Cultural Practices for Lesquerella Production

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While *Lesquerella fendleri* has good potential of becoming a domestic, water-efficient source of hydroxy fatty acids in the United States, little research has been done outside of Arizona to determine its environmental response and cultural requirements. This study examined the effects of planting date, irrigation rate and fertilizer on growth and yield in Oregon, and it also evaluated tolerance to existing herbicides as a first step in developing cost-effective weed control programs. An October planting failed, while a March planting generally out-yielded a May planting. Seed yield was maximized at irrigation plus precipitation in the range of 959 to 1111 mm. Fertilizer response was indefinite, although response to phosphorus sometimes occurred. Herbicides with excellent potential include trifluralin and benefin pre-plant incorporated, and fluazifop post-emergent. Potential herbicides also include pendimethalin preemergent, and oxyfluorfen, dicamba and clopyralid postemergent. In addition to further studies on herbicide, irrigation, fertilizer and planting date effects, studies to optimize other cultural practices (*e.g.*, row width, plant density, seed source, varietal development) that increase oil yield and quality while reducing input cost are required if lesquerella production is to occur in Oregon.

KEY WORDS: Fertilizer, herbicide, irrigation, *Lesquerella fendleri*, Oregon, planting date.

Seeds from plants of the genus *Lesquerella* often contain large amounts of hydroxy fatty acids (HFAs). HFAs are classified as a strategic material by the United States government and are used as a chemical raw material in the production of lubricants, plastics and coatings. Imported castor oil is currently the only commercial HFA source, with annual United States consumption ranging from 30,000 to 45,000 metric tons during the 1980s (1). *Lesquerella fendleri*, a native of the arid southwestern United States, is the species that has received the most interest as a potential domestic source of HFA. In Arizona seed yields have approached 1500 kg/ha, with seed containing approximately 25% oil, of which approximately 55% is lesquerolic acid (1–3). Lesquerolic acid is analogous to ricinoleic acid from castor oil, with only the addition of two carbon atoms at the carboxyl end of the molecule (3). Oil processing and product development research indicate that continued effort toward domestication and utilization of lesquerella is warranted (3–6).

The potential for adaptation to southern Oregon was suggested by native habitat studies of *Lesquerella* species. In the southwestern United States, vigorous native *L. fendleri* stands occurred in well-drained, coarse, basic pH (but not saline) soils at 600 to 1800 m elevation (7). Lesquerella typically behaved as a winter annual. It normally germinated with late summer and early fall rains, exhibited little vegetative growth during winter and then increased growth, flowered and seed set by late spring (7). However, the effects of day length and temperature on flowering are not well understood (A.E. Thompson, personal communication). Although flowering and seed production have been indeterminate, ripe seed capsules have tended to remain closed until the entire plant is mature and dry (unless shattered by heavy rain near maturity). Native lesquerella was well adapted in areas receiving 250 to 400 mm annual precipitation if most fell during its growing period (7). Temperatures below −18°C were not rare, and mean January minimum temperatures of −6 to 0°C were common in areas of natural adaptation. Thus, its native habitat and life cycle suggested it could grow well in temperate, semi-arid locations such as southern Oregon.

While genetic and agronomic research have demonstrated the potential of this new crop in Arizona, adaptation to other climates and the resulting water and fertilizer requirements are yet to be determined. Identification of appropriate cultural practices and growing areas is essential for widespread commercial production to be realized. In addition, the short stature and slow early growth of lesquerella require that reliable and economical weed control methods be developed for large-scale plantings to be successful. The objectives of this study were to evaluate the effects of planting date, fertilizer, irrigation schedule and herbicide application on the growth and yield of *L. fendleri* grown in the semi-arid Rogue River Valley in Oregon.

