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POTENTIAL NEW IOWA MULTI-USE CROPS FOR OILS AND HYDROCARBONS*

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Introduction

Many green plants contain, on a dry weight basis, more than 5 percent oil plus hydrocarbon that is not concentrated in storage organs. In these plants, oils and hydrocarbons (botanochemicals) are distributed throughout major plant tissues often as the major component of a latex. Although there has been little past interest in processing whole plants for botanochemicals, there is now great interest in these new and renewable sources of raw materials and energy. Various plant species are being regarded as potential "gasoline trees" (1), as possible domestic sources of natural rubber (2) and plastic (3), as new sources of industrial feedstocks or even as potential fuels (4).

Green plants already supply several botanochemicals competitive with, or supplemental to, synthetic petrochemicals. These products include tall oil and its derivatives (fatty and rosin acids), naval stores (rosin, turpentine, terpenes, pine tar and pitch), vegetable oils and waxes, tannins (phenolic compounds), furfural, and natural rubber. Although various energy farming concepts may soon become practical, there will always be an economic advantage to direct production of chemical intermediates, waxes, rubber and plastic rather than, or in addition to, fuels and basic feedstocks (5).

An economic requirement for high-technology processing of whole-plants is that markets be developed for each plant product including fibrous residues. Thus, botanochemical crops would actually be multi-use crops. Multi-use crops would provide fiber, protein, and carbohydrates, in addition to botanochemicals, and they appear to offer greater total production of oil and protein than soybean grain and alfalfa, respectively (5). Such crops could reduce the demand for industrial raw materials from nonrenewable sources while allowing an increase in food production and an overall improvement in economv.

Potential Products

The common milkweed is a potential botanochemical crop, and it serves to illustrate the multi-use concept. It was the subject of new

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crops research at Iowa State University in the 1930s and 1940s. As pointed out by Berkman several years ago (6), the extraordinary "common milkweed" has served as a source of bouyant insulating floss, bast fiber, woody fiber, edible seed oil and protein, and as an edible pot herb. Milkweed latex is rich in oil and contains a low-molecular weight rubber. Possible milkweed products and their uses are listed in Table 1. Product yields were calculated from Berkman's reported values (6) and our own analysis. Thus, these values are based on the composition of typical wild plants. Domestication would result in much higher productivity of the more valued components. Of course, milkweed is only one of the new crop options; several other plant species could serve as a basis for equally valuable, but somewhat different, product mixes as discussed below.

Milkweed products (Table 1) also serve to illustrate the range of multi-use crop products and their potential value to our economy. In addition to usually agricultural products (foods and fibers), industrial raw materials such as rubber, whole-plant oils, polyphenols and fuels would be produced.

Table 1
Possible Products and Yields from Milkweed as a Potential Botanochemical Crop[a]

Product	Percent of Dry Plant	Yield, lb/acre	Potential Uses
Natural rubber	1.6	176	Rubber-goods manufacture
Whole-plant (latex) oil	4.1	451	Chemical intermediates
Polyphenol fraction	7.2	792	Chemical intermediates
Seed—triglyceride oil	1.9	209	Edible oil
Seed—extracted meal	7.2	792	Foods and feeds (51% protein)
Extracted leaf—meal	16.0	1,760	Feeds (20% protein)
Floss	11.1	1,221	Insulating material
Bast fiber	11.0	1,210	Premium papermaking, cordage
Woody fiber—pod shells	12.3	1,353	Paper- and boardmaking, fuel, furfural
Woody fiber—stem shives	27.6	3,036	
Total	100.0	11,000	

[a]*Based on dry weight and composition of a typical wild plant assuming a plant density of 43,560 per acre.*

The U.S. currently imports about 800,000 tons per year of natural rubber at a price of $0.63/lb (November 1978); thus, domestic sources are urgently needed.

Whole-plant oils could be industrial raw materials for a wide variety of such chemical intermediates as sterols, long chain alcohols, rosin and fatty acids, esters, waxes, terpenes and other hydrocarbons. Crude or slightly refined whole-plant oils rich in nonglyceride esters could be marketed as extender oils, processing aids and plasticizers for rubber and plastics or for direct incorporation into wax and polish formulations. Essentially unlimited markets exist for whole-plant oils at lower prices as fuels and basic raw materials; gasoline and diesel fuels could be produced from this feedstock when economically feasible.

