# Overview of Alternative & Industrial Crop Research, 2008-2014

## Oregon State University- Klamath Basin Research & Extension Center (KBREC)

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### Introduction

The agronomy research program at OSU-KBREC has several objectives. We continue to test traditional crops such as small grains (wheat and barley), forages (alfalfa and grass hay), new forage and niche grain crops (i.e. teff), and crop production practices for these crops (i.e. conventional and organic soil fertility methods), evaluating new varieties and production practices that can help increase yield and quality, or reduce inputs (or both) with the goal of increased grower profitability while maintaining a healthy environment.

***However, with the constant threat of reduced water availability, as well as the limited current choice of crops due to weather limitations, we are also always on the lookout for opportunities to test and develop new industrial (non-food) crops that will meet one or more of the following criteria:***

- Will this crop reduce our dependence on foreign oil or other imported raw materials?
- Will this crop grow well on less fertile lands with less irrigation? Developing new crops that can be grown with minimal irrigation on less-productive soils could reduce competition for space on the Bureau of Reclamation project lands where high value, high input, irrigated crops are currently grown.
- Can the crop be processed into high-value, biobased end-products?
- Can the crop be grown and processed with existing farm equipment?
- Will the crop fit into, and provide a positive benefit to, existing crop rotations?

Almost always, these plants are not currently grown as crops elsewhere, or are grown only in limited situations, and require agronomic research to move them from the status of "interesting botanical curiosities" to becoming a viable crop choice.

Key points about this type of research are:

- "New Crop" research is not funded by commodity groups.
- Rarely does agronomic research on such crops qualify for the normal federal US Dept. of Agriculture competitive grant programs.
- Most work has been done using base funds for faculty and staff time through federal formula Hatch funds and recurring state appropriations. Occasionally, small grants have been obtained. As such, this type of research often progresses in "fits and starts".
- Only very recently have competitive grants from US Dept. of Energy, US Dept of Transportation, or the Sun Grant program become more available for industrial crop research.
- Cooperation is essential to move from "novel plant" status to a crop with proven ability to be grown, processed, and sold as a competitive end-product. We routinely cooperate with the USDA-ARS-NCAUR lab in Peoria IL, Ohio State University, other USDA labs and universities, and private industry

whenever possible to conduct research on chemical and physical processing of the raw material, as well as ultimate product development.

A brief overview of our efforts is described in this handout. Please refer to each year's annual research report for details on each set of experiments.

## Euphorbia

Background

In the late 1950s and early 1960s the USDA analyzed many plant species in a search for novel chemical compounds. They first recognized that *Euphorbia lagascae* was unique among the 58 euphorbs tested (and almost unique among all plants) in that the seed oil contained high levels of vernolic acid, an epoxidized fatty acid of great interest to the paint and coating industry as a drying solvent in alkyd resin paints. Paint made with vernolic acid emits very low levels of volatile organic compound air pollutants compared to standard alkyd resin paints. Euphorbia is a drought-tolerant native of Spain whose seed contains about 45%-50% oil, of which 60%-65% is vernolic acid.

Breeding and agronomic research was hindered until the mid 1990s because all known populations had a violent seed shattering habit, making it very difficult to harvest. At that time, chemically induced, non-shattering mutants were developed in Spain and we conducted research at the Oregon State University- Southern Oregon Research & Extension Center (SOREC) in Medford, OR for several years in the late 1990s. Since 2007, renewed interest by industry has led to new research on this potential crop.

Current Research

Research began at KBREC in 2008 and is focused on understanding euphorbia's response to differences in planting date, irrigation rate, nitrogen fertilization, plant density, seed type, cultivar, and herbicide tolerance. In 2008, 2010, and 2011 these trials were duplicated at two locations to compare responses in two dramatically different climates (Medford and Klamath Falls, OR). Excess seed from these trials was supplied to USDA-ARS-NCAUR lab for chemical processing experiments.

Future Prospects

Euphorbia seems to require a long season for maximum seed production. It has appeared to be very tolerant to drought and heat, although seed yield is reduced under completely non-irrigated conditions. Likely areas for production include much of the western U.S. and other hot, dry regions. It should compete well in situations where irrigation water is expensive or unavailable.

