Lesquerella commercialization efforts in the United States

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(Accepted 10 June 1992)

Abstract


Lesquerella fendleri (Gray) Wats. is a promising new crop for cultivation in the western United States. Its oil-bearing seed contains high amounts of the hydroxy fatty acid (HFA), lesquerolic acid (C20:1-OH), suitable as a raw material for many types of industrial applications. Currently the U.S. imports castor seed oil as its chief source of HFA, used primarily in the production of lubricants and plastics. Lesquerella could complement castor oil imports as well as provide new applications and products. Lesquerella meal is being tested as a feed source. Other lesquerella species contain varying amounts and types of HFA. L. fendleri appears to be highly cross-pollinated, and as a consequence, considerable genetic variation exists for traits such as seed oil content, HFA, yield, flowering time, and growth habit. Rapid progress is being made toward full commercialization of lesquerella with private companies and government agencies working together in parallel studies on yield improvement and on finding new uses for the seed oil. Cooperative plantings began in 1990 and included 12 ha in central Arizona and Texas. Planting for 1991 has been increased to 30 ha and covered a wider range of climatic and soil conditions. The seed oil from these plantings is being used to formulate and test lubricant and cosmetics products. Agronomic management practices being investigated include planting methods, time of harvest, and irrigation scheduling. Fortunately, existing farm equipment with minor modification can be used for planting and harvesting the crop. Genetic and germplasm improvement studies are also being conducted and covers germplasm evaluation, selection, and hybridization.

Hydroxy fatty acids; New crops; Oil seeds; Industrial oil

Introduction

Lesquerella fendleri (Gray) Wats. (Brassicaceae) is of interest in the United States as a potential new crop because of its abundance of hydroxy fatty acid (HFA) in the seed oil. These types of fatty acids are used by industry for making resins, waxes, nylons, plastics, corrosion inhibitors, cosmetics, coatings, and lubricating greases (Roetheli et al., 1991). The United States presently relies on imports of castor oil for these products.

The predominant HFA in L. fendleri is lesquerolic acid (C20:1-OH), a similar fatty acid to ricinoleic acid (C18:1-OH) of castor oil, except for two additional carbons at the car-
boxyl end of the chain. This increased chain length could provide possibilities for the formulation of other compounds and development of added markets for this oil. Although some other lesquerella species have higher content of this fatty acid, *L. fendleri* is considered the most agronomically adaptable because of high seed yields.

Recently a task force on lesquerella reported on the potential of producing, processing, and marketing of this crop (Roetheli et al., 1991). Their findings concluded that no insurmountable barriers existed to prevent the commercialization of lesquerella. Thompson (1985) presented a generalized system consisting of five major phases for new crop research and development. These phases consist of (1) germplasm collection, (2) germplasm evaluation, (3) germplasm enhancement and development, (4) cultivar development and agronomic/horticultural evaluation, and (5) commercialization. Progress has been made in each of these stages, and the present interest from industry has the potential to move lesquerella into the final phase of development.

**Botany**

*Lesquerella fendleri* is a low growing plant, reaching a height of 45 cm with adequate water and warm temperatures. As many as 24 seeds are contained in glabrous siliques, which are borne on loose inflorescences. The combination of glabrous siliques, fused trichomes and yellow flowers distinguish it from all other lesquerella species (Rollins and Shaw, 1973). The flattened seeds are small, up to 2 mm long, with a 1000 seed weight of about 0.6 g. The seed coat is normally orange-brown although variants for this trait with yellow seed coats have been observed. Seed shattering has not been a problem in Arizona, even when harvest has been delayed and mature plants were subjected to rain. Seed dormancy is not a problem as in some of the other lesquerella species. Flowering occurs from February through May. When the crop is in full bloom the field appears as a solid mass of yellow. The flowers are hermaphroditic and mainly allogamous. A high frequency of male sterility has been observed. *L. fendleri* chromosome numbers have been reported as *n*=6 except for *n*=7 from a population in New Mexico (Rollins and Shaw, 1973). Although Rollins and Shaw (1973) classify *L. fendleri* as a perennial it can be grown as a winter annual in western states of the U.S.. Both Payson (1922) and Rollins and Shaw (1973) agree that it is the most polymorphic of all lesquerella species.