Recently, there has been increased interest in low-cost polyphenols (bark extractives, for example) for wood laminating resins, plywood glues, particleboard adhesives, fortifiers for starch adhesives, oil well drilling muds, clay flocculants, plastics formulation, antioxidants and in various specialty uses such as controlled-release (fertilizer) of iron and in herbicide formulations. Low-cost polyphenols can also be degraded to simple phenol intermediates. Polyphenols are lower in calorific value than whole-plant oils; thus, their value as fuel would be lower.

Floss is a product peculiar to milkweed, and it might not be produced by a developed cultivar. However, milkweed floss is potentially valuable as a substitute for kapok; cotton, wool and polyester batting; perhaps goose down; and other insulating, padding, stuffing and buoyant materials (6).

Woody fiber products (Table 1) have the energy equivalent of about 4 barrels of petroleum per acre. Among options for use of this material as fuel are anaerobic fermentation to produce methane, saccharification to provide a fermentation substrate for fuel alcohol production and pyrolytic conversion to process gas. Byproducts of the fermentation processes can be used as soil amendments and as sources of feed protein. A non-fuel use for woody fiber is to increase its digestible matter by any of several treatments now being researched, then formulating it with an added source of nitrogen to produce a semi-synthetic cattle feed.

Potential Crop Species

Relatively few plant species have been proposed as potential botanochemical crops. Very recently the Congress mandated the development of guayule (*Parthenium argentatum*) as a domestic crop for natural rubber. This species is especially adapted for arid lands in southwestern United States and northern Mexico, but probably cannot be grown practically in Iowa.

Calvin has drawn particular attention to two *Euphorbia (Euphorbia lathyrus* and *E. turicalli)* "gasoline trees" that are adapted to arid lands and has suggested that the Euphorbiaceae and Asclepiadaceae deserve increased attention because they generally contain latices (1). Many species in these two families grow well in Iowa. However, plants in the *Euphorbia* genus produce toxic irritants and cocarcinogens that may make them impractical as crops unless non-toxic cultivars can be developed.

In a systematic search for potential botanochemical crops, more than 30 species have been designated as offering potential (5). Most of these are vigorous perennials growing wild in Iowa and adapted to wide areas

Table 2
Oil and Hydrocarbon Crop Models, Yield and Composition[a]

Component	Rubber Crop		Oil Plus Byproduct Rubber Crop		Oil Crop		Gutta Crop	
	Yield (lb/acre/yr)	Composition Dry Basis (%)	Yield (lb/acre/yr)	Composition Dry Basis (%)	Yield (lb/acre/yr)	Composition Dry Basis (%)	Yield (lb/acre/yr)	Composition Dry Basis (%)
Total dry matter	12,000	100	16,000	100	20,000	100	10,000	100
Crude protein	1,320	11	1,440	9	1,200	6	1,000	10
Rubber	1,200	10	320	2	—	—	—	—
Gutta	—	—	—	—	—	—	1,200	12
Oil	720	6	1,920	12	2,000	10	800	8
Polyphenol	840	7	1,120	7	3,600	18	700	7
Extracted residue[b]	9,240	77	12,640	79	14,400	72	7,300	73

[a]*Yields are based on harvesting and using the entire aerial plant.*

[b]*Assuming little or no protein is extracted with the other components.*

of North America. Some are competitive enough to be classed as "noxious weeds." Three species are grasses recently discovered to produce gutta (*trans*-1,4-polyisoprene) which has potential as a natural plastic. Based on characterization of these species, four crop models were developed assuming about a 50 percent improvement in dry matter yield and a two- to three-fold increase in botanochemical content during domestication. These increases are to be achieved through the combined efforts of plant breeders, agronomists and other plant scientists. Genetic improvement, fertilization, cultural practices and the use of chemical yield stimulation (7) would each contribute. Yields and compositions of Table 2 may be taken as specifications for practical botanochemical crop production.

Iowa plant species considered in developing the rubber crop model (Fig. 1) include mountain (prairie) mint (*Pycnanthemum incanum*), pale Indian plantain (*Cacalia atriplicifolia*) and common milkweed (*Asclepias syriaca*). Iowa species of interest for oil plus byproduct rubber include tall bellflower (*Campanula americana*), tall boneset (*Eupatorium altissimum*) and sow thistle (*Sonchus arvensis*). The oil crop model relates to potential woody perennial coppice (short-rotation forestry) plants high in polyphenols, such as smooth sumac (*Rhus glabra*), silver maple (*Acer saccharinum*) or sassafras (*Sassafras albidium*). The gutta crop is to be developed from a perennial grass.