*Like most of the other alternative crops described in this summary, the ability to grow euphorbia under minimal irrigation on less-productive soils could also help reduce water use conflicts since it would not need to compete for space on the highly fertile Bureau of Reclamation project lands.*

## Russian Dandelion for Rubber

Background

Virtually all commercial natural rubber comes from a single species, the Brazilian rubber tree (*Hevea brasiliensis*), which grows only in the tropics. Despite decades of effort by the chemical industry, no synthetic substitute has been developed that can match the properties of natural rubber. High performance applications such as aircraft tires, heavy truck tires, and certain medical devices are absolutely dependent on natural rubber to meet performance requirements. Natural rubber is classified as a strategic material by the US government: ***Modern aircraft simply cannot land safely on tires made from synthetic rubber.***

The United States is currently the world's largest consumer of natural rubber and is completely dependent on imports from tropical sources. Five countries (Thailand, Malaysia, Indonesia, Vietnam, and China) control about 90% of the world's natural rubber exports. World economic growth since 2000 (especially in China and India) has increased demand, increasing rubber prices more than fourfold. Because rubber trees take many years to come into full production after planting, the problem is exacerbated by the inability of the natural rubber industry to rapidly increase supply in response to rapid growth in demand. The price of things like passenger car tires is also influenced by the price of petroleum, as car tires are made from a mixture of natural rubber and synthetic (petroleum based) rubber.

In the 1930's Soviet scientists identified Russian dandelion (*Taraxacum kok-saghyz* or TKS), a species native to Kazakhstan, as the most promising source of natural rubber that could be grown within the borders of the former Soviet Union. In the wild state, individual plant roots typically only contain about 2-3% rubber on a dry weight basis, but it was found that certain individual plants contain much more. The latex is easily extracted from the roots using simple technology. The byproducts of rubber extraction from TKS roots are soluble carbohydrates (primarily inulin) and lignocellulosic bagasse. These can be converted into biofuels, or the inulin can be sold directly into the nutritional supplement market, where it is currently selling for about $1.00/lb.  Prior to and during World War II the Soviet Union cultivated Russian dandelion as a primary source of natural rubber and also produced commercial quantities of ethanol from TKS carbohydrate byproducts.

During World War II, when the natural rubber plantations in SE Asia were cut off from the US, the USDA Bureau of Plant Industry conducted extensive trials of Russian dandelion as part of the wartime Emergency Rubber Project and concluded that it had excellent potential to become a domestic source of natural rubber and ethanol that could be grown in many parts of the United States. Enough rubber was produced in these trials to allow commercial scale testing of TKS rubber in tires. Russian dandelion rubber was found to be equal in performance to Brazilian rubber tree (*Hevea)* rubber, a conclusion confirmed in recent testing using small samples at USDA labs and commercial tire companies. Of the dozens of sites where TKS was tested, one of the best WWII sites was near Klamath Falls, OR. Unfortunately, work with this species was discontinued after the war when access to supplies of *Hevea* rubber was restored and synthetic rubber was developed that could be made from then-abundant and inexpensive petroleum.

Russian dandelion combines the essential qualities of wide adaptation to temperate growing conditions and broad genetic diversity. Thanks to the work of Russian and American scientists prior to and during WWII, we have a head start towards understanding this plant's cropping and rubber extraction requirements. With additional research and development effort, this species could provide a renewable source of natural rubber and byproducts from an annual crop that can be grown in many parts of the temperate climatic zone in the US.

The excellent WWII results in Klamath Falls, combined with the existing farmer expertise in growing root crops such as potatoes, sugar beets, and onions, combine to make the Klamath Basin a likely commercial production site for domestically-produced, high quality, natural rubber. In addition, development of seed production and processing technologies are required if TKS is to be grown on a commercial scale. Oregon State University expertise is well-suited to analyze such topics, and Oregon's seed production industry is already well-developed.

Current Research

Attempts have been made since 2005 to secure funding for various aspects of TKS development including wild plant seed collection, agronomy, plant breeding, and rubber extraction/processing research, combining efforts of Oregon State Univ., Ohio St. Univ., Univ. of Akron, USDA-ARS, Ontario Ministry of Agriculture, existing major tire companies, and others operating under the "Program for Excellence in Natural Rubber Alternatives" consortium (PENRA). Cooperation has been good, while funding success has been intermittent. Several major rubber companies have expressed interest in purchasing TKS rubber from a domestic source and have recently provided small funding levels towards this goal. Various grant programs within the state of Ohio as well as federal grants have supported increased plant breeding efforts there since 2008, and Ohio State has developed improved cultivars of TKS that soon will be tested in Oregon. Oregon State cooperated in the initial selection of superior plant types from among 79,000 TKS seedlings that were grown in Corvallis and Klamath Falls from seed collected in Kazakhstan. Superior plants from this wild seed were used as the base material for the ongoing plant breeding efforts. Recently, we and cooperators in Ohio and Canada have made selections of roots having over 12% rubber by weight.

