

Midwest Plants for Potential Crops¹

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ABSTRACT

In the fall of 1975, the Northern Regional Research Center expanded its plant screening program to include midwestern plants for sources of rubber and other hydrocarbons, fiber, oil, and protein. More than 600 species have been collected. Of these, 515 species, representing 288 genera and 86 families, have already been analyzed and the results on 200 species have been published. Results on 200 more have been reported at scientific meetings (1980 and 1981). For each species a cumulative score was calculated, partly from the botanical characteristics and potential adaptability to cropping and partly from the chemical composition. Seventy-three species ranked 11 or less; therefore, they may be amenable to cropping and product utilization. These species should be studied further.

INTRODUCTION

Plants as sources of rubber have been investigated intermittently for many years in North America and Europe. The main reason for these efforts is the continuous need for importing natural rubber from South East Asia and South America. Annual U.S. imports alone are as high as 1.6 billion pounds. So far, all efforts to match the excellent properties of the natural product with petroleum-based or other manmade rubbers have failed. The first documented experiments to prepare rubber from U.S. plants were begun in 1871 by William Saunders. He used Common Milkweed (*Asclepias syriaca* L.) and published his report in 1875. Cook (1903) worked on the Central American Rubber Tree (*Castilla elastica* Sesse) and on Guayule (*Parthenium argentatum* A. Gray). A.T. Saunders (1910) examined 1,900 milkweed plants as sources of rubber. In his report he includes characteristics of the rubber. The most extensive agronomic examination of milkweed plants up to 1912 was done by Fox (1911 and 1912). Great Basin and Pacific Coast plants were analyzed in California in 1917. Results were published by Hall and Goodspeed

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²The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

(1919). Most of their work was on varieties of Rabbit-brush [*Chrysothamnus nauseosus* (Pall.) Britt.]. Pearson (1919) learned that the Germans during World War I resorted to the manufacture of rubber from weeds, e.g., Sow Thistle (*Sonchus* spp.) and Wild Lettuce (*Lactuca* spp.).

In 1917, a project on the rubber content of North American plants was begun as a war emergency project. Most of this work was done on Rabbit-brush [*Chrysothamnus nauseosus* (Pall.) Britt.] (Hall and Long, 1921), but 64 species of milkweed were examined, too. Their report also includes a list of composites that gave negative results. Widstoc and Hirst (unpublished manuscript, mentioned by Hall and Long, 1921) of Utah determined the percentage of rubber in several species and prepared rubber for examination. Also according to Hall and Long (1921), Olsson-Seffer, an experienced student of rubber plants, studied Mexico latex plants, especially *Jatropha*, *Plumeria*, and *Euphorbia* species. He learned that these three genera have the ability to reproduce from the base after the plant tops are removed. He also realized that commercial quantities of rubber could be obtained from native growth and from plantations established for this purpose. However, before his work could be published in detail, he was killed in a political disturbance in Mexico.

Thomas Edison searched for rubber-producing plants from 1927-1931 and tested products of thousands of plants. Polhamus (1967) reported the results. Edison analyzed 2,222 species representing 977 genera and 186 families. Much of his work was on goldenrods (*Solidago* spp.).

Again during World War II there was an increased effort to search for rubber-producing plants. A report published in 1945 includes a table giving the rubber content of native plants of Arizona (Anonymous, 1945). All these efforts were discontinued either because they did not appear to result in economically feasible products or because the emergency situations ended. However, during the last decade the need for additional efforts has resurfaced, since world production of natural rubber is expected to be insufficient for the demand. Also, strategic considerations play a major role, since present production sites are so distant from the major users of natural rubber.

Until now, midwestern species of plants have never been included specifically in the search for rubber and other hydrocarbons. Since 1975 the Northern Regional Research Center has been screening such midwestern plants as sources of hydrocarbons, with special emphasis on rubber, oil, and wax. Reports have been published on 200 species (Buchanan *et al.*, 1978 [4 papers]). Reports on an additional 200 species have been presented at scientific meetings in 1980 and 1981, respectively. These reports will be published soon. Approximately 100 species analyzed were legumes from many parts of the world. Analyses on the last 100 species are completed but they are not yet evaluated and organized for presentation.

At first the search was directed toward three groups of plants: (1) those with milky juice producing natural rubber, (2) local plants of the same families and genera included in the survey done at the Arizona Experiment Station in the 1940's, and (3) species analyzed by Edison in his search for rubber-producing plants. Because of the richness of the Midwestern flora, there are hundreds of plant species that can be obtained in most local areas. For example, a short-term survey of a limited area along an abandoned railroad right-of-way yielded more than 500 plant species (Cull, 1969).