EXPERIMENTAL PROCEDURES

All studies described were conducted at the Southern Oregon Experiment Station Hanley Farm, between Medford and Jacksonville, OR, on a Central Point Sandy Loam (coarse-loamy, mixed, mesic Pachic Haploxerolls). This soil is well drained and suitable for intensive row crop production, provided that fertility is maintained and irrigation water is available. Soil samples taken from the experimental area in autumn 1991 were analyzed at the Oregon State University Soil Testing Laboratory, Corvallis, Oregon. In the surface 150 mm, pH = 6.0, extractable P (Bray) = 46 mg kg^{-1}, ammonium acetate extractable K = 168 mg kg^{-1}, Ca = 9.8 cmol kg^{-1}, Mg = 2.3 cmol kg^{-1}, and organic matter = 5.36%. Elevation at this site = 423 m. Mean annual precipitation is 479 mm, with approximately 76% normally occurring from October through March. Winter daily minimum temperatures averaged from −1 to +1°C, while mean daily July maximum temperature was 33°C, with an average of 8 d annually exceeding 38°C.

Seed for all plantings in this study came from bulk seed lot S2, harvested in 1990 by the United States Department of Agriculture project at the University of Arizona Maricopa Agricultural Center (A.E. Thompson, personal communication). Mean weight of 1000 seeds was 0.60 g, measured just prior to planting. Spring 1992 field plantings were made with a Planet Jr. manual 1-row seeder (Powell Cole Manufacturing Co., Inc., Bennettsville, SC) while using plate hole 4. Opening disc was set on the fourth notch from the top, with covering bars removed. This resulted in a planting depth of approximately 6 mm, at a rate of 300 seeds per meter of row. The 0.5 m-row

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spacing was used based on the size of individual plants in a small summer 1991 planting. This planting rate equals 600 seed m^{-2}. A 1991 fall planting was made with the seeder on hole 3, resulting in 150 seed m^{-1} of row, equal to 300 seed m^{-2}.

Planting date, irrigation, fertilizer. Although experimental lesquerella plantings typically have been grown as a winter annual in Arizona, a planting date study was conducted to evaluate germination and growth through other seasons in Oregon. Seed was planted in 0.5-m rows on October 18, 1991, March 9, April 6 and May 8, 1992. For each of the spring plantings, irrigation and fertilizer treatments were imposed and analyzed as a split-plot design, with irrigation amount being the main plot and fertilizer treatment the sub-plot. After germination and early summer growth, three irrigation regimes were imposed (Table 1). Irrigation and precipitation totals for the April 6 and May 8 planting dates may be found by subtracting the values prior to those dates from the irrigation and precipitation totals. Soil water content was not directly monitored. Irrigations were scheduled according to estimated soil moisture depletion as related to calculated evapotranspiration and plant size. Unusual June and July rains resulted in probable excess irrigation during that time (Table 1).

Fertilizer treatments, combining three rates of nitrogen and phosphorus, were used with the May planting, while two rates of nitrogen and phosphorus were used with the March and April plantings. Fertilizer rates and timing were determined based on yield response observed with traditional crops as well as preliminary lesquerella research (1). One area, containing much of the April 6 planting, was abandoned due to excessive weed competition and suspected herbicide carry-over damage from a prior sugar beet experiment. Fertilizer was applied postemergent for the May planting, and at full flowering for the March and surviving April plantings. The abandoned area described above contained preplant incorporated fertilizer treatments. No herbicides were used in these studies, but the plots were hand-weeded several times.

All plants were cut by hand on September 15 and placed on tarps outside to dry. On September 21, the plants were threshed with a Hege 125C plot combine (Hege Equipment Inc., Colwick, KS). To improve threshing and seed retention, the cylinder clearance was near the minimum, cylinder speed was approximately 1400 rpm and the air intake was partially blocked to minimize air-blown seed loss from the rear of the combine. Following threshing, seed was cleaned on a small, tabletop seed cleaner (Clipper no. 400 Office Tester and Cleaner; AT Ferrell Co., Saginaw, MI) with a 1/15 (inch, circular hole) upper screen and a 30 × 30 (wire mesh per inch) lower screen, with moderate air flow.

