SELECTING WESTERN U.S. SPECIES FOR THE PRODUCTION OF LIQUID FUELS AND CHEMICAL FEEDSTOCKS

by

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ABSTRACT

As part of our research program on new phytochemical crops, we are examining several selection criteria which specifically apply to species for arid and semi-arid lands. The selection criteria are: yield (biomass yield x phytochemical yield); life cycle (annual, biennial, perennial); habit; range of adaptability; breedability; natural genetic variability; major products and co-products; toxicity; competitiveness; disease and pest problems; previous agronomic research available; and water use efficiency on marginal lands. These criteria are applied to several leading contender phytochemical species (gopherweed, milkweed, guayule, and jojoba) to demonstrate the utility of this approach. In general, it has been found that constraints encountered in the agronomic and biological attributes are more important than phytochemical yields per se.

It has now been shown for several species that non-polar hydrocarbons can be converted to liquid fuels by catalysts (Adams, 1982; Haag, Rodewald, and Weisz, 1980). However, at the current price of petroleum ($30/bbl, 9¢/lb), the economics for the production of fuel only is not promising (Adams, 1983). However, the use of plant chemicals (phytochemicals) as industrial feedstocks can present a very favorable scenario (Adams, 1983; Princen, 1982). This change in focus led us to examine several factors in the search for new phytochemical crops. The first factor to be considered is yield (biomass x product(s)). Although the goal of plant screening is to discover promising species for future research and development, the process also results in eliminating 99% (or more) of the species from further consideration at this time. Each of the four phytochemical crops (Table 1) are ranked as medium to high for yield. However, as previously mentioned, conversion to phytochemicals to liquid fuel is of much less interest than the utilization for renewable chemicals. The products of the four species ranged in value from 6¢-9¢/lb (gopherweed, sugars and HC) to $7/lb (jojoba oil). Life cycle has much to do with the farming costs. Annuals require seeding and generally considerable cultivation but can be rotated and weeds may be controlled in the off-season. Perennials are frequently difficult to establish but may be long-lived, saving annual seeding costs. However, the year-round growth/persistence may necessitate the

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use of herbicides for weed control and/or a build-up of pests in the field. In arid and semi-arid lands, perennials will likely be preferred because stand establishment is generally difficult and year-round cover is desirable to prevent soil erosion. The habit is important in determining the kind of farming equipment that can be used. A perennial forb appears to be preferable if the entire plant is to be harvested (e.g., milkweed, gopherweed). The range of adaptation is a severe limitation for guayule and jojoba. Frost areas of the southwestern U.S. are premium lands for citrus and other tropical crops where adequate water is available. In general, very little agronomic research is available for phytochemical crops. Considerable research has been done on guayule and jojoba but nothing compared to traditional crops such as corn and wheat. One potential new phytochemical crop is sunflower (whole-plant utilization, Adams and Seiler, 1983), for which a considerable amount of research has been done (at least on Helianthus annuus). The method and difficulty of crop establishment is an important factor to be considered. Direct seeding is cheaper for herbaceous crops, but transplants may be preferred for woody long-lived perennials (such as jojoba). Many of the Asteraceae present considerable difficulty in that seeds are very small and therefore the proper soil moisture conditions (a long, wet cycle) happens very infrequently in arid lands. Irrigation water may not be available, nor cost-effective to establish the crop. Milkweed and guayule both have limitations in this category. Competitiveness is difficult to assess in nature as persistence of a species may be of greater evolutionary importance than close-cover stands which crowd out competitors. However, in many of the phytochemical crops we will need aggressive species that form close-cover to crowd out undesirable competitors. This would reduce the need for cultivation and/or herbicides, making the crop less expensive to grow. Water use efficiency is of particular concern in the western U.S. where the competition between urbanization and agriculture is expected to become even more intense. Since water is generally the limiting factor for biomass growth in most of the semi-arid and arid lands, drought tolerant species and species that are very efficient in water use are of special interest. Disease and pest resistance can veto the use of some species as has been the case with gopherweed which is highly susceptible to charcoal root rot and no resistance has been found (Kingsolver, 1982). Breedability may be a significant factor, particularly if the plants only reproduce by apomixis. Having a large pool of genetic variation within a species from which breeding selections can be made and having several interfertile related species gives the breeder considerable opportunity. Some species are mono-typic,others represent isolated, relictural, endemic species that would present only a limited opportunity for breeding. Toxicity can severely limit options for biomass refining when the residue is intended for use as livestock feed or human food. Gopherweed contains the co-carcinogen, ingenol-3-hexadecanoate, which could present a serious health hazard in cultivation, harvesting and processing. In fact, each of the four taxa contain toxic compounds: gopherweed - co-carcinogen; milkweed - cardiac glycosides; guayule - allergins; jojoba - simmondsin. Harvesting methods will vary from using traditional swathing and baling to the development of new equipment for seed picking (jojoba). If processing/extraction facilities are to be used most economically, year-round processing is needed. Storage of plant material may result in the loss of volatiles, resinfication, oxidation, polymerization, and degradation. Many phytochemicals are stable if the plants are not ground and kept dry. Storage of guayule may best be accomplished in the living plant by harvesting strips of land throughout the year as needed. The extraction technology has been generally patterned after commercial solvent (oil seed) facilities. Supercritical extraction may prove to be much more economical if new facilities are constructed. Markets for most of the phytochemicals have not been surveyed. Many will have to be completely developed. Products that have no current market or have extremely small markets will likely veto the domestication of many species. Consumer acceptance can be subdivided into two categories: farmer and buyer. The farmer may be reluctant to grow "weeds" that he knows nothing about and may fear (with reason) the possible spread into traditional crops.

