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Variability in Cuphea viscosissima Jacq. collected in east-central United States

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Abstract

Accessions of *Cuphea viscosissima* were collected from the central and east-central U.S. during two field explorations, one in 1987 and the other in 1989. Characterization and evaluation data of accessions collected in 1987 have been reported earlier. This paper reports the results of characterization and evaluation trials of the 1989 collections. Thirty-one of these accessions were grown for characterization and seed-increase plantings in 1990 and twenty-four of these in replicated evaluation trials in 1991 at Ames, Iowa.

Morphological characters are rather uniform and resemble accessions collected in 1987. A new pale flowered form was identified. Glandular trichomes, which produce a sticky resin, occurred uniformly on the stems and flowers of all accessions, but their presence on leaves was variable. Fourteen of the thirty-one accessions lacked glandular trichomes on their leaves.

Statistically significant variation occurred in plant height (59 to 90 cm) and mass (89 to 216 g), seed yield (0.9 to 7.0 g/plant), and the amounts of caprylic (8:0) (14.3 to 16.8%), capric (10:0) (68.0 to 71.9%), and lauric (12:0) (2.5 to 3.4%) acids. Variations in 100-seed weight, seed germination, and oil content were non-significant.

The narrow range of variability found in these accessions collected from rather diverse ecological regions would suggest that *C. viscosissima* has occupied its native range rather recently, and has had little time to diversify genetically. The variability identified is being used in interspecific hybrid crosses with *C. lanceolata*Aiton to develop a domestic source of medium-chain fatty acids.

Keywords

Cuphea, Fatty acid, New Crop, Germplasm

Disciplines

Agricultural Science | Agriculture | Horticulture | Plant Breeding and Genetics | Plant Sciences

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Variability in *Cuphea viscosissima* Jacq. collected in east-central United States

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Accessions of *Cuphea viscosissima* were collected from the central and east-central U.S. during two field explorations, one in 1987 and the other in 1989. Characterization and evaluation data of accessions collected in 1987 have been reported earlier. This paper reports the results of characterization and evaluation trials of the 1989 collections. Thirty-one of these accessions were grown for characterization and seed-increase plantings in 1990 and twenty-four of these in replicated evaluation trials in 1991 at Ames, Iowa.

Morphological characters are rather uniform and resemble accessions collected in 1987. A new pale flowered form was identified. Glandular trichomes, which produce a sticky resin, occurred uniformly on the stems and flowers of all accessions, but their presence on leaves was variable. Fourteen of the thirty-one accessions lacked glandular trichomes on their leaves.

Statistically significant variation occurred in plant height (59 to 90 cm) and mass (89 to 216 g), seed yield (0.9 to 7.0 g/plant), and the amounts of caprylic (8 : 0) (14.3 to 16.8%), capric (10 : 0) (68.0 to 71.9%), and lauric (12 : 0) (2.5 to 3.4%) acids. Variations in 100-seed weight, seed germination, and oil content were non-significant.

The narrow range of variability found in these accessions collected from rather diverse ecological regions would suggest that *C. viscosissima* has occupied its native range rather recently, and has had little time to diversify genetically. The variability identified is being used in interspecific hybrid crosses with *C. lanceolata* Aiton to develop a domestic source of medium-chain fatty acids.

Keywords: Cuphea; Fatty acid; New Crop; Germplasm

1. Introduction

Cuphea viscosissima, which occurs throughout much of the east-central U.S, is the only *Cuphea* species widely distributed in the continental U.S. (Graham, 1988; Fig. 1). Accessions from the western portion of this range (Arkansas, Kansas, Illinois, Iowa, Missouri) were collected in 1987, and those from the eastern portion (Indiana, Kentucky, North Carolina, Tennessee, Virginia, West Virginia) in 1989 (Roath et al., 1993). This species is being used in domestication projects at Ames, Iowa, and at Corvallis, Oregon (Knapp et al., 1992; Roath et al., 1992; Knapp, 1993b) to develop a temperate-zone source of medium-chain fatty acids (MCFA). Medium-chain fatty acids have var-

