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Program Abstracts

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PLENARY SESSION

U.S. AGRICULTURE AND NATIONAL SECURITY

R. James Woolsey

Shea & Gardner
(Director, CIA, Retired)

AGRICULTURE AND THE BIO-BASED ECONOMY

Ralph W. F. Hardy

National Agriculture Biotechnology Council

INTERNATIONAL NEW CROP DEVELOPMENT INCENTIVES, BARRIERS, PROCESSES, AND PROGRESS: AN AUSTRALIAN PERSPECTIVE

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Recent Australian crop production in some areas has not been as profitable as local producers may have wished. Advisory and support personnel have responded to producers' concerns by trying to make the current rural enterprises more efficient. Alternatively, some producers have chosen to pursue their own commercial futures through diversification of their farming systems with new crop (or animal or aquaculture) industries. A new crop can be defined as a crop that has not previously been commercially successful in an area. How does one choose a new crop for research and development? The objective of this review is to describe some recently developed Australian processes aimed at answering this question, through market-focussed, industry involvement.

Incentives for new crop development range from personal motivation, community-based ideals and regionally-based needs to national imperatives. Personnel incentives for pursuing new crops have included attempts by producers to recover from (or avoid) financial crises, the pursuit of windfall profits, or the commercialization of a hobby. Such incentives distract attention from the ultimate purpose of any new rural business, which is to create value through satisfying the needs of the consumer. Regional or national funding initiatives can also have incentives other than value creation.

Barriers to the diversification of farming systems through new crops include the lack of reliable information about the available new crops options, the high risks inherent in establishing a supply chain for a new crop product and the long lag period before profits are forthcoming, if they come at all. The new processes developed in Australia assist with:

- Personal analyses of the role of new crop diversification (The 10 Steps for Planning),
- Community action (Diversification Workshops using the DOOR Marketing (Do Our Own Marketing Research) Approach and Networking) and
- New rural industry development (The 13 Steps for Commercialization of New Rural Industries).

The future viability of new crop enterprises cannot be predicted accurately. This is because marketing and economic factors are chaotic in their behavior. Instead, this new approach empowers the members of a new crop industry, such as producers, processors, agents, entrepreneurs, etc. to collectively focus their goals and to pursue them. Groups identify consumer needs, describe the new crop product, establish the components of their supply chain and then enter a commercial market, once appropriate benchmarks for their investment, growth, and returns have been set.

Such an approach encourages many new industry-driven niche industries, each of which can determine its own needs in terms of future research and development. Some of these new crop industries may eventually prove to be commercially significant over large areas. Trying to predict the latter has proven to be a waste of resources. In conclusion, a new crop industry's greatest resource is people.

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INTERACTIVE EUROPEAN NETWORK FOR INDUSTRIAL CROPS AND THEIR APPLICATIONS

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Whilst considerable data on crop species and their metabolites existed from both national and European Commission-funded studies, little collated or critical evidence existed on extract of markets or market specifications for non food crops in European Union.

The objective of the IENICA project was to correct the deficiency through a series of reports and technology transfer events supported by a website (http://www.csl.gov.uk/ienica).

Whilst coordination of the project was undertaken in UK, 14 EU member states were assessed by their national representatives in the IENICA project then individual reports collated centrally and presented on the website. Approaches were regulated through a structure and protocol.

Significant market opportunities for biorenewables were identified in the oils, fibres, carbohydrates and speciality product sector although degree of exploitation was variable between EU member states. Constraints were also identified and reported. Surprisingly it was concluded that industry was not necessarily keen to take up new products, and sometimes they were even unaware of the opportunities available to them.

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INTERNATIONAL NEW CROP DEVELOPMENT: INCENTIVES, BARRIERS, PROCESSES AND PROGRESS-THE CANADIAN EXPERIENCE

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Canadian agriculture is based upon the introduction and successful adaptation of crop species into various regions of the country. The catalyst for successful expansion of spring wheat production in the prairie region was the introduction and development of adapted germplasm and region-specific agronomic management strategies. The continued success of the canola industry was brought about by a multidisciplinary approach to creating a unique oilseed crop (through the elimination of erucic acid and glucosinolates from the seed) and involved biochemists, plant breeders, physiologists, pathologists, agronomists, nutritionists and a great diversity of other expertise. Canada has a strong history of identifying new crop opportunities, and putting together the necessary expertise to ensure both production and market success.