MATERIALS AND METHODS

Collections

More than 600 species of mature plants from the midwest have been collected for chemical analyses up to December 1, 1982. A voucher specimen of each species has been preserved in our Center's herbarium. A 500-gram sample of each species, usually composed of several plants or twigs, was collected at one location. If the plants were small, they were collected at several places until the desired amount was obtained. Herbaceous and small woody plants were clipped at the soil line. New growth was clipped from large woody plants. Where possible or desirable, material included flowers and/or fruits and seeds. Individual species were collected in a large paper sack. On the sack and in a field notebook were written the common or scientific name and the date and place of collection. Pertinent information about each sample was provided to the analytical chemist. This included scientific name, common name if there was one, family, collector, place and date of collection, and sometimes additional notes where deemed desirable.

Gray's Manual was the source for the scientific names and authorities (Fernald, 1970).

Drying

The green material was air-dried indoors, usually in the sacks. However, large plants and woody ones were spread on plastic sheets on the floor or a table top to dry. The degree of dryness was judged satisfactory if the leaves crumbled when squeezed and the stems snapped when bent.

Sample Grinding and Analysis

When dry, each sample was coarsely chopped and ground to 1 mm sieve size and analyzed by chemists. The analyses included oil, polyphenols, hydrocarbons, and protein. Also, the presence of natural rubber, wax and fiber was noted.

Botanical Evaluation

Plants were evaluated on the basis of their botanical characteristics. Each species was scored in each of five categories, namely, temperature requirement (scoring range 1-5), moisture requirement (1-5), growth rate (1-4), plant habit (1-5), and adaptability to pollarding (1-3). Lowest numbers indicate the best possibilities for crop development. Table 1, developed for country-wide use, served as a guide. Plants that score high but have hydrocarbon-rich fruits, roots, rhizomes, bulbs, etc., or which are lactiferous and can produce hydrocarbons by tapping, are scored one number lower on the scale than their botanical characteristics indicate. Growth rate for perennials, including woody species, has been defined as the amount of annual growth after clipping at ground level. A score of 4 applies to all species of vines, marsh plants, rosette-forming plants, low-growing succulents and sod-forming grasses, including those with a high rate of growth. An ideal candidate would score 5 and a useless one 22. The total botanical rank for each species was used in the cumulative rating by dividing the score by 5, rounding to the nearest whole number, and adding the result to the total chemical evaluation score. Any species having more than one undesirable characteristic was rated 5 on this reduced botanical scale.

Chemical Evaluation

Plants also were evaluated on the basis of their chemical composition. Each species was ranked in each of four categories, namely, fiber (score of 1 or 2), pro-

tein (1 or 2), oil (1 through 4), and hydrocarbons (1 through 4) (Table 2). Plants potentially useful for making fiber, paper, or board products were rated 1, all others were rated 2. Species that contained more than 14% protein were rated 1, all others were rated 2. Oil fraction over 8% was rated 1; 5-8%, 2; over 2-5%, 3; and less than 2%, 4. Hydrocarbon content was rated likewise. Species with more than 2% hydrocarbons were rated 1; 1.2 to 2.0%, 2; 0.4 to 1.2%, 3; and less than 0.4%, 4. Each species was then ranked in each of four categories, namely, fiber, protein, oil, and hydrocarbons. This approach was chosen to give additional consideration to those plant species whose total biomass may be utilized for the manufacture of desirable products.

The total scores were used in determining the cumulative rating.

Cumulative Rating

A cumulative rating was calculated for each species, based on the sum of the reduced botanical rating and the chemical evaluation (crude protein, fiber, percentage of oil and of hydrocarbon). The smaller the number, the greater the possibility for a future crop. If a species were suitable for oil or hydrocarbon but not both, it would score 9. Species having a cumulative score of 11 or less appear to have potential and warrant further study. It should be understood that this cumulative rating system is not perfect, but that it can be used satisfactorily to identify the more promising species.

RESULTS AND DISCUSSION

The first 515 species analyzed represented 288 genera and 86 families. All species analyzed contained hydrocarbons, but the amount was often very small. Plant families containing the most hydrocarbon-producing midwestern species analyzed are shown in Table 3. Natural rubber is found in 92 Midwestern species. The highest concentration levels of natural rubber occurred in the family *Asclepiadaceae*, the milkweeds. The species analyzed were Common Milkweed (*Asclepias syriaca* L.), Swamp Milkweed (*A. incarnata* L.), Whorled Milkweed (*A. verticillata* L.) and Butterfly Weed (*A. tuberosa* L.). Common milkweed (*A. syriaca* L.), the largest of the milkweeds, contained the most rubber.