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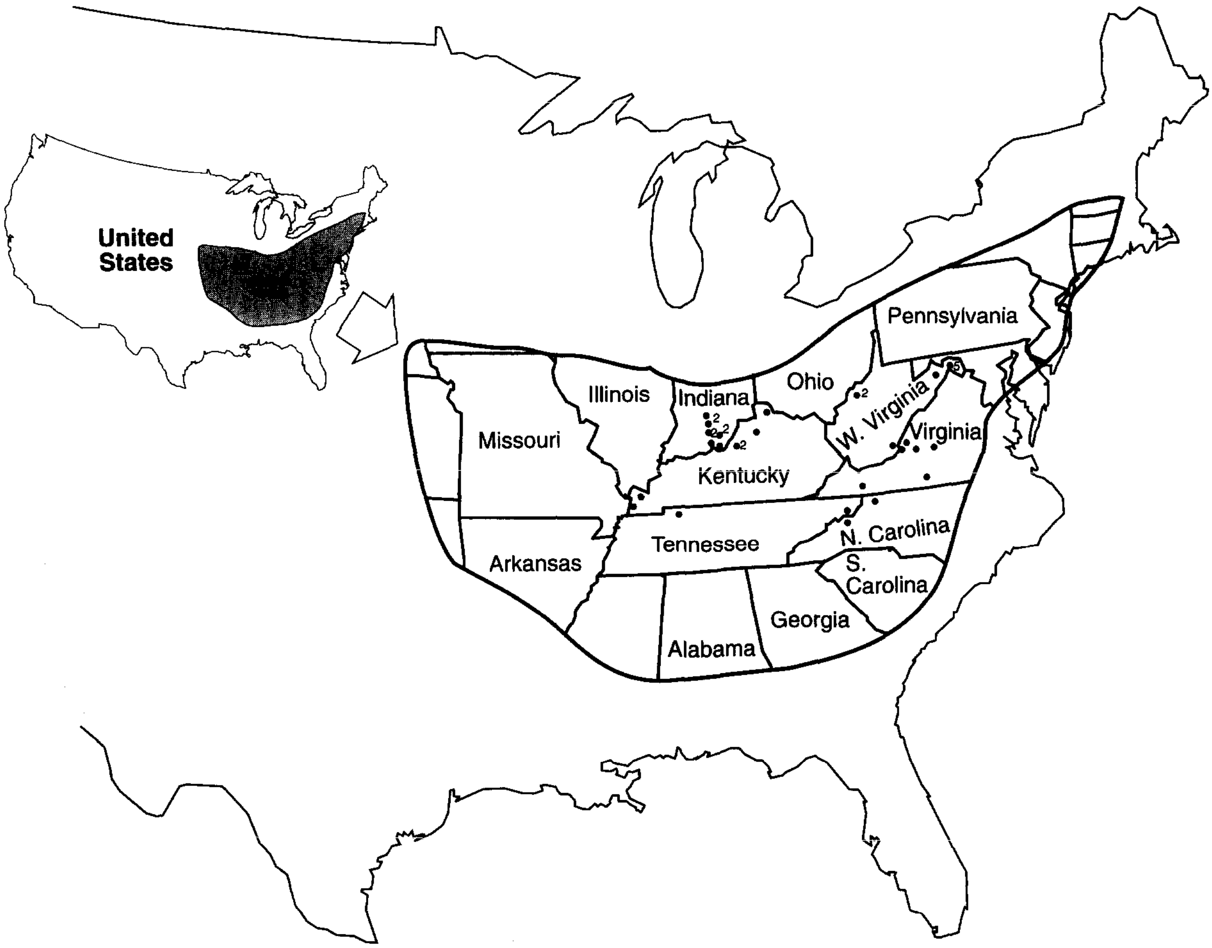

Fig. 1. Location of 1989 *Cuphea viscosissima* collection. Locations with numbers indicate the number of accessions >1 collected at that site.

ious industrial and food applications, the most important use is in the soap and detergent industry (Graham, 1989).

We have reported (Roath et al., 1992) limited variability among accessions of *Cuphea viscosissima* obtained in 1987. This paper reports results of characterization and evaluation of 30 *C. viscosissima* accessions collected in 1989.

