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Collecting *Cuphea* in Brazil, Mexico and the United States¹

W.W. Roath², M.P. Widrlechner² and J.H. Kirkbride³

Introduction

Cuphea, a genus of nearly 300 species, has two major centres of diversity, Mexico and eastern Brazil (Koehne, 1903; Graham, 1988). The USDA-Agricultural Research Service (USDA-ARS) National Center for Agricultural Utilization Research (NCAUR), Peoria, Illinois, identified several *Cuphea* species with seed oils rich in medium chain-length fatty acids (MCFAs) during the 1950s (Earle *et al.*, 1960). During the 1980s, researchers began to domesticate *Cuphea* as an annual crop adapted to temperate conditions (Hirsinger and Knowles, 1984; Thompson, 1984). This research has involved USDA-ARS, Oregon State University and industry funding.

Seed oils of *Cuphea* species have diverse fatty acid compositions (Earle *et al.*, 1960), with most species possessing relatively high percentages of MCFAs, especially caprylic, capric and lauric acids (Gillis, 1988; Graham, 1989; Hirsinger, 1985; Hirsinger and Knowles, 1984; Knapp *et al.*, 1991). Lauric acid (12:0) is used primarily in the manufacture of soaps and detergents. Triglycerides of caprylic (8:0) and capric (10:0) acids are used in specialized clinical diets for alleviating digestive disorders caused by the metabolism of the long-chain fatty acids (Babayan, 1981) and in other food uses (Thompson, 1985). The primary source of MCFAs for the United States is the (approximately) 500 000 metric tonnes of coconut and palm kernel oils that are imported each year.

A total of 191 seed accessions of *Cuphea* was assembled at the USDA-ARS Water Quality Laboratory, Phoenix, Arizona by A.E. Thompson and subsequently transferred to the North Central Regional Plant Introduction Station (NCRPIS), Ames, Iowa, in 1986. These accessions came from germplasm collected by S.A. Graham and material gathered by F. Hirsinger during his work in Germany and the United States. Preliminary screening in Arizona, Oregon, Iowa and other United States locations of *C. laminuligera* Koehne, *C. lanceolata* Aiton, *C. lutea* Rose in Koehne, and *C. wrightii* A. Gray determined that each of these species had traits that limited their potential for domestication. These species were limited primarily by their poor yield potential and lack of variability. Attention

then turned to *C. viscosissima* Jacq., a species indigenous only to the United States, as a potential domesticate (Knapp *et al.*, 1991; Roath *et al.*, 1992). It was evident that the germplasm available then was inadequate for domesticating *Cuphea*. We developed and initiated plans to collect additional germplasm from the two major centres of *Cuphea*'s genetic diversity and from the United States.

United States expeditions

Cuphea viscosissima is the most widespread indigenous species of *Cuphea* occurring in the eastern and central United States (Graham, 1988). A predominately self-pollinated annual, it is well adapted to a wide range of temperate environments. Two collecting trips were planned, the first during September 1987 for the western half of the range and the second during September 1989 for the eastern half of the range. The collecting strategy involved obtaining collection data from herbaria located in the states within the species range, plotting collection sites on maps and developing itineraries to explore the most recent sites. Fig. 1 shows the routes taken. Sites from eastern Kansas to southern Illinois were visited in 1987 and those from western Kentucky and Tennessee to central Virginia were visited in 1989. Table 1 lists the states and the number of accessions collected.