Herbicide tolerance. Because of lesquerella's small size and relatively slow vegetative growth, early weed competition can be devastating. Therefore, a test of herbicide tolerance was carried out in greenhouse flats and field plantings. Commercially available herbicides were used at rates that are registered for other crops. All treatments were applied with a four-nozzle spray boom, operated with compressed air and attached to a twin bicycle tire, hand-pushed sprayer frame. Preplant incorporated treatments were applied and mixed into the soil just prior to planting. Preemergent treatments were applied within two days after planting. Experimental areas were watered following preemergent applications. Postemergent treatments were applied 43 d after planting in the greenhouse trial and 31 d after planting in the field trial. At this point, plants in the greenhouse were 40 to 60 mm tall with 9–11 leaves visible. In the field, they were approximately 25 to 50 mm tall with 7–10 leaves visible. Tolerance evaluations relative to check plots were made periodically until 40 d after postemergent applications in the greenhouse trial, and until 10 days after postemergent applications in the field trial.

RESULTS

Planting date, irrigation, fertilizer. Although a few plants emerged from the October 18 planting, none survived the winter. The March 9 planting resulted in a good stand while the April 6 planting had a thin stand. Plants occupied less than 20% of the row length, and yield results were deemed meaningless. First flowering occurred on May 19 for the March 9 planting, June 18 for the April 6 planting and July 5 for the May 8 planting. The May 8 planting resulted in widely varying stands, ranging from 40 to nearly 100% of the row length. These variations did not correlate to any known management factor. Therefore,

TABLE 1

Irrigation Regimes Applied to Lesquerella Plantings

Irrigation and precipitation dates	Irrigation regime (mm)			
	Wet	Medium	Dry	Precipitation (mm)[a]
March 9–April 6 (one irrigation)	20	20	20	13 (8)
April 7–May 8 (three irrigations)	122	122	122	38 (10)
May 9–June 26 (eight irrigations)	478	478	478	52 (7)
July 10[b]	61	0	0	60 (5)
July 24	81	81	0	1 (1)
August 5	81	81	81	0 (0)
August 17	81	0	0	0 (0)
August 25	71	71	0	0 (0)
September 4	91	91	91	3 (2)
September 5–21	0	0	0	0 (0)
Total June 27–September 21	466	324	172	64 (8)
Season total	1066	944	792	167 (33)

[a]Days of recorded precipitation during time period appear in parentheses.
[b]Precipitation amount and number of days include time span from previous date listed.

TABLE 2

Lesquerella Mean Seed Yield (kg/ha) for Planting Date, Irrigation and Fertilizer Treatments[a]

Fertilizer rate[b]	Irrigation regime		
	Wet	Medium	Dry
		March 9 planting date	
0-0	167	416	264
67-0	132	343	313
0-90	238	496	485
67-90	340	314	359
		May 8 planting date	
0-0	139	157	25
34-0	229	103	10
67-0	242	78	27
0-45	238	120	15
0-90	241	62	27
67-90	162	81	33

[a]Seed yield least significant difference ($P = 0.05$) between irrigation regimes = 74, between fertilizer rates = 49.
[b]Expressed as kg/ha N and P_2O_5, respectively.

where continuous, significant gaps existed, yield results for the May 8 planting were adjusted to compensate. Weed competition tended to increase as planting date was delayed, but none of the plantings would have been able to out-compete weed growth on their own. Repeated hand weeding of the area was required. Seed yield from the spring plantings was strongly influenced by planting date and applied water, and to a lesser degree by applied fertilizer (Table 2). Fertilizer, especially nitrogen, tended to favor weed growth over lesquerella during late spring and early summer.

Herbicide tolerance. Tolerance rating for each treatment was enumerated relative to the check plots with 100 = complete tissue damage, and 0 = no visible damage. Lesquerella usually exhibited either excellent tolerance or little tolerance to tested herbicides (Table 3). In most cases, response was similar in both greenhouse and field trials.