The sudden death of Oregon State's project leader Daryl Ehrensing in August 2009 caused a major disruption in the project. Promising material from Daryl's testing in Corvallis was transferred to Klamath Falls, and the focus of Oregon State's portion of the research has gradually shifted to coincide with the expertise and facilities in Klamath Falls.

Future Prospects

Dr. Roseberg was successful in obtaining significant new Sun Grant funding (US Dept. of Transportation) to expand TKS crop production research starting in 2012. This funding should allow us to examine and help solve several vexing problems regarding seed germination, planting and harvest timing and methods, and related crop production issues that have been problems in Oregon, Ohio, and elsewhere. We will also continue evaluation of improved cultivars in cooperation with Ohio State. If these multi-institutional efforts succeed, Russian dandelion has a great potential to become a new domestic source of high quality rubber that would also further increase farmer's crop options in the Klamath Basin and elsewhere in the US.

## Grindelia

Background

Resinous compounds known as "Naval Stores" were once used to caulk wooden ships, but now these compounds (including turpentine, fatty acids, rosins, and their derivatives) are now used in large quantities by the papermaking industry. These resins are incorporated into the liquid pulp or as a coating on the finished paper to improve color brilliance and ink permanence, while eliminating ink "bleeding". These compounds are also used in smaller amounts for producing rubber, chemicals, ester gums, and resins for many other specialty applications (i.e. rosin used on baseball bats and violin bows).

The primary current source for these resinous compounds is tapping old-growth pine trees, or by grinding up their stumps after logging. The complex chemical structure of these resin compounds cannot be synthesized from petroleum or other simple oils. US consumption of these resins was fairly static from the 1960s until the 1990s at about 500,000 Ton/yr, but has increased in recent years due to increased demand for quality paper used in ink-jet, laser-jet, and copier applications. Increased use of recycled paper in paper manufacturing has also increased demand for these resins.

U.S. production (which once met the demand) has nearly disappeared. In recent years, this need has been met by increased imports of resin collected from trees and stumps in China, Brazil, and nearby countries. These supplies are potentially unreliable and expensive. About 60% of the world resin comes from tapping live trees, and 70% of that market is controlled by China. The price of resin has ranged between $0.27 and $0.55/lb in recent years, with a general upward demand trend.

In the early 1980s, it was discovered that *Grindelia camporum* and related species produce large quantities of a valuable resin (grindelic acid) that is nearly identical to the high quality resins from pine trees. *G. camporum* received more initial interest than other species due to its greater size. *G. camporum* is a perennial, grows under non-irrigated conditions in its native habitat of California's Central Valley, and thus may be suited to less productive, non-irrigated lands. However, virtually no crop research was done on it between the few early studies in the mid 1980s and Dr. Roseberg's preliminary studies in the mid 1990s.

Current Research

Small grants and base funds supported small studies in the mid to late 1990s at OSU-SOREC (Medford), where we looked at how factors such as soil type, irrigation amount, seed germination methods, and harvest methods affected final resin yield. In 1999-2001 we also cooperated with Dr. Damien Ravetta of the Universidad de Buenos Aires (Argentina) to look at a South American species (*Grindelia chiloensis*) that also produces this resin. No further research occurred in the US until 2010, when we received another small grant to resume studies through 2011 under the very different climate conditions found at KBREC. The South-Central Oregon region may be better suited to grindelia cropping because it is sunnier, yet cooler than the Rogue Valley or California's central valley, but winter survival may be more of an issue in the Klamath Basin.

Future Prospects

Due to reasons of weather and labor markets, China is unlikely to be able to rapidly increase their resin output when global markets rebound, pointing towards likely upward resin price pressure in the future. Looking to the future, chemical companies have shown an increased interest in developing a stable, domestic source of these resins.

Dr. Ravetta has continued with cultivar selection and improvement in Argentina, and now has several lines that appear more promising than those available in the late 1990s. He has also continued work on crop management aspects, such as N fertilization, air temperature, water use, and related factors. However, other crop management practices such as plant density, irrigation, multi-year management, etc. still need to be worked out for both *G. chiloensis* and *G. camporum*. Dr. Ravetta is willing to continue cooperation with KBREC- a potentially huge benefit to Oregon agriculture.

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## Oilseeds for Biofuel
(Canola & Camelina)

Background

The recent political instability in the Middle East and large fluctuations in fuel prices have led to renewed interest in renewable bio-fuels from many sources. Biodiesel can be made from simple seed oils, including crops that are better adapted to our cooler climate such as canola and camelina.

