TRENDS IN NEW CROPS AND NEW USES

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Jacket photograph: Michael Dana.
A contemporary landscape with ornamental grasses *Imperata cylindrica* 'Red Baron' (left) and *Miscanthus sinensis* 'Morning Light'.

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Rooting Characteristics and Water Requirements of *Cuphea*

Brenton S. Sharratt and Russell W. Gesch

Maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] have been the predominate crops grown in the Midwestern United States for the past several decades. Alternative crops are sought in this region due to the historic low price of maize and soybean and to degradation of soil and water quality under continuous maize or maize-soybean rotations. *Cuphea* (Lythraceae) has the potential to become an alternative crop as a result of being a source of medium chain fatty acids. These acids are important in the manufacturing of commodities such as soaps and detergents. The manufacturing of these commodities now rely upon the availability of palm kernel oils, which are likely to be of limited supply in the near future due to diminishing resources in Indonesia and in the Philippines. A renewable supply of medium chain fatty acids is therefore vital to the future manufacturing of industrial cosmetic products.

Cuphea is native to North, Central, and South America and favors moist and temperate growing environments. Graham (1989) observed that most species of *Cuphea* have a small taproot, a morphological characteristic that likely induces water stress when grown in semi-arid and arid environments. Indeed, Graham (1989) noted that annual species are very susceptible to wilting without adequate soil water. Some species of *Cuphea*, however, have been found to tolerate drought. These species avoid water stress by developing thick leaves or a large taproot (Graham 1989).

Little is known concerning the growth and production of *Cuphea* in the North Central United States. The climate of this region is more extreme in temperature and sunlight compared to the native environments at more southerly latitudes. Information is needed concerning the thermal requirements for development as well as water requirements for production of *Cuphea*. This study was undertaken to assess the water requirements and to characterize the rooting pattern of *Cuphea* when grown under a range of environments imposed by sowing dates and plant populations in the North Central United States.

METHODOLOGY

Cuphea (cross between *C. lanceolata* and *C. viscosissima*) was sown near Morris, Minnesota (45°35'N 95°55'W) on 3, 16, and 31 May 2000. These dates represent an early, normal, and late sowing date for crops grown in this region. Seed was sown at a depth of 13 mm in rows spaced 0.61 m apart using a grain drill. A row spacing of 0.61 m resulted in near maximum yields in a previous field study (Gesch et al. 2000) and was used due to the limitations of field equipment. The soil surface was compacted with a roller packer after sowing to ensure good contact of the seed with the soil. Main treatments (planting date) were established in 6 × 18 m plots and split to accommodate secondary treatments (plant population). Secondary treatments were established after emergence. Each treatment was replicated thrice. At the time of emergence, rows were thinned by hand to achieve plant populations of 320,000, 160,000, and 80,000 plants ha^{-1}. These populations correspond to spacing between plants within the row of 50, 100, and 200 mm, respectively.

Instrumentation to measure soil temperature, soil water content, and soil water potential was installed in each plot after sowing. Thermocouples were placed at a depth of 10, 50, and 100 mm to measure temperatures between and within the seed row. Thermocouples were monitored continuously using a data logger. Soil water content was assessed weekly in each plot by neutron attenuation. Neutron access tubes were placed both within and between plant rows; soil water content was determined at 0.30 m depth increments to 1.5 m. Soil water potential was determined at a depth of 1.5 and 2.0 m in each plot using tensiometers. These measurements, made weekly, aided in determined the direction of water flux below the root zone. Water use (WU) was determined according to: $WU = P + \Delta SW - RO \pm WFBR$ where P is precipitation received from emergence to harvest, ΔSW is change in soil water content from emergence to harvest, RO is water loss due to lateral surface water flow (i.e. runoff), and WFBR is the water flux below the root zone. Precipitation was measured daily with a precipitation gage. Runoff was assumed negligible.

Cuphea root and harvest (for biomass and seed yield) samples were taken when the dorsal surface of the most mature pods began to split (24 Aug., 30 Aug., and 5 Sept. 2000). Root length density profiles were ascertained from soil core samples (32 mm diameter) taken to a depth of 400 mm. This depth was chosen as a result of periodic excavations made during the growing season. Samples were collected from four locations in each plot both within and between rows. Samples were sectioned to ascertain root length density at depths of 0–50, 50–100, 100–200, 200–300, and 300–400 mm. The four samples collected at each depth within or between rows were consolidated into one within row and one between row sample per plot. Root length density was determined by the line intersect method (Böhm 1979). This method entails soaking the samples in water and then extracting root material by washing. Root and other organic material were then spread uniformly in a glass dish filled with water. A grid was placed under the glass dish. Root length was then determined by assessing the number of roots that intersected a grid line. Biomass samples were obtained by hand clipping an area of 5 m^2 within each plot. These samples were then dried at 60°C, weighed, threshed, and cleaned prior to obtaining seed weight. Final plant populations were obtained from the harvest area within each plot.

EXPERIMENTAL RESULTS

Cuphea biomass (above ground) and seed yield were influenced by both sowing date and plant population (Table 1). Early and normal sown *Cuphea* produced about 5800 kg ha^{-1} of biomass while late sown *Cuphea* produced 4950 kg ha^{-1} of biomass (Table 1). Similar results among sowing dates were found for seed yield. Seed yield declined from about 450 kg ha^{-1} for the early and normal sowing date to 370 kg ha^{-1} for the late sowing date.