DISCUSSION

Planting date, irrigation, fertilizer. Seed yields were only about one-third of those previously reported for fall plantings in Arizona. This is much lower than optimal for commercial production (2). Because the October 1991 planting did not survive, it is unknown at this time if yield in Oregon can be increased by a longer fall vegetative period. Based on reports of lesquerella's level of cold tolerance (7), the winter temperatures experienced did not seem severe. From October 1991 through February 1992, there were 49 d when the minimum temperature was 0°C or less, compared to the long-term average of 75 such days. The lowest temperature of −5°C was reached on three nights. Every day, the maximum temperature was above 0°C, and it failed to exceed 4°C on only 10 d. Thus the winter mortality was not felt to be the result of freeze damage *per se*, but rather the inability of the small plants to photosynthesize enough to survive during the long, cool, often cloudy or foggy, winter period. Earlier fall planting dates used in a current experiment should clarify the planting date effect on yield.

TABLE 3

Evaluation of Herbicide Tolerance by Lesquerella

Herbicide	Method[a]	Rate (kg ha^{-1} a.i.[b])		Tolerance rating[c]	
		Greenhouse	Field	Greenhouse	Field
Trifluralin	PPI	0.56	0.56	5	0
		—	1.12	—	0
Benefin	PPI	1.34	1.34	0	0
		—	2.02	—	0
EPTC[d]	PPI	3.36	3.36	95	70
Pendimethalin	PRE	1.12	0.84	20	15
		—	1.68	—	75
Metolachlor	PRE	2.24	2.24	100	100
DCPA[d]	PRE	6.72	6.72	95	70
		—	10.08	—	85
Metribuzin	PRE	0.42	0.42	100	100
Oryzalin	PRE	2.24	2.24	100	100
Atrazine	PRE	2.24	2.02	100	100
Propachlor	PRE	4.48	4.48	95	20
Diuron	PRE	—	1.34	—	100
Fluazifop	POST	0.21	0.14	0	0
		—	0.28	—	5
Oxyfluorfen	POST	0.22	0.22	15	20
		—	0.45	—	40
Dicamba	POST	0.28	0.28	15	10
		—	0.56	—	25
Bromoxynil	POST	0.28	0.28	80	95
Clopyralid	POST	0.11	0.11	30	10

[a]PPI = preplant incorporated, PRE = preemergent, POST = postemergent.
[b]a.i. = Active ingredient.
[c]100 = Complete injury, 0 = no visible injury.
[d]EPTC, S-ethyl dipropylthiocarbamate; DCPA, dimethyl-2,3,5,6-tetrachloroterephthalate.

Plant spacing and density were not optimal in 1992. The largest plants attained a height and breadth of only 0.3 m—not enough to create a closed canopy in the 0.5-m rows. Plants in the medium and dry irrigation regimes were significantly smaller. The intensity of flowering through the summer was less than that observed in Arizona, and probably limited potential seed yield. The 1992 experiments used seed collected in 1990 in Arizona. These plants in general were smaller in size, appeared to flower less and exhibited greater seed shattering than 1991 plants grown from seed of a different source. The 1991 plants were seeded at a low rate (0.4 kg ha^{-1} or 41 seed m^{-1} row) due to limited seed supply, but still yielded up to 998 and 508 kg ha^{-1} for April 4 and February 26 plantings, respectively. Thus, use of plants selected for Oregon growing conditions may prove important. A comparison of plantings with seed from the two harvest years is planned to evaluate the effect of selection on seed yield. In addition, current experiments are carried out with a higher seeding rate and 0.3-m rows to improve canopy closure. Experiments with a commercial alfalfa planter and 0.15-m rows are also planned.

