBB, MMBB, table 1) and 2 trees changed in all combinations (FFMB, OMFB, Table 1). Thus, of the 84 trees tagged and followed, 3/43 *australis* and 7/41 *osteosperma* trees showed sex changes.

Table 1. Sexual expression of tagged plants in the San Bernardino Mtns. (*J. o.* subsp. *australis*) and White Mtns. (*J. osteosperma*). M = male cones only, F = female cones only, B = both male and female cones, O = no cones produced. Each letter represents an observation for one year. For example, OMFB means that the tree was observed 4 years with no cones (O) in the first year, male cones (M) in year 2, female cones (F) in year 3 and both male and female cones (B) in year 4. (data from Vasek, 1966)

J. o. subsp. *australis*				*J. osteosperma*			
# trees	pattern	# trees	pattern	# trees	pattern	# trees	pattern
1	MMMMMM	4	FFF	11	BBBB	1	FBBBB
5	MMMM	2	FF	15	BBB	3	FBBB
2	MMMO	1	BBB	7	BB	1	FBB
5	MMM	1	OOOO	2	FFFF	2	FFB
3	MM	1	MBMBM	1	FFF	2	MBBB
10	FFFF	1	OMMB	1	FFFO	1	MMBB
5	FFFO	1	MMMB	1	MM	1	FFMB
1	FOOO			1	OOO	1	OMFB

It is also interesting that Vasek (1966) observed a female australis tree with a broken, forked branch. The lower (cambium intact) portion produced female cones and the upper (presumably stressed) portion produced male cones. This seems to imply that environmental conditions may play a role in sex expression.

Jordano (1991) reported on sex expression in *J. phoenicea* L., a species that is largely monecious. He found that strongly male trees did not convert to females (Table 2) and that the strongly female trees did occasionally convert to strong male trees (Table 2). One of the inconstant (inconsistent) male trees did have some female cones the next year. Jordano (1991) reported that strong males produced fewer than 10 female cones, whereas inconstant males rarely exceeded 200 females cones. Strong female trees produced more that 100 cones, except in years of crop failures. In addition, he reported that male trees produced smaller female cones with fewer seeds and these female cones tend to be aborted before maturity (Jordano, 1991). He speculated that self-fertilized might be the cause of self-abortion.

Table 2. Gender expression in consecutive years of *J. phoenicea* (data from Jordano, 1991).

	Gender expression in the next year				
Gender in current year	Male	Incon-stant male	Mono-ecious	Incon-stant female	Female
Male	2	8	0	0	0
Inconstant male	6	17	1	1	0
Monecious	0	4	1	0	0
Inconstant female	0	0	1	0	1
Female	3	1	0	0	21

The purpose of the present study was to tag and examine the changes in sex expression in a population of *J. arizonica*.

MATERIALS AND METHODS

Approximately 200 *J. arizonica* trees near Cottonwood, AZ were examined to determine if any male trees had female cones. Those male trees that produced some female cones were tagged and re-examined annually for the production of female cones.

RESULTS AND DISCUSSION

In March, 2009, 18 male trees were found that had mature female cones (Table 3). In June, 2010, 3 additional male trees were discovered with female cones (Table 3, trees 19-21). Interestingly, none of the trees that bore new female cones in 2008 produced female cones (YF) in the winter of 2009 (Table 3). The mature fruit (MF) were from the 2008 pollination season (winter). Since none of the 21 trees had young fruit in March, 2009, then, of course, they would not have any mature fruit (MF) in June, 2010. Many of the trees that bore a few female cones in 2008 (YF, Table 3) did not bear any female cones in either 2009 or 2010. Two trees (#2 and 10) bore more, or about the same, number of female cones from 2008 to 2010 (but none in 2009).

Table 3. Sex expression in tagged male trees on successive years (2008, 2009, 2010). MF = mature fruit (1 yr old), YF = current year's fruit. No data is available for MF in 2008. YF in 2008 is based on MF found on the same tree in 2009.

	2008	2009		2010	
Tree	YF	YF	MF	YF	MF
1	50+	0	50	12	0
2	1+	0	1	9	0
3	3+	0	3	2	0
4	1000+	0	1000+	8	0
5	2+	0	2	0	0
6	11+	0	11	0	0
7	6+	0	6	0	0
8	1+	0	1	1	0
9	2+	0	2	0	0
10	10+	0	10	14	0
11	5+	0	5	0	0
12	5+	0	5	0	0
13	2+	0	2	0	0
14	13+	0	13	0	0
15	2+	0	2	0	0
16	9+	0	9	0	0
17	100+	0	100+	13	0
18	3+	0	3	0	0
19	?	0	?	5	0
20	?	0	?	0	0
21	?	0	?	1	0

Most of the male trees had only a few fruits (female cones), but trees #4 and 17 had at least 100 female cones (Table 3). Trees #1 and 4 that bore larger numbers of female cones (50, 100) in 2008 (YF, Table 3), had fewer fruits (12 and 8, respectively) in 2010 (Figure 1).