Twenty-one species of the midwestern plants analyzed contained more than 1% hydrocarbon (Table 4).

Pale Indian Plantain (*Cacalia atriplicifolia* L.) had the highest percentage of hydrocarbon. Also the seed oil contains dammarenediol II esters (Spencer 1981). This species grows well in sand and in prairie soil and is widely distributed east of the Mississippi River.

Wild Bergamot (*Monarda fistulosa* L.) was an outstanding rubber-producing plant, having a large amount of high-quality rubber. Abandoned fields colonized by Wild Bergamot indicate it could be grown like hay.

Natural rubber is found also in Compass Plant (*Silphium laciniatum* L.), Giant Ragweed (*Ambrosia trifida* L.), Sow Thistle (*Sonchus arvensis* L.), Common Elder (*Sambucus canadensis* L.), Indian Hemp (*Apocynum cannabinum* L.), New England Aster (*Aster novae-angliae* L.) and Stiff Goldenrod (*Solidago rigida* L.).

Tall Bellflower (*Campanula americana* L.) in addition to high natural rubber content is high in oil and protein.

Pokeweed (*Phytolacca americana* L.) contains more than 15% protein.

Sassafras [(*Sassafras albidum* (Nutt.) Nees] is high in oil and grows rapidly even on poor soil.

Our survey indicates that many midwestern plants have potential as future crops. Hydrocarbon crops that also produce fiber, oil, and protein can be developed. The analyses indicate that a common weed, toothed spurge (*Euphorbia dentata* Michx.), as it is today, could produce more oil and protein per specified area than soybeans or alfalfa. This spurge can produce 649 kg/ha/yr of oil and 1,223 kg/ha/yr of protein, whereas soybeans yield 347 kg/ha/yr of oil and 743 kg/ha/yr of protein, and alfalfa 148 kg/ha/yr oil and 1,096 kg/ha/yr, respectively (Buchanan, 1978). Although it may have toxic properties, since many plants of the Euphorbiaceae do, it could still serve as an energy crop. Perhaps the protein could be isolated from the toxins, or the toxins might be removed from the plants through breeding.

Factors to Consider in Developing New Crops

Many factors must be considered when developing a new crop. Some of these are shown in Table 5. Large plants would be better than small ones, because more material could be produced on an equivalent amount of ground. Upright plants are easier to harvest than mat types or vines. A mesic habitat is easier to work than either wet or very dry habitats. Plants that thrive in various types of soil lend themselves to wider geographical distribution. The higher the concentration of the end-product in the plant or its components, the more useful it should be. Sometimes fertilizers or other chemical treatment can increase a desired component in a crop plant. Yokahama has found that chemical stimulants can increase rubber content in plants two- to sixfold (Anonymous, 1977).

Seed germination may require certain special conditions, such as a cold period for a certain length of time before germination. In some species, such as sunflower and milkweed, components naturally present in the seed or seed coat may hinder germination or kill the seedlings. Allelopathic properties may have to be considered for some species. Often there is more genetic variability in a wild species than in a cultivated one.

Methods of processing the material and utilization of the by-products are necessary. We will have to learn whether these plants have diseases and insect pests when grown as crops. Here in Illinois, the Common Milkweed (*Asclepias syriaca* L.) appears to be a healthy species without serious insect pests, even though many kinds of insects visit it. However, there may be serious problems when the species is grown in monoculture or in a different part of the country. Dr. Yokahama from California obtained seeds and plants of Common Milkweed (*A. syriaca* L.) from us in early spring. He grew them and found that California insects liked this species so much that he was unable to raise enough material for his research.

Another problem in developing a new crop from local plants will be convincing farmers that they should grow species now considered weeds on which much time and many dollars have been spent for eradication. Whether these plants will grow as well in cultivation as they do in the wild remains to be seen.

FUTURE RESEARCH

Much research will have to be done before some of our wild plants can be grown as profitable crops (see Table 6). Agronomic research on all phases of crop

production is required (planting, cultivating, fertilizing, harvesting). Diseases and insect pests must be determined and methods of controlling these must be found.

Genetic research will be necessary: (1) to produce plants of uniform size that will mature at the same time, (2) to increase the concentration of the desired products, (3) to develop resistance to diseases and insect pests.

Other areas of research required include transportation, storage, processing, and by-product and end-product utilization.