SUMMARY

Comparisons among four taxa currently being considered/developed for phytochemicals showed their strengths and weaknesses for 18 different criteria. This list could be greatly expanded, particularly in the markets area. It is anticipated that this or a similar framework will be useful as species are evaluated for the domestication of new phytochemical crops.

Literature Cited

Adams, R.P. 1983. Chemicals from arid/semi-arid land plants: whole plant utilization of milkweeds. In Assessment of Plant Extracts. Office of Technology Assessment Publ. (in press).

Adams, R.P. 1982. Production of liquid fuels and chemical feedstock from milkweed. In Energy from Biomass and Wastes VI. D.L. Klass (ed.). pp. 1113-1128. Instit. Gas Tech. Symp. Proc.

Adams, R.P. and G.J. Seiler. 1983. Whole plant utilization of sunflowers. Biomass (submitted).

Haag, W.O., P.G. Rodewald, and P.B. Weisz. 1980. Catalytic production of aromatics and olefins from plant materials. Symposium on alternative feedstocks for petrochemicals. Amer. Chem. Soc. Meeting. Las Vegas, NV, August 24-25.

Kingsolver, B.E. 1982. *Euphorbia lathyris* reconsidered: its potential as an energy crop for arid lands. Biomass 2: 281-298.

Princen, L.A. 1982. Alternate industrial feedstocks from agriculture. Econ. Bot. 36: 302-312.

Table 1. Selection Criteria Applied to Four Potential Phytochemical Crops.

	Gopherweed	Milkweed	Guayule	Jojoba
Yield (biomass x product	med/high	medium	med/high	medium
Products	HC, sugar	HC, specialty chemicals	rubber, resin	oil/wax
Life cycle	biennial	perennial	perennial	perennial
Habit	forb	forb	shrub	shrub-tree
Range of adaptation	frost tol. to -10°F, semi-arid	temperate, semi-arid	frost sensitive, arid, semi-arid	frost sensitive, arid
Previous agronomic research available	some	little	considerable	considerable
Crop establishment:				
Direct seeding	easy	variable	difficult	easy w/ irrig.
Transplants	N.A.	N.A.	preferred	preferred
Competitiveness	poor	fair	fair/var.	fair/var.
Water use efficiency	poor	fair	good/exc.	excellent
Disease and pest resistance	unacceptable	good	exc./var.	excellent
Breedability	good	poor	good	good
Genetic variation	fair	fair	good/fair	good
Toxicity	co-carcinogens allergens	toxic	allergens	toxic
Harvesting	swath/bale	swath/bale	special. swath/bale	hand/mech. pickers
Storage	rel. stable (?)	rel. stable	some oxidation	stable
Extraction tech.	oil seed & dev.	oil seed & dev.	solvent & dev.	oil seed
Markets	needs dev.	needs dev.	avail/dev.	avail/expand
Consumer acceptance:				
Farmer	problem	problem	fair	good
Buyer	poss. problem	poss. prob.	good	excellent