Crop diversification in Canadian agriculture is experiencing a time of growth and excitement. Chickpea area has increased dramatically in the past three years to 450,000+ ha. The production of both field pea (1,460,000 ha) and lentil (732,000 ha) has increased several fold in the last decade. The rapid expansion of these three crops makes Canada their largest global exporter. Canada is also the world’s largest exporter of mustard and canaryseed. This production is primarily based in the prairie provinces of western Canada (Saskatchewan, Alberta and Manitoba). In addition, the prairies have thriving dry bean and sunflower industries, plus developing activity in spice production (coriander, caraway) and essential oil crops (peppermint, spearmint). Many other potential alternate crop species (linola, fenugreek, low-THC hemp, borage and safflower) are in various stages of commercial research and development in western Canada. Other parts of Canada have been expanding production of ginseng, cranberry, and other crops with exciting value-added opportunities.

Canada’s diversification success has come about because of four major influences: (1) the need to diversify crop production in the face of large global surpluses in some of our primary crops; (2) Canada has a huge agricultural land area available with a diversity of climatic conditions for which suitable introduced crops can be found; (3) Canada’s primary producers are motivated, knowledgeable growers who have been willing to take on new challenges; and (4) the Canadian research community has developed focused, multidisciplinary programs to identify and develop new crops for Canada, which have strong market potential in collaboration with industry and commodity groups.

Many hurdles must be overcome for continued crop diversification in Canada. Research funding has been identified as a key to continued success (by both the federal and provincial governments), although the resources needed to make continued progress are still not adequate. Crop diversification still has to compete with research funding to established crops and struggles to find industry money to "match" public investment. Canada faces specific production issues as the area planted to some of these crops expands at an extraordinary rate. Markets continue to fluctuate as global competition increases. Global buyers need to understand that Canada is a long-term player in these markets, although Canada is now sometimes viewed as the "new kid on the block."

The past twenty years have seen a tremendous increase in crop diversification throughout Canada. Efforts are being intensified so that Canada can realize its full potential in both crop diversification and value-added processing of these "new" crops.

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ROUND TABLE DISCUSSION

POLICY ISSUES IN NEW CROPS AND NEW USES

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NEW CROPS: NEW FUELS

ETHANOL FROM CELLULOSE: A REVIEW

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In 1950, the United States produced one-half of the world's oil and historically has dominated world oil production. However, dominance has now shifted to the middle east where three-fourth of the world's oil reserves with two-third located in the Persian Gulf. Currently, over one-half of all oil used in the United States is imported and the amount of these imports exceeds all of Saudi Arabia's production. Approximately two-third of all petroleum in the United States is used for transportation purposes, which is essential for commerce, and the lifeblood of our economy. During Iraq's occupation of Kuwait, Iraq controlled one-third of the world's oil supply, making Americans keenly aware of our dependence and vulnerability.

Additionally, as the rest of the world strives for the American standard of living, energy use in developing countries has increased 250 percent in the past 25 years. This increase is expected to continue well into the future, meaning that the demand for ever-decreasing supplies will continue to grow, causing economic and political turmoil throughout the world.

Programs to promote ethanol production and use as a gasoline supplement or substitute have been part of the U.S. Department of Energy since its inception. In addition to being renewable and domestically produced, biomass sources are available wherever plants grow and organic wastes are generated.

Traditionally, U.S. ethanol production has focused on starch, and more specifically, corn grain feedstocks. The technology to produce ethanol using starch and sugar feedstocks is considered mature in the United States. However, these resources are in the human food chain, and therefore are relatively expensive, making cost-effective ethanol production difficult. For example, approximately 2.5 gallons of ethanol can be produced from a bushel of corn. If corn costs $2.50 per bushel (a reasonable average for U.S. conditions), then ethanol production cost for the feedstock alone is $1 per gallon. These conditions make cost-effective ethanol production from corn grain difficult without government incentives and byproduct sales.

Lignocellulosic feedstocks are more plentiful and not in the human food chain, and thus are less expensive. However, due to their chemical bonding and mix of C5 and C6 sugars and other reasons, these feedstocks are difficult to convert cost-effectively into ethanol. After almost 200 years of research, cost-effective technologies are on the horizon and several commercialization efforts are underway.

These technologies include acid and enzymatic processes followed by fermentation, thermochemical processes, and thermochemical processes followed by fermentation. All have advantages and disadvantages. Companies striving to commercialize these technologies are working with a variety of feedstocks and trying a variety of approaches. The first commercial ethanol-from-cellulose plants are projected to be online within two to five years.

