Meadowfoam: potential new oil crop

Prospects are good that plant breeders will be able to improve meadowfoam so that it will eventually be grown as an oil-seed crop.

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Meadowfoam (*Limnanthes* spp.) derives its name from its showy masses of white flowers in April and May along vernal streams, meadows, pools, or moist depressions in the valley grasslands and surrounding foothills in California and southern Oregon. This genus has recently aroused agricultural interest, because its seed oil has unique biochemical characteristics. At least 95 percent of its fatty acids are long chains, e.g., C_{20} and C_{22}. One of these ($C_{22:2}$) has unique positions of unsaturation that impart oil stability at high temperatures. Several USDA scientists have considered the seed oil to be a useful substitute for sperm whale oil, of which more than 50 million pounds were imported into the United States annually until 1972 for use in cosmetics, waxes, pharmaceuticals, lubricants, and other products.

An extensive agronomic evaluation by J. J. Higgins and other USDA scientists at Chico, California, disclosed some optimum procedures of planting, harvesting, weed control, and fertilizer application. A research team headed by Wheeler Calhoun of Oregon State University, Corvallis, has made significant progress toward better seed retention and upright growth habit with one species, *Limnanthes alba*. A variety called Foamore was released for commercial production in Oregon in 1976.

Jojoba and crambe are two other potential substitutes for sperm whale oil. USDA scientist George White noted that meadowfoam might offer an advantage, because a wide range of genetic resources is available for breeding work, and cultivation as an annual crop plant is relatively easy. Its adaptation to low temperatures and low-lying waterlogged fields and its maturing in early May could fit into a double cropping with rice in northern California.

Meadowfoam research was initiated at Davis in 1972 to: evaluate the Oregon selections for productivity in California; broaden the genetic resources by larger collections through wild and agronomic surveys; and develop new materials through hybridization, selection, and genetic analyses of variation. Our primary breeding objectives are to select for taller, more competitive plants with higher seed yield, higher oil content, and a better branching pattern. Breeding work is required for selection of flowers and seed development in synchrony and, of course, better seed retention. Here, we report briefly on the diversity in this genus, agronomic evaluation of this diversity, and yield assessments of the Oregon variety Foamore.

Botanists have described nearly 19 different *Limnanthes* species or varieties, many of which are easily identifiable in the field by such characters as flower color, size of floral parts, corolla shape, and seed shape and size. We have collected plant and seed materials in California and southern Oregon. Because populations within each species have many botanical and other genetic differences, extensive sampling of genetic resources in this initial phase of crop development seemed highly useful.

USDA scientists H. S. Gentry and R. W. Miller reported an excellent study of variation in habitat preference, growth habit, adaptation, and response to climate in several species and varieties. Table 1 summarizes the findings of three groups of workers on seed size, oil content, and a measure of genetic variation.

Breeding systems vary from predominant cross-pollination in *Limnanthes alba* to predominant self-pollination in *L. floccosa*. Different varieties of *L.*

Flowers of *Limnanthes gracilis.*

douglasii show marked variation in the amount of vegetative growth, flowering time, and seed yield per plant. Similarly, *L. floccosa* varieties differ in seed set per flower and seed size. Seed retention at maturity varies in populations of *L. alba*, *L. floccosa*, and others. In several species or varieties, flowering time varies by three to four weeks and also depends on location and habitat.

Data on several species and varieties from Miller and co-workers and on various populations of *L. alba* and *L. floccosa* from our work show significant correlations between increased seed size and higher oil content. We have also found a genetic male sterility factor in the variety *L. douglasii nivea*, which would be very useful in hybridization work. In general, combinations of characters of agronomic value appear to be worthy of intensive research in breeding work.

From this survey of natural diversity in plant type and productivity, we hope to define optimal plant types (ideotypes) with desirable combinations of yield components: erect and rapid vegetative growth, especially in winter; branches along the top half or two-thirds of the primary stem; many flowers within a small size range, produced over a short period; high seed set; late senescence of photosynthetic organs (leaf, sepal, stem); large seed size; high oil content; and non-shattering habit.