SUMMARY

Since 1975, more than 600 species of plants have been collected to search for sources of hydrocarbons, especially natural rubber and wax. Of these species, 515 representing 86 families and 288 genera have been analyzed. All species contained hydrocarbons. Many of those species with high hydrocarbon content, especially natural rubber, have characteristics that make them suitable for future crops. Some of the more promising common weeds appear, indeed, to be good prospects for new crops. However, many factors must be considered in developing these species as crops, and a vast amount of research needs to be done in many areas before these plants can become profitable crops.

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Table 1. Botanical Rating

Parameter	Rating				
	1	2	3	4	5
Temperature requirement	Zone 1-2-3	4-5	6-7	8-10	Tropical
Moisture requirement	Mesic	Mesic	Subxeric	Xeric, marsh	Aquatic
Growth rate, m	> 1.5	1.0-1.5	0.5-1.0	< 0.5	---
Plant habit	Tall upright	Short upright	Mat, prostrate	Vines, ^{a)} etc.	Epiphytes and parasites
Adaptability to pollarding	Multiple annually	Once annually	No	---	---

^{a)}Includes vines, marsh plants, rosette forming plants, low-growing succulants, and sod-forming grasses.

Table 2. Rating of Plant Species According to Their Composition

Component	Rank			
	1	2	3	4
Fiber	Suitable for fiber, paper or board	Not suitable for making fiber, paper or board products	---	---
Crude protein	> 14%	< 14%	---	---
Oil fraction	> 8%	5-8%	2-5%	< 2%
Hydrocarbon fraction	> 2%	1.2-2.0%	0.4-1.2%	< 0.4%

Table 3. Midwest Plant Families With Most Hydrocarbon-Producing Species
(First 300 midwest species analyzed)

Family	Species analyzed	Number of species with natural rubber and/or wax	Percent of species showing promising results
Asclepiadaceae	11	10	90.9
Caprifoliaceae	8	7	87.5
Apocynaceae	4	3	75.0
Labiatae	34	21	61.7
Euphorbiaceae	17	10	58.8
Compositae	85	49	57.6
Gramineae	29	9	31.0

Table 4. Midwest Species Containing More Than 1% Hydrocarbons

Scientific name	Common name	Percentage
<i>Cacalia atriplicifolia</i> L.	Pale Indian Plantain	3.10
<i>Asclepias tuberosa</i> L.	Butterfly Weed	2.54
<i>Agropyron repens</i> (L.) Beauv	Quack Grass	1.72
<i>Lonicera tatarica</i> L.	Tartarian Honeysuckle	1.68
<i>Asclepias syriaca</i> L.	Common Milkweed	1.59
<i>Humulus japonicus</i> Sieb. and Zucc.	Japanese Hop	1.53
<i>Teucrium canadense</i> L.	American Germander	1.44
<i>Solidago graminifolia</i> (L.) Salisb.	Grass-leaved Goldenrod	1.43
<i>Artemisia vulgaris</i> L.	Common Mugwort	1.41
<i>Solidago rigida</i> L.	Stiff Goldenrod	1.39
<i>Triosteum perfoliatum</i> L.	Tinker's Weed	1.33
<i>Aster laevis</i> L.	Smooth Aster	1.31
<i>Elymus canadensis</i> L.	Wild Rye	1.28
<i>Pycnanthemum incanum</i> (L.) Michx.	Hoary Mountain Mint	1.24
<i>Lippia lanceolata</i> Michx.	Fog-fruit	1.24
<i>Phalaris canariensis</i> L.	Canary Grass	1.22
<i>Rudbeckia subtomentosa</i> Pursh.	Sweet Coneflower	1.22
<i>Monarda fistulosa</i> L.	Wild Bergamot	1.15
<i>Monarda punctata</i> L.	Horsemint	1.15
<i>Elaeagnus multiflora</i> Thunb.	Cherry Elaeagnus	1.13
<i>Apocynum cannabinum</i> L.	Indian Hemp	1.01

Table 5. Factors to Consider When Developing a New Crop

Plant size	Effect of chemical stimulation
Plant habit	on desired product
Type of habitat	Germination of seed
Type of soil	Genetic variability
Annual, biennial, or perennial	Processing
Density of stand	By-product utilization
Effect of fertilizers	Diseases
Concentration of end product	Insect pests
in plant or its components	Convincing farmers to grow the crop

Table 6. Research Needed

<i>Agronomy</i> All phases of crop production	
<i>Genetics</i>	<i>Other</i>
Evaluation of genetic variability	Transportation
Concentration of desired products	Storage
Uniform maturity	Processing
Plant habit	End product utilization
Disease resistance	By-product utilization
Insect resistance	Chemistry