Native habitats of *C. viscosissima* include roadside ditches, creek banks and open grasslands where there is ample moisture and soils are well drained. The genus *Cuphea* has an unusual seed dispersal mechanism (Graham, 1988). As the fruits develop, they split along the

Table 1. The locations of *Cuphea viscosissima* collections in the United States

State	No. accessions	Region
Arkansas	2	North-central
Illinois	14	Southern
Indiana	9	South-central
Iowa	1	Southeastern
Kansas	7	Eastern
Kentucky	2	Western
Kentucky	4	North-central
Missouri	8	Southwestern
Missouri	7	Southeastern
North Carolina	3	Western
Tennessee	1	Northwestern
Tennessee	1	Northeastern
Virginia	6	Western
West Virginia	2	Western
West Virginia	7	Eastern

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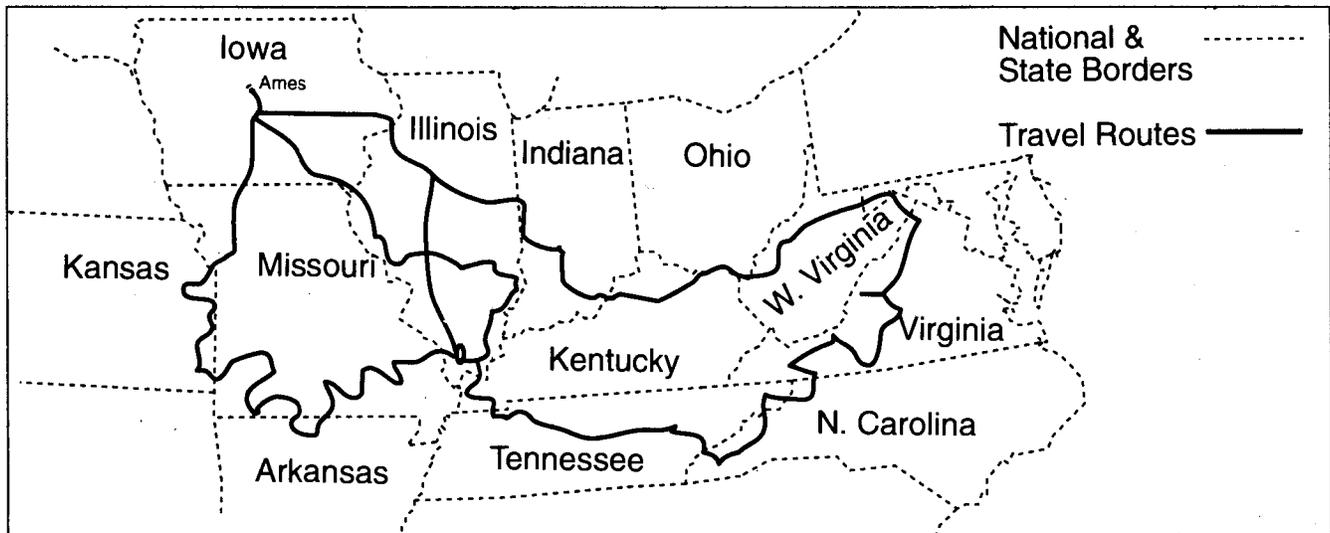