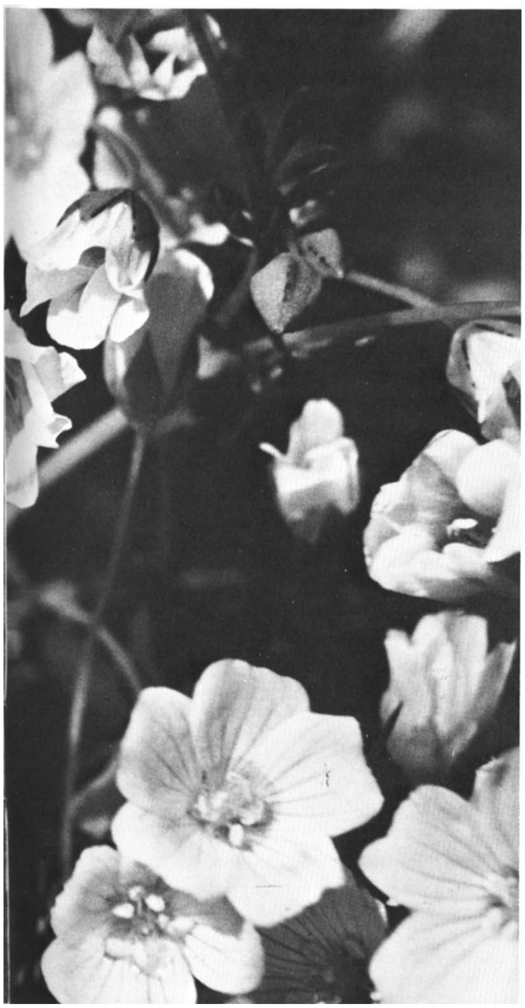

TABLE 1. RELATIVE QUALIFICATIONS OF *Limnanthes* SPECIES AND VARIETIES AS SEED CROP PROSPECTS

Source species or variety	Gentry and Miller*						Miller *et al.**		Brown *et al.**	
	Growth habit	Water requirement	Earliness†	Yield	Seed retention	Percent oil	Seed weight (g/1,000)	Percent protein	Genetic variation‡	Relative reproductive efficiency§
L. gracilis	Good	Medium	8	Good	Fair	28.8	5.5	17	Medium	1
L. alba	Good	Light	4	Good	Excellent	26.8	5.1	20	High	1
L. nivea (Willits)	Good	Medium	5	Good	Fair	30.4-33.2	4.3-7.6	15-20	High	1
L. montana	Good	Medium	6	Good	Fair	25.8	3.2	21	Low	2
L. nivea (Calistoga)	Good	Heavy	5	Good	Poor	26.1	–	–	High	2
L. bakeri	Good	Heavy	6	Good	Poor	25.6	4.1	16	None	2
L. douglasii	Good	Heavy	6	Good	Poor	24.0-29.8	–	–	High	3
L. versicolor	Fair	Heavy	5	Fair	Poor	30.9	–	–	High	2
L. parishii	Poor	Medium	8	Good	Good	33.3	4.5	18	Medium	2
L. floccosa	Good	Light	2	Light	Poor	28.3	6.5	25	v. low	2
L. rosea	Fair	Heavy	1	Good	Poor	20.0-21.7	4.3-5.5	15-16	Medium	3
L. pumila	Fair	Medium	4	Light	Good	–	–	–	v. low	2
L. striata	Fair	Heavy	3	Light	Poor	29.0	4.0	29	High	3
L. bellingeriana	Poor	Medium	8	Light	Good	–	–	–	v. low	4

* After H. S. Gentry and R. W. Miller, 1965, Economic Botany, Vol 19:25-32; R. W. Miller *et al.*, 1964, J. Amer. Oil Chemists Society, Vol. 41:167-169; and C. R. Brown, H. Hauptli, and S. K. Jain, Economic Botany (submitted for publication).

† Earliness of flowering time was ranked such that 1 = April 15-25, 2 = April 25-30, etc., and 8 = June 1-10.

‡ Based on allozyme and quantitative genetic studies.

§ Relative reproductive efficiency measured by the seed output per unit of plant growth, at harvest. Rank orders 1 to 4 indicate the range from nearly 30 percent to 65 percent efficiency.

Several of the components are highly variable and occur in varied combinations within different species or varieties. Yield components, such as number of flowers per plant and seed set per flower, are being critically examined over a range of agricultural conditions in controlled plantings, and several heritability studies are under way.