In general, seed yield was better under the medium irrigation regime for the March 9 planting, and the wet irrigation regime for the May 8 planting. Including rainfall, these regimes resulted in similar amounts of water applied (1111 and 1040 mm for March 9 Medium and May 8 Wet, respectively). Summer 1992 was hotter than normal, resulting in a greater than expected water requirement. There were 14 d where the maximum temperature exceeded 38°C, compared to the long-term mean of eight. Data collected for a concurrent pear entomology study indicated that 1992 degree-day accumulation from April 22 to September 9 was 22% greater than the ten-year mean. Although the greater water applications encouraged vegetative growth, they did not seem to improve flowering density and seed set. Nitrogen applications also seemed to encourage vegetative growth at the expense of flowering and seed set. Continued study of nitrogen rates and timing is required to improve understanding of their contribution to yield. Phosphorus application seemed to increase yield for the situations where vegetative growth occurred during periods of medium to low water stress. The available phosphorus for the experimental area was considered moderate to good, depending on the phosphorus needs of the crop grown. Thus, it is suggested that lesquerella may require significant amounts of available phosphorus for maximum yield. However, higher yields than those observed in this study will be necessary to validate this relationship.

Herbicide tolerance. Lesquerella herbicide tolerance varied greatly between greenhouse and field trials for S-ethyl dipropylthiocarbamate (EPTC) and propachlor. Tolerance was better in the field, and may have been due to conditions following application. Both EPTC and propachlor are mobile in soil water, and must be activated and moved into the germination zone by applied water for optimum weed control. In the shallow greenhouse flats, which were carefully watered by hand, the herbicide probably remained in the germination zone and had little opportunity to leach out. In the field, irrigation applied the day following herbicide application was 61 mm, instead of the 20 mm intended, potentially moving some of the mobile herbicides past the germination zone. Weed control for EPTC and propachlor was less complete in the field than the greenhouse, also suggesting less than normal herbicide activity. Even under field conditions, EPTC herbicide tolerance was poor, and thus it is not a likely herbicide candidate for lesquerella. Further testing with propachlor under better conditions would determine if it is a good herbicide candidate for lesquerella.

Excellent herbicide candidates for weed control in lesquerella include trifluralin or benefin preplant incorporated, and fluazifop postemergent. Other potential candidates include pendimethalin and propachlor preemergent, and oxyfluorfen, dicamba and clopyralid postemergent. Further testing on these potential herbicides is required to determine rates and application methods to minimize lesquerella damage while providing desired weed control. Testing of suitable herbicides for lay-by applications in fall seedings is planned, including trifluralin, pendimethalin and dimethyl-2,3,5,6-tetrachloroterephthalate (DCPA). In addition, testing of additional postemergent materials, possibly including 2-4,D, sethoxydim and pronamide, is planned. Commercial use of materials depends on registration and presence of weeds that are susceptible to control by given herbicides. Identification of several tolerated herbicides suitable for different weed situations would be desirable and appears achievable.

ACKNOWLEDGMENTS

Lesquerella seed and valuable information were provided by Anson Thompson and David Dierig, both of the U. S. Water Conservation Laboratory, USDA/ARS, Phoenix, AZ. This is Agricultural Experiment Station Technical Paper no. 10,252.

REFERENCES

1. Roetheli, J.C., K.D. Carlson, R. Kleiman, A.E. Thompson, D.A. Dierig, L.K. Glaser, M.G. Blase and J. Goodell, *Lesquerella as a Source of Hydroxy Fatty Acids for Industrial Products*, USDA/CSRS, Growing Industrial Materials Series (unnumbered), Washington, D.C., Oct. 1991, 46 pp.
2. Thompson, A.E., D.A. Dierig and E.R. Johnson, *J. Arid Env. 16*:331 (1989).
3. Kleiman, R., in *Advances in New Crops*, edited by J. Janick, and J.E. Simon, Timber Press, Portland, 1990, pp. 196–203.
4. Carlson, K.D., A. Chaudhry and M.O. Bagby, *J. Am. Oil Chem. Soc. 67*:438 (1990).
5. Carlson, K.D., and R. Kleiman, Poster Abstract 28, 2nd National New Crops Symposium, Indianapolis, Oct. 6–9, 1991.
6. Arquette, J., and J. Brown, Poster Abstract 29, *Ibid.*, Indianapolis, Oct. 6–9, 1991.
7. Gentry, H.S., and A.S. Barclay, *Econ. Bot. 16(3)*:206 (1962).

[Received February 5, 1993; accepted June 28, 1993]