**Seed Oil**

All species of lesquerella that have been analyzed contain HFA as a major oil component in varying quantities (Kleiman et al., 1972. One of three types of HFA (lesquerolic, densipolic, and auricolic) found in relatively large amounts. The type of HFA appears to be related to the species native geographic location: lesquerolic acid, western states; densipolic acid, east of the Mississippi River; and auricolic acid, Texas and Oklahoma. Representative species of these three major types of HFA are shown in Table 1 along with an aver-

<table>
<thead>
<tr>
<th>Species</th>
<th>Seed weight (g/1000)</th>
<th>Seed oil (%)</th>
<th>Densipolic C18:2-OH (%)</th>
<th>Lesquerolic C20:1-OH (%)</th>
<th>Auricolic C20:2-OH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. fendleri</em></td>
<td>0.60</td>
<td>24</td>
<td>0.2</td>
<td>55.2</td>
<td>3.8</td>
</tr>
<tr>
<td><em>L. densipila</em></td>
<td>0.83</td>
<td>24</td>
<td>50.7</td>
<td>trace</td>
<td>trace</td>
</tr>
<tr>
<td><em>L. auriculata</em></td>
<td>0.70</td>
<td>33</td>
<td>2.1</td>
<td>9.8</td>
<td>32.0</td>
</tr>
</tbody>
</table>

*Kleiman (personal communication).*
age 1000 seed weight and seed oil content.

The seed oil in *L. fendleri* ranges between 53 and 60% lusquerolic acid with the seed oil content ranging between 20 and 35%. Based on the current HFA content and the value of other fatty acids, the price of the oil is estimated to be worth US$ 0.23 to 0.30 per kg (Roetheli et al., 1991).

**Seed Meal**

Carlson et al. (1990) have shown that the defatted lusquerella seed meal has an excellent distribution of amino acids for animal feed. Table 2 compares the essential amino acids of *L. fendleri* meal with the meal from soybeans and crambe, another crucifer. Favorable levels of lysine, methionine and threonine were found in comparison to these. The protein content is about 35% (Carlson et al., 1990). Glucosinolates are present in the meal. However, a simple heating procedure can inactivate the thioglucosidase enzyme to overcome this problem (Carlson et al., 1990).

Feeding trials with cattle, mice and chicks are currently in progress at the University of Arizona, Tucson, Arizona and Kansas State University, Manhattan, Kansas. Preliminary information indicates that the meal would provide quality protein for animal feed. In these trials, where various ratios of the meal were used, animal preference and palatability have not been a problem. Research on the oil and meal utilization is also being conducted at the USDA-ARS National Center for Agricultural Utilization Research, Peoria, Illinois.

**Crop Status**

A cooperative venture was initiated in 1990 between two private industrial companies, Agrigenetics Company and the Jojoba Growers and Processors, Inc., the USDA-Agricultural Research Service and the University of Arizona. Seven hectares were planted in 1990 and harvested in 1991. The seed oil procured was shared among the participants in order to formulate and test products of interest. In 1991, approximately 30 ha were planted by farmers in California, Arizona, Texas, and Oklahoma for pilot scale production and utilization research.

**Agronomic**

Improvement of cultural practices for lusquerella has taken place over the past six years in Phoenix, Arizona (Thompson and Dierig, 1988; Thompson et al., 1989). Irrigation studies indicate that approximately 600 mm of water is required in Arizona for optimum yields. This water requirement is similar to that for winter wheat. We have found that application timing is critical, with differences in yield when the same amounts of water were applied at different times during the growing season. We are continuing this work to define the critical timing more precisely.

In the past year, cooperators in central Texas (Dr. M. Foster, Texas A&M) and in southern Oregon (Drs. R. Roseburg and S. Knapp, Oregon State University) have evaluated lusquerella’s potential in their respective areas. A successful stand was established in Texas when planted in October. In Oregon, with a cooler climate than either Arizona or Texas, lusquerella may be better adapted as a summer annual, planted in late March and harvested in September. An early October planting is best in central Arizona. This allows for adequate vegetative

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**TABLE 2**

Comparison of essential amino acids contents for defatted *Lusquerella fendleri* flakes to that of other seed oil species

<table>
<thead>
<tr>
<th>Amino acid</th>
<th><em>L. fendleri</em></th>
<th>Soybean (g/16 g N)</th>
<th>Crambe (g/16 g N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>2.30</td>
<td>2.55</td>
<td>2.2–2.7</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>3.37</td>
<td>4.58</td>
<td>3.7–4.1</td>
</tr>
<tr>
<td>Leucine</td>
<td>5.45</td>
<td>7.75</td>
<td>5.9–6.8</td>
</tr>
<tr>
<td>Lysine</td>
<td>5.67</td>
<td>6.43</td>
<td>4.9–5.7</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.77</td>
<td>1.13</td>
<td>1.6–1.9</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>4.12</td>
<td>5.01</td>
<td>3.4–4.0</td>
</tr>
<tr>
<td>Threonine</td>
<td>4.08</td>
<td>3.93</td>
<td>3.1–4.5</td>
</tr>
<tr>
<td>Valine</td>
<td>4.52</td>
<td>4.56</td>
<td>4.5–5.6</td>
</tr>
</tbody>
</table>

Adapted from Carlson et al. (1990).
growth before flowering is initiated following the onset of warm temperatures in late February. Plantings in November and December decreased vegetative development time and substantially reduce yields.