2. Materials and methods

Thirty of the thirty-eight *C. viscosissima* accessions collected in the eastern U.S. in September 1989 (Table 1; Fig. 1) were cultivated for seed increase in isolation cages during the 1990 growing season at Ames. Plant height, color of stems, hypanthia, and petals, and presence of glandular trichomes on stems, leaves and flowers were measured. The mean height of extended branches of four plants selected at random from the plots was used to calculate plant height. Color was determined by comparing the appropriate organ against Munsell color charts under full sunlight (Munsell Book of Color, 1976). The presence of glandular trichomes was observed under a 10× hand lens.

Twenty-four of the accessions collected in 1989, six accessions collected in 1987, plus three accessions collected at other locations were planted in a replicated field trial at Ames (Table 1). Seeds were germinated as described by Roath and Widrlech-

Table 1
Geographical origin of *Cuphea viscosissima* accessions collected in September 1989 [a]

PI No.	State	County
560084	Kentucky	McCracken
560085	Kentucky	Carlisle
560086	Tennessee	Montgomery
560087	North Carolina	Mitchell
560088	Tennessee	Carter
560089	North Carolina	Alleghany
560090	Virginia	Smyth
560091	Virginia	Nelson
560092	Virginia	Rockbridge
560093	Virginia	Bath
560094	Virginia	Alleghany
560096	West Virginia	Morgan
560097	West Virginia	Morgan
560098	West Virginia	Morgan
560099	West Virginia	Morgan
560100	West Virginia	Hampshire
560101	West Virginia	Wirt
560102	West Virginia	Wirt
560103	Kentucky	Campbell
560104	Kentucky	Owen
560105	Kentucky	Jefferson
560106	Kentucky	Jefferson
560107	Indiana	Harrison
560108	Indiana	Crawford
560109	Indiana	Washington
560110	Indiana	Washington
560111	Indiana	Orange
560112	Indiana	Orange
560113	Indiana	Orange
560114	Indiana	Lawrence
534726 [b]	Virginia	–
534739 [c]	Kansas	Cherokee
534741 [c]	Kansas	Cherokee
534745 [c]	Missouri	Polk
534756 [c]	Missouri	Reynolds
534757 [c]	Missouri	Iron
534762 [c]	Illinois	Pope
534911 [d]	West Virginia	Morgan
561500 [e]	Indiana	Monroe

[a] Collected by Roath and Widrlechner, 1989.
[b] Collected by Balough, 1985.
[c] Collected by Roath and Widrlechner, 1987.
[d] Collected by Balough.
[e] Collected by Widrlechner, 1988.

ner (1988), and seedlings were transplanted into the greenhouse. Up to 40 approximately three-month-old plants were transplanted to 0.9 m × 6 m field plots on 7 June 1991. There were three rows per plot, 0.46 m apart with plants ca. 0.30 m apart.

All the plants in a plot were harvested, placed in mesh bags, and dried at ca. 32°C. Dried plant material was weighed, and the total weight divided by the number of plants harvested to determine mean weight per plant. The seeds were threshed from the plants and weighed. Weights of seed per plant and 100-seed weight were determined.

Germination was determined both from seed with seed coats excised and from seed within their seed coats. Two 50-seed replications of each were used. Germination tests were performed under continuous light at room temperature (ca. 20°C). Counts of germinated seedlings were made weekly for 21 days after initiation of germination. Parental seed of the 33 accessions used in the 1991 trial were germinated in 1993 using the same procedures described above.

Three grams of seed from each replicate were sent to the New Crops Research Group, USDA Agricultural Research Service, National Center for Agricultural Utilization Research, Peoria, Illinois, for determinations of oil and MCFA percentage as described by Roath et al. (1992).

Analysis of variance was performed as completely randomized design for plant height and randomized complete block design for plant mass, 100-seed weight, seed yield, germination, and oil content plus fatty acid percentages.

3. Results and discussion

Most morphological traits of these accessions, such as growth habit or stem, hypanthium, and petal color, are strikingly similar to those previously reported (Roath et al., 1992).

