

Development of Cuphea as a Unique Oilseed Crop for the U.S.

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Introduction:

During the 1960s a team of United States Department of Agriculture, Agricultural Research Service (USDA-ARS) scientists were given the task of identifying chemicals from renewable plant material that could replace chemicals for industrial uses. Particular emphasis was placed on identifying plant oils that could replace or supplement industrial oils that are mainly derived from petrochemicals. During that time it was discovered that several species from the plant genus *Cuphea* (family Lythraceae) synthesized large amounts of short- and medium-chain triglycerides (i.e., C8, C10, C12, and C14) in their seed-storage oils (Miller et al. 1964). Additionally, many of these species grow in temperate climates. Oils comprised of medium-chain triglycerides serve as important feedstocks for the chemical manufacturing of a wide range of commercial products including soaps and detergents, personal care products, and nutraceuticals (Thompson 1984). The present sources for these oils are coconut (*Cocos nucifera* L.), palm kernel (*Elaeis guineensis* Jacq.), and petrochemicals, which are imported from foreign countries. Between 1995 and 2000, the United States alone imported an average 644,165 metric tons of coconut and palm kernel oil per year at a yearly mean cost of about \$450 million (United Nations FAO, 2002) to meet chemical manufacturing demands for medium-chain triglycerides. Furthermore, “developed” countries together imported 2.1 million metric tons per year during this same period (United Nations FAO, 2002). Presently, the U.S. has no domestic crop source for this oil, and therefore, cuphea could serve as a replacement source.

Since the discovery of cuphea’s important oil properties, key studies conducted by Shirley Graham and Frank Hirsinger led the way to identifying plant characteristics of several

different species (Graham 1989) and determining which ones have good potential for agricultural domestication (Hirsinger 1985). Soon after this, Steven Knapp was successful in developing semi-domesticated germplasm lines from crossing two species, *C. viscosissima* and *C. lanceolata* (Knapp 1993).

Agronomic Evaluation of Semi-Domesticated Cuphea:

The objectives of the USDA-ARS North Central Soil Conservation Research Laboratory in Morris, Minnesota are to: 1) determine the agronomic potential of elite cuphea germplasm, provided by Steven Knapp (OSU), for the upper Midwest; 2) develop best agricultural management practices for producing elite lines; and 3) identifying and characterizing environmental limitations to cuphea production. Since the beginning of our study in 1999, we have discovered that cuphea is well adapted to the upper Midwest. A performance trial led by Frank Forcella in 2002 shows that along a transect from northern Minnesota to southern Iowa, cuphea seed yield was greatest near Morris, Minnesota (Fig. 1).

Cuphea seed is quite small (each seed weighs approximately 3 mg) and therefore must be planted shallow (i.e., ≤ 1.5 cm). We have had relatively good success mechanically planting cuphea with a no-till grain drill and afterwards packing the seed bed with a solid-stand grass seeder. However, stand establishment and seed yield can vary considerably from year to year and are greatly influenced by planting date (Fig. 2). The best time to plant cuphea in west central Minnesota is early to mid May (Gesch et al. 2002).

Variable seed yields of cuphea may largely be due to its response to environmental factors, particularly temperature and moisture. Leaf photosynthesis and plant growth and development tend to favor mild temperatures. The apparent temperature optimum for cuphea leaf photosynthesis is about 23°C (Gesch et al. 2002), slightly higher but similar to that of small

grains such as spring wheat. Daily mean temperatures above 27°C can result in loss of seed-set and a dramatic decline in seed size (Gesch et al. 2002). Soil moisture availability may also strongly affect yields. Sharratt and Gesch (2002) found that cuphea grown on a sandy loam soil lacked a deep root system. In fact, they showed that 65 to 80% of cuphea's root length density was found in the upper 20 cm of the soil profile. Furthermore, water use efficiency (WUE) of cuphea seed production is relatively low (Sharratt and Gesch 2002), ranging from 1.0 to 2.0 kg of seed ha⁻¹ mm⁻¹ of water used. In terms of other oilseed crops, the WUE of cuphea is similar to that of flax (*Linum usitatissimum* L.) (2 kg ha⁻¹ mm⁻¹), but much lower than soybean [*Glycine max* (L.) Merr.] (5 kg ha⁻¹ mm⁻¹) and canola (*Brassica napus* L.) (5 - 10 kg ha⁻¹ mm⁻¹). Taken together, these data indicate that cuphea may be highly susceptible to drought.