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FEDERAL INITIATIVES IN BIOBASED PRODUCTS AND BIOENERGY

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In a systems approach, basic research moves to applied research and is then transferred to a commercial entity. Demonstration and market identification lead to commercialization. Market penetration is where the best ideas often falter. Push marketing--a company pays to promote products--is often not as effective as pull marketing. Federal mandates to "buy green," along with similar state and local programs, have the potential of using the $800 billion leverage of the U.S. governments (local, state, federal) to pull biobased products into the market and make companies manufacturing those products successful.

Executive Order 13101, Greening the Government Through Recycling and Waste Prevention, charged USDA with listing biobased products in the Federal Register by March 2000 and promoting biobased products to the federal procurement community. On August 13, 2000, a notice of intent to publish such a list with a request for public comment was printed in the Federal Register. It will be a definitive source of information on the makeup and size of the emerging biobased products and bioenergy industry and will provide a mechanism for tracking the growth of those industries.

With limited funding, USDA-ARS has developed a pilot biobased products web site (www.usda-biobasedproducts.net). Information on only three of thirteen categories of biobased industrial products is now on the site, but work continues.

Leading by example, in July Secretary Veneman announced that USDA agencies will use biodiesel and ethanol fuels in their fleet vehicles where practicable and reasonable in cost. The Department will request coordination in the following areas:

- All USDA diesel fuel storage tanks nationwide will be filled with blends of 20 percent (B20) or higher biodiesel fuel where practicable and reasonable in costs.
- All USDA-maintained gasoline fueling facilities will buy and use ethanol-blended fuels containing at least 10 percent domestically produced ethanol to the extent practicable, where the fuel is readily available, and reasonably priced compared with unleaded gasoline.

Current federal discussions about biobased products and bioenergy have created a favorable climate to increase funding for biobased products and bioenergy research as requested by the Administration.

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BIOFUELS: THE EUROPEAN EXPERIENCE

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Biofuels in Europe, as typified by European Union (EU-15), have been developing for more than a decade in both the solid and the liquid biofuels sector.

The drivers for development have been diverse and often unlinked although all combine to give new uses for land, agricultural crops, products or wastes. Considerable contribution to energy supplies can be made from forestry sources although the extent to which this occurs varies considerably from state to state.

EU-15 energy policies are developing and "white papers" have set targets for achievement. These have a specified "biomass" component as well as wind, water, photovoltaic, and other contributing components.

An examination of such proposals, allied to analysis of other EU-15 policies (e.g., Common Agricultural Policy) and overlaid by wide overarching protocols and concordats (e.g., Kyoto; WTO) will explain how the current European position has been arrived at and those developments which are likely to come from it.

It is to be noted that the regulatory/legislative systems in EU-15 run upon a two-tier system whereby the broad EU-15 regulation is implemented at member state level by national legislation.

Hence, the UK Energy Crops Scheme falls under European Council Regulations 1257/1999.

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MEDICINALS, AROMATICS, NUTRACEUTICALS

NEW AROMATIC ESSENTIAL OILS

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Aromatic oils extracted from plants have long been used in foods, flavorings, and fragrances. Plants which provide new and unique fragrances and aromas have potential for commercialization as new crops. In this context, a wide range of sub-Saharan African aromatic plants will be reviewed as potential new sources of essential oils, and the challenges in the commercialization of these plants will be discussed. Some of the selected plants include *Acorus calamus* (calamus), *Aframomum* spp., (Grains of Paradise), *Agathosma* spp. (buchu), *Artemisia afra* (African wormwood), *Cananga odorata* (Ylang ylang), *Cinnamomum camphora* (camphor tree, ravintsara), *Eriocephalus africanus* (wild African rosemary), *Eucalyptus citriodora*, *Helichrysum* spp. (helichrysum), *Lantana aromatica*, *Lippia japonica* (African fever tea), *Lippia multiflora* (Ghana bush tea), *Melaleuca viridiflora* (niauli), *Mentha* spp. (wild mint), *Mondia whitei*, *Ocimum* spp., *Pelargonium* spp., *Pteronia incana*, *Ravensara aromatica* (ravensara), *Salvia* spp., *Tarchonanthus camphoratus* (African wild camphor bush), *Valeriana capensis* (South African Cape valerian), *Xylopia aethiopica* (West African pepper), and *Zingiber officinale* (ginger).