Fig. 1. Route followed on *Cuphea* explorations in the United States

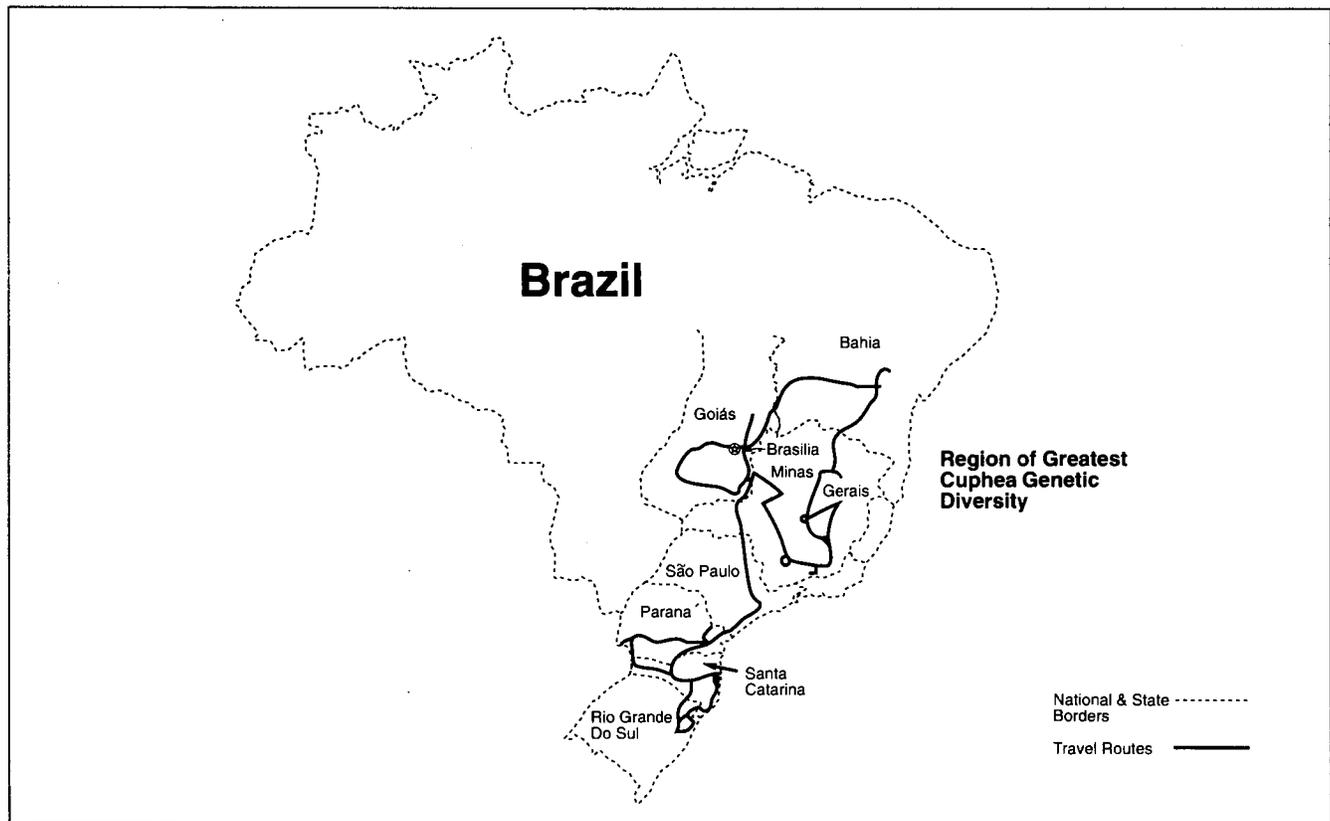


Fig. 2. The Brazilian centre of diversity for *Cuphea* and routes taken on Brazilian *Cuphea* explorations

dorsal side and the placenta rotates up to expose the seed to the elements. The authors' extensive field observations indicate that this dispersal system is responsible for *Cuphea* being distributed near places where water will run after rain. These populations are usually small (generally fewer than 100 plants) and scattered.

In total, 74 accessions of *C. viscosissima* were collected. Thirty-eight have been characterized, evaluated and assigned plant introduction numbers and are being distributed (Knapp *et al.*, 1991; Roath *et al.*, 1992). The remainder have been characterized and evaluated, and are

available for distribution. These accessions have become the backbone of the current domestication efforts.

Voucher specimens of the *C. viscosissima* accessions listed in Table 1 are deposited in the Kent State University research herbarium of S.A. Graham, Kent, Ohio.

Brazilian expeditions

Eastern Brazil is a major centre of diversity, if not the centre of origin, for *Cuphea* (Graham, 1988). Kirkbride recorded the locations and number of collections of Brazilian *Cuphea* species held in the New York Botanical Gar-

den and the Smithsonian Institution herbaria. These data were used to plan the expedition itineraries. Fig. 2 shows the Brazilian centre of genetic diversity and the expedition routes.