Figure 1. Single female cone surrounded by male cones on *J. arizonica*.

It might be noted that no strongly female trees with abundant female cones were found with male cones. However, seeing a few of the small male cones amongst the female cones is often very difficult.

In addition to counting the cones, in April, 2009, forked limbs were cut about 1/3 through the top portion (to mimic the broken branch noted by Vasek, 1966) on 25 male trees. In the spring of 2010, these cut branches were observed. All of these produced male cones on both the upper and lower forked branchlets. It seems reasonable that stressed branchlet (Vasek, 1966) might produce male cones if a species has that facultative ability. I (RPA) have observed that often one finds very few female cones on junipers in areas of severe drought.

However, floral sex ratios in monecious plants change in response to hormones: both auxins and gibberellins (Heslop-Harrision, 1972; Friedlander et al. 1977)

Freeman et al. (1981) reported that *J. osteosperma*, a monecious species, had a significantly higher frequency of male cones than female cones on trees in a xeric population (Table 4). It is interesting that *J. osteosperma* on the xeric site had slightly fewer trees (27.15%) with no cones (male or female)

Table 4. Comparison of the frequencies of male and female cones on terminal limbs (2 per tree), 25 trees per site of *J. osteosperma*, a monecious species.

Xeric site			Mesic site			F value for site-sex
male	female	nothing	male	female	nothing	interaction
54.85	17.50	27.15%	30.60	34.25	31.15%	30.57**

than on the mesic site (31.15%). Freeman et al. (1981) found a similar pattern with Gambel oak (*Quercus gambelii*) and black greasewood (*Sarcobatus vermiculatus*), the plants in mesic sites having a higher ratio of female flowers vs. male flowers. Freeman et al. (1981) concluded that there is a tendency for male flowers (cones) to be more prevalent in xeric sites and female flowers (cones) to be more prevalent in mesic sites.

Vasiliauskas and Aarssen (1992) examined the growth and special distribution of male and female *J. virginiana* trees. They reported that sex ratios were not related to age structure, stand density, or local competition intensity. However, they did find that male trees were taller than female trees and concluded that female trees pay a slightly greater cost for reproduction in terms of reduced vegetative growth.

However, Marion and Houle (1996) found no differences in radial growth patterns, annual elongation of the main axis, or size between male and female plants of *J. communis* var. *depressa* in a north-south transect on the eastern coast of Hudson Bay. But they did report that the northern-most populations had a male-biased sex ratio in contrast to the southern-most populations that had a female-biased sex ratio. If the northern-most populations are under more environmental stress, then there appears to be an increase in males with more stressful environments.

Gehring and Whitham (1992) reported that, for *J. monosperma* Engelm., plants highly infested with mistletoe (*Phoradendron juniperinum* Engelm.) growing on a stressful (volcanic cinder, ash and lava) site, female plants were more highly infested than male plants. But on a less stressful site (sandy-loam), there was no significant difference between the infestation rates for females or males. Again, there does seem (at least in *J. monosperma*) to be some costs associated with berry (female cone) production under stressful conditions.

The present study merely focused on the production of a few female cones on otherwise male trees in the dioecious species *J. arizonica*. Is *J. arizonica* truly dioecious? It has been my (RPA) experience that one can find a few monecious individuals among thousands of trees examined for all the dioecious species of *Juniperus* (and nearly all species are dioecious). The presence of a few monecious individuals would not invalidate one saying that a given species is dioecious. In the present case of *J. arizonica*, it may be more correct to describe the species as dioecious, but rarely monecious.

The apparent ease with which male *J. arizonica* plants appear to produce a few female cones seems to indicate the dioecious/ monecious mode is somewhat porous and may be easy to bridge. Could *J. arizonica* have the facultative ability to produce viable seed from 'male' trees to aid in colonization by long distance dispersal? If only a few male tree seeds are dispersed (by chance), then it could be advantageous to produce some seed by a 'partially' monoecious plant(s) to start a new population. Of course, we do not yet know if the seeds produced on the 'male' plants in this study are viable (Adams and Thornburg, in progress).

Sex changes and conversion from dioecious to monecious *Juniperus* plants (Vasek, 1966; Jordano, 1991, this study) raise some evolutionary questions that deserve a closer look in the future.

ACKNOWLEDGEMENTS

This research was supported in part with funds from Baylor University.

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