Since most conventional crops in the Midwest are planted and harvested in rows and most farm machinery is designed for this purpose, we are utilizing the same methods and equipment for developing guidelines for cuphea production. Our research shows that inter-row spacing from 13 to 75 cm, when keeping plant populations relatively constant, does not significantly affect yield (Gesch et al. 2003). Mainly this is due to the yield plasticity of cuphea plants. As inter-row spacing increases, plants form more branches and seed capsules per plant, thus compensating seed yield on wider rows (Gesch et al. 2003). However, plant population density, and thus seeding rate, does have a significant impact on yield (unpublished data). We have found that the best seeding rate is around 9 kg ha⁻¹.

Successful large-scale field production of cuphea, like other crops grown in the Midwest, will greatly depend on efficient weed control. Because cuphea is a dicotyledonous plant, monocot weed species (i.e., grass weeds) are easily controlled with most herbicides designed for

this purpose without harming cuphea. However, sufficient chemical broadleaf (i.e., dicot weeds) has proven elusive. Partial success has been accomplished with incorporating Treflan or Sonalan into the seed bed prior to planting, and more recently we have successfully tested Balance as a pre-emergent herbicide. Marginal weed control has also been achieved using Raptor and Pursuit as post-emergents when used at 50% or less of their recommended rate for soybeans. We have also successfully used cultivation on rows spaced at least 61 cm apart. But, this requires the use of guards on each side of the cultivator tines to prevent soil from being displaced onto the plants.

The best time to harvest cuphea in west central Minnesota is late September to early October (Fig 3). At this time cuphea is nearing the end of its life cycle, but still may be growing. Waiting until after a hard frost helps kill and hasten the drying of plant material making harvesting much easier. However, waiting too long after a hard frost (i.e., ~2 to 3 weeks) can result in significant seed shattering and loss. We have found that up until mid October, seed shattering in the field can be as high as 22%, based on total harvested yield. A substantial amount of seed may also be lost during combine harvesting. This we have found can range from 15 to 30% of the total harvested seed.

Potential Limitations to Commercialization:

There are still some obstacles to overcome before commercial production of cuphea becomes a reality. From an agronomic standpoint, sufficient weed control to warrant the production of large acreages and proper harvesting technique are two primary issues needing further research. Undoubtedly, sustained commercial success of cuphea will require further crop improvements. This will likely include developing varieties that are fully shatter resistant, have

increased seedling vigor, have a determinate growth habit, and a greater harvest index. Further research will also be necessary to address the rotational effects of cuphea, and where it will best fit into a producer's crop rotation. Also, to put the knowledge and technology that we and other scientists have developed for cuphea into the hands of producers, will require collaboration between researchers and industry with agricultural extension specialists and educators.

The oil produced by current semi-domesticated cuphea lines is mainly composed of C10, capric acid, although other species are rich in C12 (lauric) and C14 (myristic). Capric acid (C10) can be used to manufacture high quality lubricants (Graham 1989), thus replacing petrochemicals, but the market for this type of oil is smaller than that for lauric (C12). Therefore, success of cuphea in the immediate future may depend on marketing C10 oil until a C12-producing plant can be developed. Processing of seed oil and byproduct evaluation are presently being explored by Archer Daniel Midland Company, but further research is needed.

Future of Cuphea: Summary:

Present semi-domesticated cuphea germplasm appears to have its greatest potential for production in the upper, or northern, Midwest. To achieve on-farm production and commercial success of cuphea there will need to be a concerted effort among research scientists, chemical industry representatives, and agricultural extension/educators. In the near future, success of cuphea may also depend on targeting capric based oil, produced by present lines, for niche markets until a C12-producing line is developed.