A Foamore yield trial with seed supplied by Dr. Calhoun was established at Davis in the 1974-75 season with three planting dates (November 15, December 15, January 15) and four densities (rows 5 inches apart, two or three seeds per inch within rows; rows 10 inches apart, two or three seeds per inch within rows), with and without application of herbicide (Ramrod = propachlor). Plots were 5 by 10 feet, and treatments (densities and herbicide application) were randomized within each planting-date block and replicated twice. Because there were late spring rains in April 1975, only two irrigations in May were needed.

The January planting was abandoned as too infested by weeds, but the first two plantings had good weed control with or without herbicide treatment, presumably because of an early vigorous stand of meadowfoam.

Plots were harvested during the first week of June by three different methods to check seed retention and optimum harvest method: a 4- by 4-foot subplot within each plot handcut with a sickle; a 4- by 5-foot subplot harvested with a leaf vacuum; and a 4- by 10-foot subplot harvested with a Hege Combine 125. Yields were measured after drying (6 to 7 percent moisture in seed) and cleaning, and seed size, oil content, etc., were scored on two 100-seed samples from each subplot.

Analysis of variance for yield data showed that planting dates and harvest methods gave large, significant differences. For the November planting, the average seed yields for the four densities were 1,052, 1,167, 1,227, and 1,165 pounds per acre, respectively. However, the density effects were not significant. Some of the highest yields—up to 1,400 pounds per acre—were in plots with two seeds per inch in rows 10 inches apart.

Table 2 summarizes results for two planting dates and three harvest methods. Only the seed yields show significant differences among treatments. Note seed losses in plots harvested by the leaf-vacuum and combine methods, apparently resulting from shatter, because these methods required a longer wait for the plants to mature entirely.

An important measure of plant productivity can be obtained in yields of the total plant growth. We harvested eight samples by cutting all aboveground plant materials in 1- by 1-foot quadrants on April 15, during the onset of flowering,

TABLE 2. ESTIMATES OF MEAN (± SE, STANDARD ERROR) YIELD, OIL CONTENT, AND SEED SIZE OF FOAMORE

Harvest method	Yield (kg/acre)	Percent oil	Seed weight (g/1000)	Percent seed loss*
November planting				
Sickle	524.6 ± 5.6	19.03 ± 2.88	6.84 ± .05	
Leaf vacuum	474.2 ± 6.1	20.06 ± 1.79	6.52 ± .08	10
Combine	198.7 ± 4.5	19.96 ± 2.07	6.61 ± .07	63
December planting				
Sickle	427.9 ± 21.4	19.56 ± 2.56	6.66 ± .04	
Leaf vacuum	349.5 ± 20.3	20.61 ± 1.71	6.76 ± .07	19
Combine	80.0 ± 11.9	20.97 ± 1.52	6.87 ± .06	82

* Percent seed loss under leaf-vacuum and combine harvest methods as compared with handcutting by sickle.

"Fairy ring" stand of meadowfoam in a vernal pool (Sacramento County).

and weighed the total oven-dried plants. For the November planting, the estimates of primary productivity were 4 to 6 grams per square meter per day, and for the December planting 4 to 5 grams. Thus, plant growth was significant in winter, and these values compare very favorably with the estimates of net primary productivity in various plant communities as well as in many annual crop stands. The relative harvest index was nearly 40 to 60 percent, a rather high range compared with most annual crops. If selection could improve height and foliage development without changing this ratio, meadowfoam could rate among the very highly efficient crop species.

Domestication of any wild plant species is likely to be slow with problems such as poor adaptability to field practices and disease and pest vulnerability. However, meadowfoam clearly has a great diversity of botanical forms and a genetic variation in agronomic traits for further improvements in the hands of breeders and agronomists.

We plan to evaluate all our germplasm collections and their genetic variants in the field, estimate the heritability of various desirable traits or trait combinations, and extend the inter- and intraspecific hybridization programs, including the evaluation of induced polyploids. Our preliminary efforts already show that crosses between species and varieties can be made and utilized for some interesting genetic and biosystematic research. Parallel and intensive agronomic work is needed to facilitate plant breeding research along these lines.

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Flowers of Limnanthes douglasii **var.** douglasii.