L. Coridin, Empresa Brasileira de Pesquisa Agropecuária - Centro Nacional de Recursos Genéticos e Biotecnologia (EMBRAPA-CENARGEN), planned and arranged the Brazilian participation. The first expedition was conducted from 28 January to 23 March 1989, the second from 26 October to 15 December 1989. The Brazilian team during the first expedition included Glocimar da Silva and Aldicir Scariot (EMBRAPA-CENARGEN); Luis Carlos Ramos, Instituto Agronômico de Campinas, São Paulo; and Taciana Cavalcanti, Departamento Botânico, Universidade de São Paulo (currently at EMBRAPA-CENARGEN). The Brazilian team for the second trip included da Silva, Ramos, Gilberto Pedralli (EMBRAPA-CENARGEN) and Nilson Maia, Instituto Agronômico de Campinas, São Paulo. Kirkbride and Roath accompanied the first expedition and G.M. Christenson (formerly of USDA-ARS) and Roath accompanied the second.

More than 22 500 km were travelled in a region approximately 3300 km north (11°07'S) to south (30°29'S) and 1600 km east (40°29'W) to west (54°36'W). *Cuphea* was found from sea level to 1500 masl.

A total of 504 *Cuphea* accessions, representing 42 species, was found during the two trips. Seed of 327 accessions, representing 34 species of *Cuphea*, have been deposited at NCRPIS and at EMBRAPA-CENARGEN, Brasília. Only herbarium vouchers were taken for the other accessions. In addition, a sample of a closely related genus from Bahia, *Pleurophora anomala* (St. Hil.) Koehne, was collected. Table 2 summarizes the species that are represented at NCRPIS and the states from which they were collected. These species represent a wide range of genetic diversity. Efforts to increase the numbers of seed and characterize and evaluate these accessions have been initiated at NCRPIS. Characters as described by Ramos *et al.* (1992) will be recorded in the US National Plant Germplasm System - Germplasm Resources Information Network.

Cuphea carthagenensis (Jacq.) MacBryde is the most widely dispersed species in the genus, occurring throughout Brazil, Central America, southern Mexico and the southeastern United States. It is a common roadside weed and often grows in disturbed areas. *Cuphea calophylla* Cham. et Schlecht. is often sympatric with *C. carthagenensis*, but is more common in the southern part of *Cuphea*'s Brazilian range. *Cuphea micrantha* H.B.K., another species resembling *C. carthagenensis* both morphologically and ecologically, is common to the northern part of *Cuphea*'s Brazilian range. *Cuphea glutinosa* Cham. et Schlecht. occurs most frequently along steep roadside cuts in the southern range. Selections from this species have been released as ground cover for the southeastern United States (Jaworski, 1991). Species growing in or near

Table 2. *Cuphea* species collected in Brazil, 1989

Species	No. accessions	States ¹
<i>carthagenensis</i>	53	MG, GO, SP, PA, SC, RG
<i>calophylla</i>	52	MG, PA, SC, RG
<i>glutinosa</i>	35	PA, SC, RG
<i>micrantha</i> ²	25	BA, MG, GO
<i>ingrata</i> ²	21	MG, PA
<i>ericoides</i> ²	20	BA, MG, GO
<i>lutescens</i>	15	BA, MG
<i>varia</i> ²	15	PA, SC, RG
<i>linifolia</i>	13	PA, RG
<i>urbaniana</i> ²	11	PA, SC
<i>acicularis</i>	<10	GO
<i>confertiflora</i> ²	<10	PA, RG
<i>costata</i> ²	<10	MG
<i>diosmifolia</i> ²	<10	MG
<i>disperma</i> ²	<10	MG
<i>erectifolia</i> ²	<10	MG
<i>ferruginea</i> ²	<10	GO
<i>fruticosa</i>	<10	PA
<i>fuchsifolia</i> ²	<10	MG
<i>gardneri</i> ²	<10	GO
<i>glareosa</i> ²	<10	BA
<i>hyssopifolia</i>	<10	SC
<i>inaequalifolia</i> ²	<10	GO
<i>linarioides</i>	<10	PA, RG
<i>melvilla</i>	<10	MG, GO
<i>pohlii</i> ²	<10	GO
<i>polymorpha</i> ²	<10	MG
<i>pseudovaccinium</i> ²	<10	MG
<i>pulchra</i> ²	<10	BA
<i>racemosa</i>	<10	MG, PA, SC
<i>retrorsicapilla</i> ²	<10	BA
<i>sessilifolia</i> ²	<10	BA, GO
<i>thymoides</i>	<10	MG, PA
<i>tuberosa</i> ²	<10	PA, RG

¹BA = Bahia, MG = Minas Gerais, GO = Goiás, SP = São Paulo, PA = Paraná, SC = Santa Catarina, RG = Rio Grande do Sul.