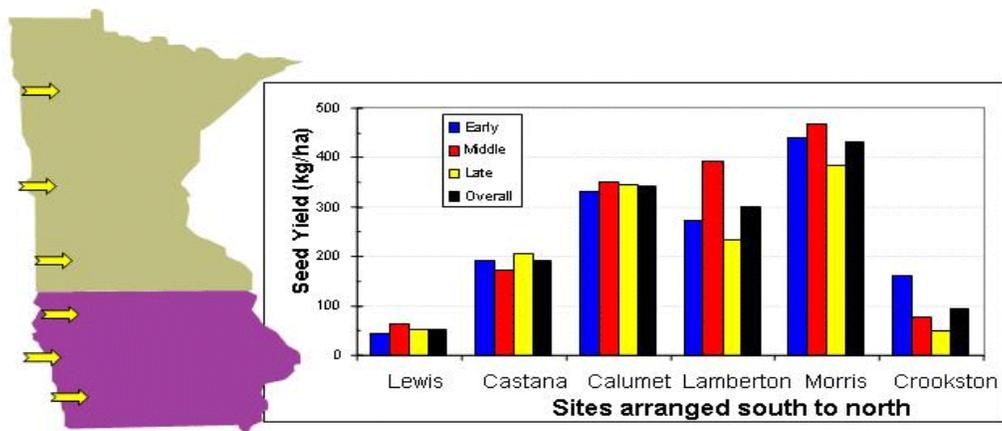
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1Figure 1. Seed yield for a cuphea performance trial conducted by Frank Forcella in 2002.

The graph legend refers to cuphea planting dates of Early, Middle, and Late May of 2002.

Locations on the X-axis run from south to north as shown on the map to the left of the graph.

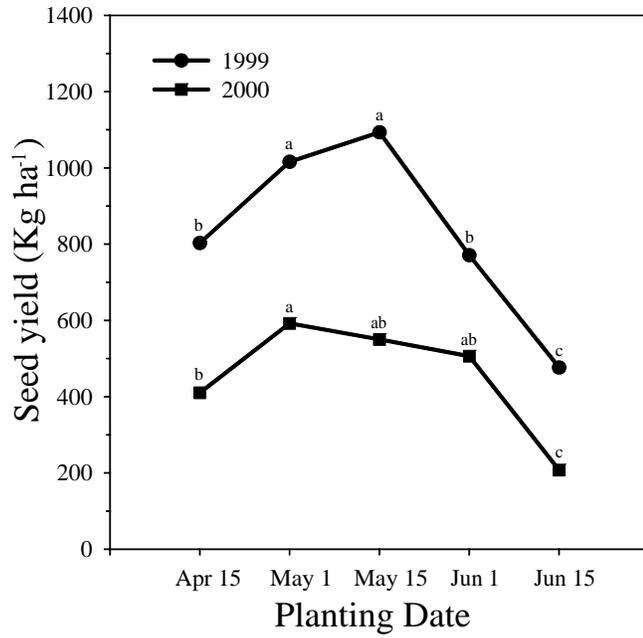
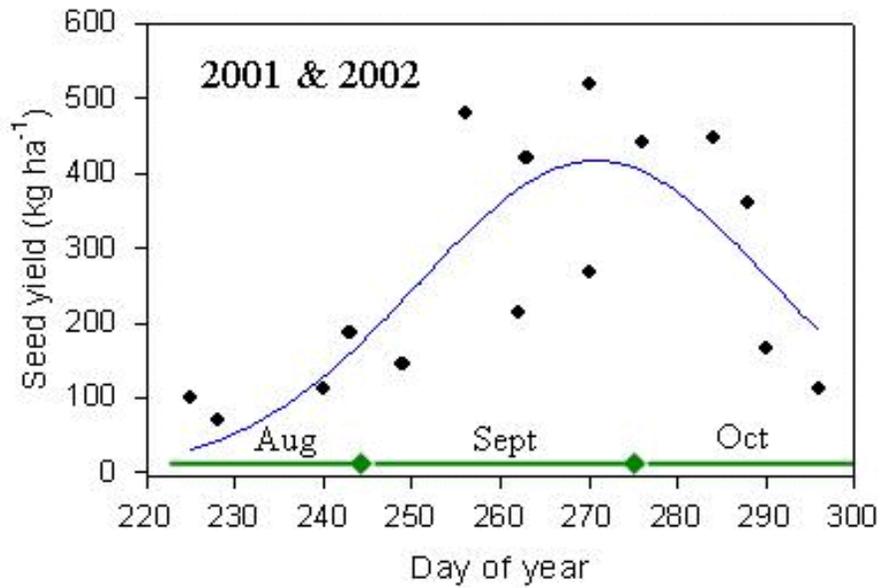


Figure 2. 3 Cuphea seed yield as a function of planting date during 1999 and 2000. Cuphea was grown near Morris, MN.



2Figure 3. Cuphea seed yield as a function of harvest date for 2001 and 2002.

Cuphea was grown near Morris, MN.