One exception was PI 560100 with petals of a lighter shade of red-purple than other wild-type accessions. PI 560100 also differed from PI 534750, a 1987 collection, which has lighter red-purple petals and yellow-green stems (Roath et al., 1992). PI 560100 has a wild-type (red-purple) stem color. PI 534750 petal and stem colors are apparently conditioned by a single gene with a 3 : 1 segregation of wild-type: pale petals and stems in F_2 populations of wild-type × pale crosses (W.W. Roath, unpubl. data). The genetic control of petal color for PI 560100 has not been determined.

Table 2
Mean plant height, mean plant mass, and leaf trichome occurrence of selected *Cuphea viscosissima* accessions

PI No.	Plant height (cm)	Plant mass (g)	Leaf trichomes
560084	81.7	–	absent
560085	85.7	168.9	absent
560086	62.2	–	absent
560087	83.5	–	present
560088	59.0	–	present
560089	80.7	174.6	present
560090	86.2	145.1	present
560091	72.2	140.4	absent
560092	78.0	145.3	present
560093	68.0	183.1	absent
560094	76.7	188.1	absent
560096	77.3	145.1	present
560097	88.0	133.8	present
560098	76.5	104.0	present
560099	62.3	137.3	present
560100	84.5	216.2	present
560101	75.0	130.1	absent
560102	73.5	145.7	absent
560103	80.5	89.4	absent
560104	65.0	169.0	present
560105	74.0	127.6	absent
560106	70.5	146.8	present
560107	90.0	209.2	absent
560108	84.0	–	absent
560109	76.5	166.3	present
560110	78.0	171.3	present
560111	78.7	–	absent
560112	65.0	175.0	present
560113	77.5	142.3	absent
560114	–	152.4	absent
534726	–	123.3	–
534739	–	169.9	–
534741	–	163.0	–
534745	–	157.5	–
534756	–	121.3	–
534757	–	161.5	–
534762	–	162.4	–
534911	–	134.3	–
561500	–	133.5	–
LSD p = 0.05	8.9	3.2	–

Glandular trichomes occurred on stems and flowers of all observed accessions. Presence of glandular trichomes on leaves varied between accessions (Table 2). Our attempts to quantify the amount of resin produced by trichomes on various organs have been discontinued because of the environmental effects on resin production.

Both plant height and plant mass of accessions collected in 1989 varied significantly as did these features in accessions collected in 1987 (Table 2; Roath et al., 1992). Plant mass was only weakly associated with seed yield in these accessions ($r = 0.29$, $p = 0.019$). Plant mass of 1989 accessions was somewhat greater than the accessions included in this trial as checks. The mean plant mass of the 24 accessions collected in 1989 was 154.5 g per plant compared to the 147.4 g per plant for check accessions. Because of the weak correlation between plant size and seed yield, the larger plants would not necessarily be expected to yield more seed, and indeed this was true in this trial. The average seed yields were 2.13 g per plant for the 1989 accessions and 3.35 g per plant for the check accessions, well within trial error.

The 100-seed weight of the accessions collected in 1989 was uniform (Table 3) and similar to the accessions collected in 1987 (Roath et al., 1992). Seed size was not significantly correlated with seed yield ($r = 0.11$, $p = 0.54$). Apparently seed size does not contribute significantly to variability in seed yield of these accessions.

There was significant interaccession variation for seed yield (g per plant; Table 3). The six checks (534739 through 534762, Table 3) were the highest yielding accessions of the 1987 group (Roath et al., 1992). The check accessions outyielded the average of the 1989 accessions slightly, but individual 1989 accessions yielded as much as or more than the checks. For instance, PI 560100 had seed yield of 6.97 g per plant, slightly greater than the best yielding check accession, PI 534741, with 6.84 g per plant. The degree of interaccession variation for seed yield suggests that increasing seed production through selection is possible.

The 1989 accessions also have wild-type seed presentation at maturity, and would be expected to shatter easily.