Plant population positively influenced above-ground biomass and seed yield. Averaged across sowing dates, biomass decreased from 6200 kg ha^{-1} at a population of 320,000 plants ha^{-1} to 4650 kg ha^{-1} at a population of 80,000 plants ha^{-1}. Likewise, seed yield declined from 515 kg ha^{-1} at a population of 320,000 plants ha^{-1} to 330 kg ha^{-1} at a population of 80,000 plants ha^{-1}.

Seasonal water use varied with sowing date, but not by plant population (Table 2). Water use declined with sowing date; *Cuphea* sown early utilized 330 mm of water while that sown late utilized 260 mm of water. Differences in water use were largely associated with differences in precipitation among sowing dates. Precipitation received during the growing period declined from 295 mm for *Cuphea* sown early to 217 mm for *Cuphea* sown late. In addition, early sown *Cuphea* utilized more water possibly as a result of more extensive root exploration leading to greater root water extraction. Although soil water extraction did not vary among sowing dates, greater precipitation received during the growth cycle of early sown *Cuphea* may have been available for root uptake.

Water-use efficiency (WUE) was influenced by both sowing date and plant population (Table 2). *Cuphea* that was sown in mid-May had the highest WUE as compared with that sown at an earlier and later date. WUE ranged from 1.63 kg ha^{-1} mm^{-1} for *Cuphea* sown in mid May to 1.35 kg ha^{-1} mm^{-1} for *Cuphea* sown at an earlier or later date. The higher WUE for the normal sowing date resulted from similar seed yield, but less

Table 1. Total above-ground biomass and seed yield of *Cuphea* sown on three dates at three plant populations in spring 2000 near Morris, Minnesota.

	No. plants/ha		
Sowing date	320,000	160,000	80,000
	Biomass (kg ha^{-1})		
3 May	5,900	5,950	4,950
16 May	7,150	6,100	4,900
31 May	5,600	5,150	4,100
	Seed yield (kg ha^{-1})		
3 May	541	423	370
16 May	571	448	339
31 May	435	391	275

Table 2. Water use and water-use efficiency (WUE) of *Cuphea* sown on three dates at three plant populations in spring 2000 near Morris, Minnesota.

	No. plants/ha		
Sowing date	320,000	160,000	80,000
	Water use (mm)		
3 May	338	334	325
16 May	285	265	285
31 May	262	263	262
	WUE (kg ha^{-1} mm^{-1})		
3 May	1.60	1.27	1.14
16 May	2.00	1.70	1.19
31 May	1.67	1.49	1.05

water consumed as compared with the early sowing date. WUE over the range of 1.05 to 2.00 kg ha^{-1} mm^{-1} observed in this study appears to be relatively low as compared with other oilseed crops. For example, WUE of canola is about 10 kg ha^{-1} mm^{-1} (Grey 1998) and for sunflower, soybean, and mustard about 5 kg ha^{-1} mm^{-1} (Berglund 1995). Flax, however, has a WUE very similar to *Cuphea* of about 2 kg ha^{-1} mm^{-1} (Berglund 1995).

Rooting was restricted to the upper 0.40 m of the soil profile (Fig. 1). Few roots were found below this depth. In fact, from 65% to 80% of the roots were found within the upper 0.20 m of the soil profile. Sowing date and plant population influenced the rooting distribution of *Cuphea* in the soil. Rooting was more proliferous in the upper portion of the profile for *Cuphea* sown early as compared with that sown late. In addition, roots were more proliferous near the soil surface when *Cuphea* was grown at high versus low plant densities.

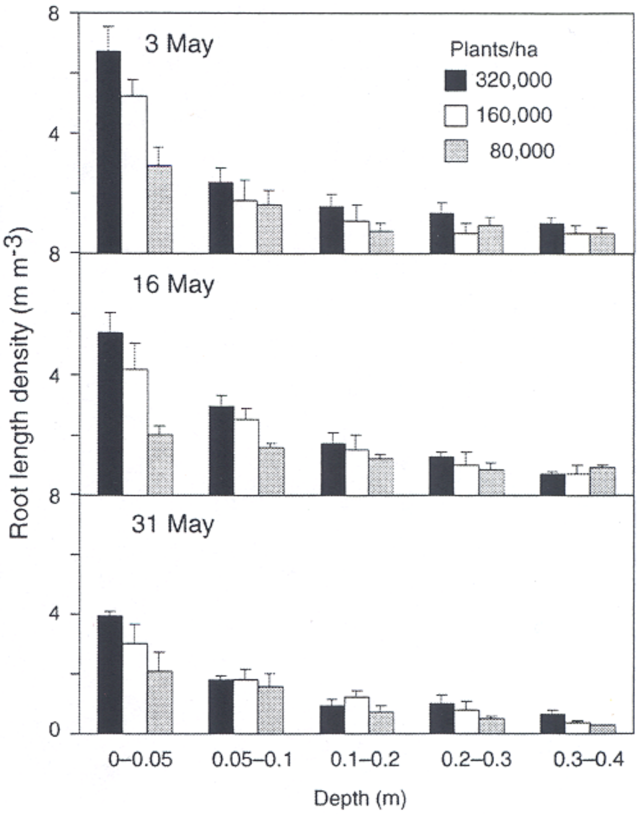

Fig. 1. Root length density (±SE) of *Cuphea* as a function of soil depth in late summer 2000. Populations of 320,000, 160,000, and 80,000 plants ha^{-1} were established on three dates.

CONCLUSIONS

Cuphea production is favored by early sowing in the North Central United States. Cool weather in the early season favors both root and shoot development and thereby circumvents potential water stresses that typically occur in the late season. The shallow rooting characteristic, however, makes *Cuphea* particularly vulnerable to water stress.

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