²Species added to the NCRPIS collection by these explorations.

small streams or along river banks include *C. melvilla* Lindley, *C. racemosa* (L.f.) Spring, *C. sessilifolia* Mart., *C. urbaniana* Koehne and *C. varia* Koehne. Other species occurred in undisturbed areas, usually in open grasslands, and often among rocky outcroppings. *Cuphea hyssopifolia* Kunth in H.B.K. was the only accession not collected from its native habitat. Seeds of this accession were collected from plants cultivated at one of the Brazilian hotels visited. *Cuphea glareosa* Cavalcanti has recently been described based on material collected during the first Brazilian trip (Cavalcanti, 1991).

Mexican expedition

The main objective of the Mexican expedition was to collect seed of *C. lutea* and other *Cuphea* species from the south-central and southern states of Puebla, Oaxaca and Chiapas. *Cuphea lutea* is of interest because of its possible contribution of genes for lauric acid, greater seed yield and overall agronomic performance to the *Cuphea* domestication programme. The expedition was planned with the cooperation of the Herbario Nacional, Instituto de Biología,

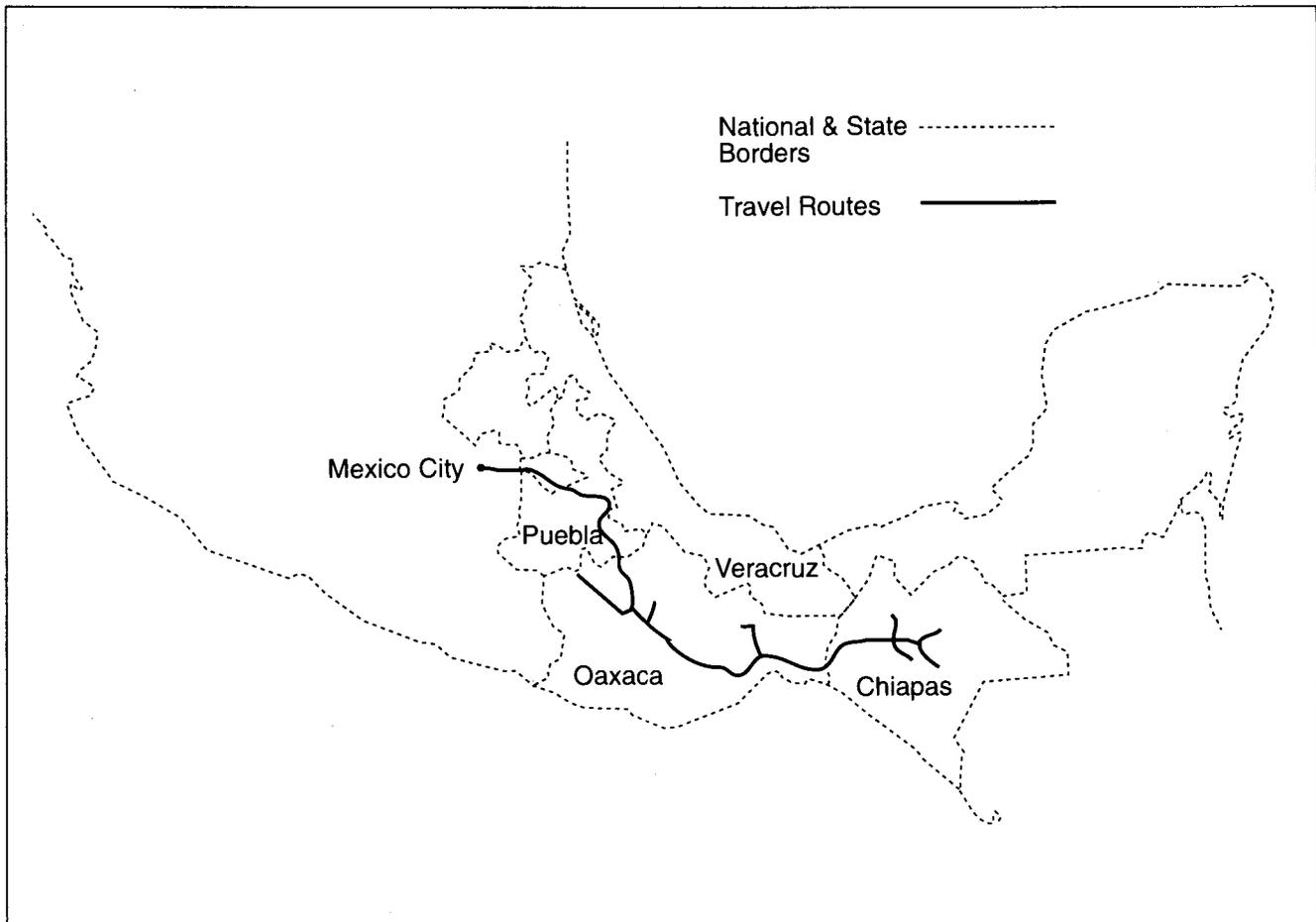


Fig. 3. Route followed exploring for *Cuphea* in Mexico

Universidad Nacional Autónoma de México (UNAM), Mexico City. Alvaro Campos, a graduate student at UNAM, and Roath travelled some 5000 km from 7 to 27 September 1991 along routes shown in Fig. 3. The region explored measured approximately 244 km north ($18^{\circ}41'N$) to south ($16^{\circ}29'N$) by 550 km east ($92^{\circ}26'W$) to west ($97^{\circ}53'W$). *Cuphea* was found growing at elevations of 240 to 2350 masl.

Table 3. *Cuphea* germplasm collected in Mexico, 1991