No significant variation in germination of either excised (seed coats removed) or non-excised seed (seed intact) was present (Table 4). The amount of dormant seed from accessions grown in the 1991 trial, as calculated by subtracting percent germination of non-excised seed from the germination of the excised seed, probably does not reflect the true degree of dormancy. The percent dormancy

Table 3
Seed characteristics of selected *Cuphea viscosissima* accessions

PI No.	SWT[a] (g)	Yield (g/pl)	Oil[b] (%)	8:0[c] (%)	10:0[c] (%)	12:0[c] (%)
560085	0.17	1.38	26.6	16.1	69.0	3.1
560089	0.20	1.41	28.4	14.3	69.6	3.1
560090	0.27	2.17	24.3	14.5	69.4	3.3
560091	0.22	2.08	29.0	14.3	71.9	2.8
560092	0.21	2.67	31.6	14.4	71.1	2.8
560093	0.22	0.88	23.6	15.3	69.2	3.2
560094	0.21	2.56	26.7	14.5	69.3	3.0
560096	0.21	0.97	31.3	15.7	70.6	3.0
560097	0.23	5.95	26.4	14.9	70.9	3.0
560098	0.20	5.76	29.2	16.2	68.9	3.3
560099	0.20	3.69	28.9	15.2	69.8	2.9
560100	0.20	6.97	23.2	14.3	68.0	3.1
560101	0.19	1.26	28.6	15.8	70.1	3.0
560102	0.16	1.87	22.9	14.6	68.8	3.2
560103	0.19	0.90	30.9	16.8	70.2	2.7
560104	0.22	1.69	31.1	15.6	70.2	2.8
560105	0.20	2.64	28.2	13.6	69.5	3.3
560106	0.21	0.92	25.6	15.3	69.1	3.3
560107	0.17	1.59	27.4	15.4	70.0	2.5
560109	0.19	1.70	27.1	15.5	70.3	3.1
560110	0.21	0.68	24.7	16.0	68.6	2.9
560112	0.19	0.74	29.5	15.4	70.8	2.9
560113	0.20	0.47	25.7	14.8	70.7	2.6
560114	0.17	0.20	27.1	14.3	70.5	3.2
534726	0.16	4.06	26.1	16.1	68.9	3.2
534739	0.17	3.27	29.5	15.9	70.7	3.0
534741	0.24	6.84	30.1	14.8	69.4	3.3
534745	0.22	3.45	23.9	13.9	69.4	3.3
534756	0.18	3.05	24.1	13.8	69.1	3.3
534757	0.20	3.77	29.1	15.3	69.9	3.2
534762	0.19	1.16	25.3	15.7	68.8	3.4
534911	0.20	3.74	30.2	15.9	70.7	2.6
561500	0.18	0.82	30.3	14.8	70.4	3.2
LSD $p = 0.05$	ns	3.52	ns	1.1	1.5	0.3

[a] Mean weight of 100 seeds. [b] Percent oil on an oven-dry basis. [c] Percent of total fatty acids.

in parental seed varied from 70% to 100%, which suggests that some of the seed from the 1991 trial had some degree of embryo dormancy. Seed-coat induced dormancy is still present in stored *C. viscosissima* for three to five years after harvest. Knapp (1993a) has used the interspecific hybrid, *C. lanceolata* Aiton × *C. viscosissima*, as source of non-dormancy and auto-fertility for improved genotypes.

Percent seed oil varied from 22.9% to 31.6%, a range which was statistically nonsignificant (Table 3). The mean oil percent of the twenty-four 1989 accessions was 27.4% compared to the mean of the nine checks of 24.3%. Even though no significant differences in oil percent were measured, the relatively wide range of oil percentages and the significant differences reported in the 1987 accessions (Roath et al., 1992) suggest that oil content can be improved by selection from within hybrids of these accessions. Indeed this has been the case. Knapp (1993b) reports 3 to 4% increases when *C. viscosissima* was hybridized with *C. lanceolata* and the resulting lines selected for increases in oil content.