Canola (*Brassica napus* and *B. rapa*) is a type of industrial rapeseed that was bred in Canada in the 1970s to have improved edible oil properties. Canola and industrial rapeseed are excellent sources of raw oil, as the seed yields can be high and the seeds each contain 35-40% oil by weight. However, to achieve high production canola requires fairly high inputs of fertilizer and irrigation in our region.

Camelina (*Camelina sativa*) is an ancient crop (grown as far back as 1000 BC) that was later used extensively as a source of edible oil and lantern oil for lighting in Eastern Europe in the middle ages. Its use decreased with the increased use of olive oil from southern Europe for these purposes, and later still it nearly disappeared as a crop with the advent of petroleum-based oils and then electric lighting in the 20th century.

Camelina is of interest for dietary reasons due to its unusually high levels of Omega-3 fatty acids. It is of interest for biodiesel production because it seems to grow well in conditions of relatively poor soil, low fertility, and low moisture availability. Its seed contains 30-35% oil by weight, and while seed yields are less than canola under ideal (high input) growing conditions, canola and camelina yields may be similar under more stressful conditions. Both canola and camelina have been reported to exhibit some natural pesticidal properties in the following crop, which could potentially reduce costs of chemical weed or nematode control in the crop planted following the oilseed crop.

Current Research

We found no evidence of oilseed-to-biodiesel research or commercialization efforts in the arid south central Oregon plateau, including the Klamath Basin, prior to 2005. Much of this region has irrigation water available, and oilseed crops that are suited to a cooler climate such as canola, industrial rapeseed, mustards, and camelina seem to have a possible fit in rotation with existing crops such as potatoes, alfalfa hay, and small grains.

Starting in 2006, we have evaluated the seed yield potential of several public and private varieties of spring-planted canola, rapeseed, mustard, and camelina under a range of Klamath Basin growing conditions. We have examined response to differing soil types, amounts of irrigation, and both fall and spring planting dates for both canola and camelina. In 2010-2012 our canola efforts were funded by a grant from the PNW Canola Research program (USDA).

Future Prospects

A commercial biodiesel production facility is currently in operation south of Klamath Falls, and private companies have been scouting for contracts in this area, but high grain prices for most of the time period since 2007 led growers to plant wheat and barley instead of the more speculative canola and camelina. Based on our research information, a commercial 25-acre field of camelina was grown in the Rogue Valley (Medford) in 2008 with good results, and other small test plantings in south-central Oregon were also reported each year since 2009. If camelina proves to be well adapted to poorer growing conditions, it may be a viable oilseed crop on the less valuable, marginally irrigated lands; thus it would not have to compete directly with higher value, more intensively farmed food crops in this area.

## Prior Research Efforts

In the past we have worked on a number of different new industrial crops in southern Oregon's Rogue Valley. Some have good potential; others do not fit the region's climate or current market demands.

**Lesquerella**: *Lesquerella fendleri* is a native of the SW US and Mexico. Its seed oil is high in hydroxy fatty acids (HFAs), which are used to make high performance greases. HFAs are classed as a strategic material due to their use by the US military. It will grow in SW Oregon, but seed yields are lower than when grown in Arizona.

**Hesperaloe:** *Hesperaloe funifera* is also native to the SW US and Mexico. It produces a very long, thin, strong fiber suitable to make thin, strong specialty paper (paper currency, bibles, etc.). It will grow in SW Oregon, but fiber yields are lower than when grown in Arizona or Mexico.

**Cuphea:** *Cuphea viscosisima* and related species produces seed oils containing medium-chain fatty acids that are useful in soaps, cosmetics, and lubricants, and could replace tropical oils such as palm kernel oil. It grew and produced reasonable seed yields in SW Oregon, but seems to do well in slightly cooler, more humid climates.

**Meadowfoam**: Species of the *Limnanthes* genus have been domesticated and are a current, small acreage crop in Oregon's Willamette Valley. Our testing confirmed that meadowfoam prefers that climate to those in southern Oregon, northern California, or western Washington.

**Miscanthus, Bamboo,** and **Hybrid Poplar:** We tested these plants as potential fiber crops that could be irrigated with non-potable water such as treated effluent from sewage treatment plants. All grew well and had potential in SW Oregon. The lifting of the ban on imported fresh bamboo shoots greatly damaged the regional fresh edible bamboo shoot market. In recent years bamboo flooring products have become more readily available, made from imported bamboo.

**Iranian Poppy**: *Papaver bracteatum* grew well in SW Oregon, and testing by a pharmaceutical company showed it had potential to produce a pain reliever that could replace the Asian poppy-based pain relievers (raw material for morphine and codeine). Iranian poppy is safer in commerce, since its raw material is not easily converted to morphine or heroin.

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