Species	No. accessions	States ¹
<i>aequipetala</i>	4	CH, OA
<i>carthagenensis</i>	2	OA
<i>cyanea</i>	3	CH, OA
<i>glossostoma</i>	2	CH
<i>hookeriana</i>	3	CH, OA
<i>ignea</i>	1	OA
<i>laminuligera</i>	1	CH
<i>leptopoda</i>	3	CH
<i>lutea</i>	11	CH, OA, VE
<i>palustris</i>	1	OA
<i>schumannii</i> ²	1	OA
<i>wrightii</i>	5	CH, OA

¹CH = Chiapas, OA = Oaxaca, VE = Veracruz.

²Species added to NCRPIS by this exploration.

The collecting strategy involved travelling to a central location and then proceeding to a site where *Cuphea* had been previously collected or to sites with similar habitats. This strategy was partly successful. *Cuphea lutea* was difficult to find and did not always grow where it had been collected previously. Of the 39 accessions collected, 11 were *C. lutea* and nine of these were growing near Ciudad Oaxaca. This species grows mostly at mid-elevations, from 760 to 1830 masl. Most of the *C. lutea* accessions were found in rather dry areas along roadsides or in grazed areas associated with thornscrub. *Cuphea schumannii* Koehne was not represented in the NCRPIS collection until this expedition. Table 3 summarizes the material collected in Mexico.

The Mexican *Cuphea* was collected during the optimal fruiting period; 36 of the 39 samples found had seed. In Brazil, 35% of the samples found lacked seed, possibly because of the wider range of fruiting periods among the Brazilian species.

Accessions of *C. lutea* were cultivated and characterized during 1992. An attempt will be made to cross *C. lutea* accessions with *C. viscosissima* to continue studies of lauric-acid biosynthesis and to incorporate genes encoding specific fatty-acid variants into *C. viscosissima*.

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