Table 4
Germination characteristics of selected *Cuphea viscosissima* accessions

PI No.	1990 seed [a]; 1993 germination			1991 seed; 1991 germination		
	excised [b] (%)	non-excised [b] (%)	dormant [c] (%)	excised [b] (%)	non-excised [b] (%)	dormant [c] (%)
560085	98.0	18.0	80.0	61.4	1.0	60.4
560089	100.0	2.0	98.0	52.0	3.5	48.5
560090	96.0	0.0	96.0	57.5	8.0	49.5
560091	96.0	8.0	88.0	54.0	3.0	51.0
560092	100.0	4.0	96.0	59.5	8.5	51.0
560093	94.0	2.0	92.0	55.0	2.0	53.0
560094	96.0	2.0	94.0	47.0	6.0	41.0
560096	98.0	0.0	98.0	58.5	5.0	53.5
560097	96.0	0.0	96.0	78.4	1.0	77.4
560098	100.0	6.0	94.0	38.4	4.0	34.4
560099	100.0	0.0	100.0	41.5	5.0	37.5
560100	100.0	2.0	98.0	57.0	4.5	52.5
560101	98.0	0.0	98.0	53.5	2.0	51.5
560102	100.0	4.0	96.0	56.0	8.4	47.6
560103	98.0	0.0	98.0	46.0	1.4	44.6
560104	100.0	2.0	98.0	78.5	1.5	77.0
560105	96.0	0.0	96.0	57.0	8.0	49.0
560106	92.0	0.0	92.0	62.5	3.5	59.0
560107	86.0	16.0	70.0	51.5	2.4	49.1
560109	100.0	2.0	98.0	54.4	2.0	52.4
560110	88.0	2.0	86.0	49.0	1.4	47.6
560112	94.0	1.0	93.0	50.5	3.0	47.5
560113	100.0	0.0	100.0	74.5	3.5	71.0
560114	94.0	18.0	76.0	37.5	3.5	34.0
534726	100.0	18.0	82.0	79.4	3.0	76.4
534739	98.0	4.0	94.0	63.0	8.0	55.0
534741	100.0	24.0	76.0	72.0	8.5	63.5
534745	98.0	28.0	70.0	71.0	0.4	7.06
534756	97.0	4.0	93.0	46.5	5.0	41.5
534757	100.0	4.0	96.0	44.5	7.5	37.0
534762	98.0	2.0	96.0	68.0	3.5	64.5
534911	90.0	24.0	66.0	59.5	3.4	56.1
561500	98.0	4.0	94.0	39.0	10.0	29.0
LSD $p = 0.05$	ns	7.1	–	ns	ns	–

[a] Seed produced in 1990 used as parental seed for 1991 trials. Parental seed for checks was produced in 1988, except for PI 534726-1990 seed, and PI 534911-1987 seed. [b] Seed coats excised. [c] Post-harvest dormancy.

Statistically significant variation was measured in the three primary fatty acids (Table 3). Capric acid was the predominant fatty acid in the seed oil of these accessions, and was within the range of previous reports (Knapp et al., 1992; Roath et al., 1992). Capric acid is used primarily in the food industry and is a small market compared to the market for lauric acid. Capric acid is also used as feed stocks for perfumes, lubricants, and cosmetics. The amount of lauric acid found in these accessions is too small for commercial use, and must be improved if these accessions are to serve as a source of this important fatty acid.

4. Conclusions

The amount of variability found in the 1987 and 1989 collections of *C. viscosissima* is relatively narrow. All of these accessions are remarkably similar, particularly in morphological characteristics. Only one accession was observed with a different flower color. Statistically significant differences are limited to quantitative traits, i.e. plant height, plant mass, seed yield, and fatty acid content. This variation is exploitable in some cases, but is still within a relatively limited range. This narrow degree of variability would suggest that *C. viscosissima* has originated rather recently from a narrow genetic base and has spread throughout its large range rather rapidly and recently so that adaptive variation has been minimal.

These accessions are now contributing genes for domesticating *Cuphea* as a source of MCFA's. They are serving as germplasm sources (in interspecific hybrids with *C. lanceolata*) for autofertility, seed yield, and for adaptation. Additional accessions of *C. lanceolata* were collected in Mexico in October 1993 to expand the germplasm base for domestic production of MCFA's.

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