Summary

On a world basis, agriculture is already under pressure for increased food production. Moreover, dwindling reserves of fossil hydrocarbons make it probable that agriculture will also be called upon to produce industrial raw materials and fuels. Thus, the need for combining the production of both food and industrial feedstocks with overall increased productivity is imperative. The concept of multi-use botanochemical-producing crops in an adaptive agricultural system appears to offer hope for this major social and economic accomplishment. Iowa, with its varied flora, abundant farm resources, and progressive farmers and business people, can expect to lead in the production of such new and different crops and in the development of a new botanochemical industry.

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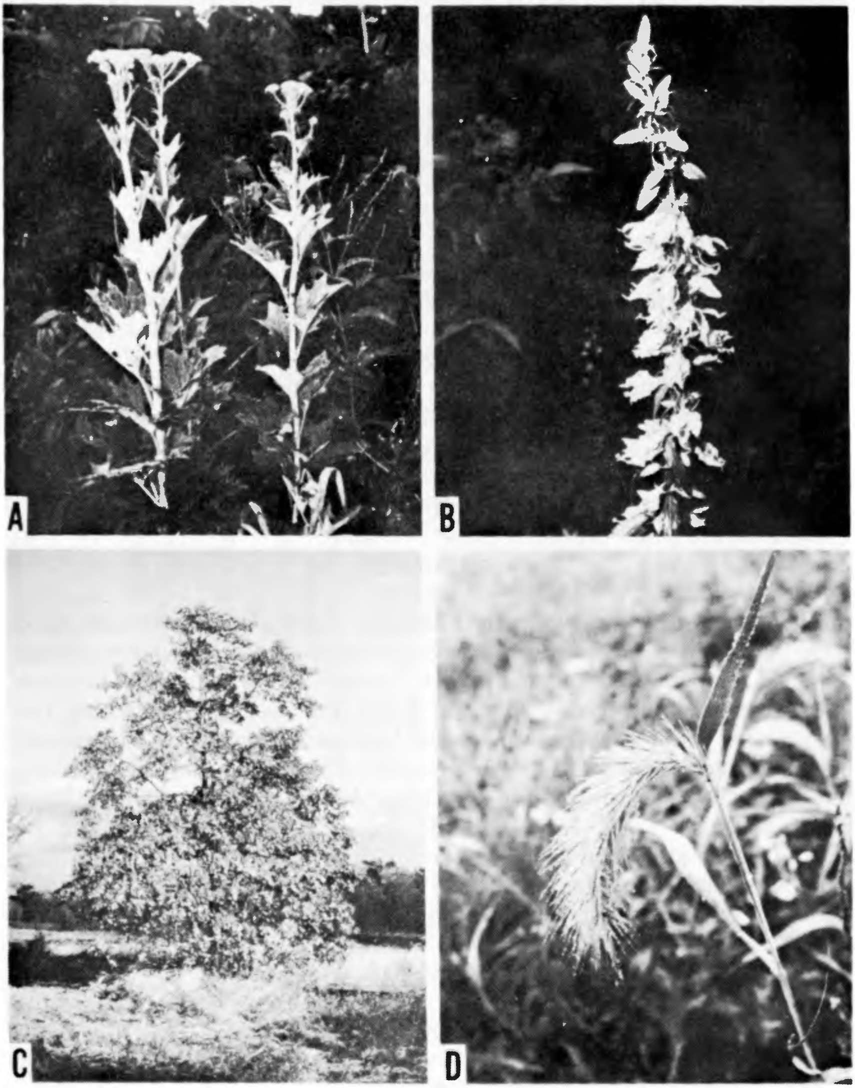

Fig. 1. Representative Iowa plant species considered in developing oil- and hydrocarbon-producing crop models. A—Pale Indian Plantain (*Cacalia atriplicifolia*), rubber crop. B—Tall Bellflower (*Campanula americana*), rubber plus by-product rubber crop. C—Sassafras (*Sassafras albidium*), coppice oil crop. D—Wild Rye (*Elymus canadense*), gutta crop.