We have compared various types of planters for optimum stand establishment. A broadcast seeder has proven to be more successful than a row type vegetable seeders due to even seed distribution and the easy adjustment of rate settings for desired plant populations. This type of seeder is commonly used by farmers to grow such small seeded crops as alfalfa and clovers and may not incur a cost for equipment.

Various types of seed bed preparations were also investigated. No significant differences were found in yields between raised bed and level basin plantings. However, seedling establishment may be more difficult and variable in level basins due to increased soil crust on certain types of soils. Weed management was easier on raised beds since cultivation was possible. Raised beds may also be preferred if water quality is a problem, so that salts could be better managed. Combined harvesting on raised beds is difficult because the tractor will ride on top of the beds and plants may lodge into the furrow. Conventional lifters could not successfully gather up plants in the furrows resulting in reduced yields. This problem can probably be overcome by a slight modification to the combine. Also, changing the distance between rows with shallow furrows may solve this problem.

Statistical differences in seed yields were not detected among seeding rates of 4.5, 6.75, and 9.0 kg/ha, when planted on either raised beds or level basins. However, highest yields were obtained from a seeding rate of 6.75 kg/ha and populations of about 600,000 plants/ha. These data correspond to an earlier study by Thompson and co-workers (1989) which indicated that yields decreased somewhat when plant populations exceeded 800,000 plants/ha.

Plant Breeding

Germplasm evaluation of 90 accessions from 23 lesquerella species of a USDA collection began at the USDA-ARS, U.S. Water Conservation Laboratory, Phoenix, AZ in 1985 (Thompson, 1988). Lesquerella fendleri was considered the best candidate for domestication because of its abundant seed production, plant growth characteristics, hardness, and germination qualities. No major domestication barriers were seen for many of the other species, which still may be developed for specific areas in the future. It is anticipated that much of the same technological and management skills developed for L. fendleri could be directly applied to other species.

The primary breeding goals for lesquerella improvement are: (a) to increase seed yields; and (b) to increase oil and fatty acid content. Mean characteristics of six superior half-sib selections are shown in Table 3. These six families were selected for further study and incorporation into a recurrent selection program for our breeding objectives. The amount of variation present and the yield performance are very promising for successful lesquerella development. This is especially true in view of the relatively short amount of time invested to date in its development.

Interspecific hybridization is being investigated for improvement of oil and fatty acid content and increased seed size. Several of the other lesquerella species exhibiting traits such as larger seed size, higher oil or lesquerolic acid content have the same chromosome number as L. fendleri of n=6. Natural or artificial interspecifics involving L. fendleri have not been reported in the literature. Successful artificial hybrids between some of these species with a high degree of fertility have been developed (Rollins and Shaw, 1973). It is likely that L. fendleri would hybridize with these species and result in hybrids possessing desirable characteristics.

Other traits of interest include early flowering. If flowering can be initiated early, the growing season could be shortened to avoid the onset of high temperature and heat stress, and water use can be lessened. Yellow seed coat lines which may minimize the problem of pigmentation in the seed oil are also being developed.

As with any seed crop, information on pollination, outcrossing rates, variation in allo- or
TABLE 3

Performance of six superior half-sib selections from *Lesquerella fendleri* in 1988

<table>
<thead>
<tr>
<th>Plant population (million/ha)</th>
<th>Plant height (m)</th>
<th>Seed weight (g/1000)</th>
<th>Seed yields (kg/ha)</th>
<th>Oil content (%)</th>
<th>Leq. acid content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.92</td>
<td>0.34</td>
<td>0.56</td>
<td>2022</td>
<td>26</td>
</tr>
<tr>
<td>Range</td>
<td>0.54–1.56</td>
<td>0.29–0.46</td>
<td>0.51–0.62</td>
<td>1803–2698</td>
<td>23–29</td>
</tr>
</tbody>
</table>

Autogamy, rates of male sterility in populations, is important. Since *lesquerella* appears to be primarily allogamous, we are presently examining individual plants for autogamous variation, and will recurrently select in successive generations. This would insure pollination for seed production without the added cost for bee pollinators in commercial production. In the past year, when the small research plots were increased to large farm size plantings, we noted that the yields were less in the larger plots even though the plant stands and flowering were comparable in both plantings. The major reason for the reduction in yield may be the lack of adequate number of pollinators in larger fields. In future plantings we plan to increase the bee population, to check this hypothesis. Cooperative work is planned with researchers at the USDA-ARS Carl Hayden Bee Research Laboratory, Tucson, Arizona.

Conclusion

Cooperative participation by industry and government agencies has greatly enhanced the speed at which *lesquerella* can attain full commercialization. Parallel investigations are being made in seed oil extraction and use, agronomic management, and genetics/breeding to improve seed yields. Larger plantings over a wider range of climatic and soil conditions are being made in order to evaluate the potential for cultivation of the crop in other regions. *Lesquerella* has started from a zero base in 1985 and it is anticipated that full commercialization will be a reality within the next decade.

References