The commercialization of new aromatic oils can also be targeted around the bioactivity of the extractable oils, and in this context the discovery of new uses and applications of the essential oils will further drive the research and development process. Essential oils with promising antimicrobial activity, antioxidant activity, and/or health-related properties will be presented.

A final consideration in the field of new aromatic essential oils is the potential impact of genetic engineering of aromatic plants, and its potential utility to both increase total essential oil production and/or to strategically alter aroma. As genes involved in the biosynthesis of aromatic compounds are being cloned, such genes are becoming available for the modification of targeted aroma profiles in other plants. This has exciting ramifications to increase the diversity and improve the aroma characteristics in our foods, herbs, ornamental, and floricultural plants.

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CHINESE MEDICINAL PLANTS

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Chinese medicinal plants have the potential to become an important, minor crop in the U.S. Public interest in oriental medicine appears to be increasing as the concept of using herbal remedies becomes more acceptable and legitimate for treatment of human ailments. Current imports of these plant materials from China, according to Chinese medicine practitioners, frequently lack the quality necessary for marketing in Western countries. Domestic production by U.S. growers offers the possibility of clean, quality plant material that could be directly marketed to practitioners and processors.

Preliminary evaluation of data indicates that many Chinese medicinal species (over 150 species have been tested) can grow well in North America. Indeed, many Chinese medicinal plants grown in China come from ecological zones similar to those of the U.S. Cultivation of these plants will depend on adapting culture of the plants to Western field conditions and to successful marketing of the plant materials. Practitioners of traditional Oriental medicine are trained to use a wide variety of medicinal plants combined according to established formulas. Processors develop formulas, which generally includes six to ten plant species, to be used by practitioners in developing a treatment for patients.

Although the traditions of cultivation, harvesting, and processing of Chinese botanicals are ancient and specific to each species of plant, no impediments to domestic productions in America or Europe are apparent. Many Chinese medicinal plants are similar to native American species and should acclimatize well to local environmental conditions. Some difficulty may arise because of the long term growth required for woodland species (10-15 % of Chinese medicinal plants), but these would probably be satisfactory for agriculture under orchard conditions.

While most Chinese medicinal plants have not been produced for the medicinal botanical market in the U.S., a number of these plants are grown as ornamentals and are commonly available in the nursery trade. Because a large number of the Chinese medicinal plants are perennials that appear to require few environmental inputs, the plants should be excellent candidates for ecologically beneficial, low maintenance specialty crops.

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FROM PHARAOHS TO FREE RADICALS: FORGOTTEN AND FUTURE VEGETABLE PHYTOCEUTICALS

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Plants are the foundation for a significant part of human medicine and for many of the most widely used drugs designed to prevent, treat, and cure disease. A number of our cultivated crop plants, including many vegetable crops, were domesticated for medicinal purposes prior to their current use as food. Folkloric transmission of plant-based cures represents a fundamental and formidable reservoir of information for most human cultures.

While such remedies are still widely practiced throughout the world, recent scientific developments in the U.S. and other developed countries ushered in a new era of synthetic medicine. During the 20th century, modern medical science introduced monomolecular drugs, many of which have achieved great success and improved public health. However, along with this revolution has come a realization that many traditional plant-based remedies, which generally contain a wide variety of secondary compounds, have been forgotten or obscured.

Beginning with the discovery of the vitamins in the early part of the 20th century, key elements of the health functionality of specific crop plants were elucidated. This information led to a greater understanding of the importance of vegetable crops in the human diet. In the past decade, great strides have been made to improve our understanding of how plant secondary compounds in vegetable crops influence human health.

The current emphasis on food functionality in the marketplace has highlighted the importance of nutritional components in vegetable crops. While a few vegetable crops have been substantially modified in this regard, much of the research in this area has focused on gaining a better understanding of how secondary compounds that are already present may impact human health, or be influenced by the horticultural environment. This presentation will include a review of the historical development of vegetable phytoceuticals with an emphasis on underutilize crops, new versions of old crops, and strategies for future crop development.

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THE AMERICAN MAYAPPLE AND ITS POTENTIAL FOR PODOPHYLLOTOXIN PRODUCTION

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Podophyllotoxin is the starting material for the semi-synthesis of the anticancer drugs etoposide, teniposide, and etopophos. These compounds have been used for the treatment of lung and testicular cancers as well as certain leukemias. It is also the precursor to a new derivative CPH 82 that is being tested for rheumatoid arthritis in Europe, and to other derivatives used for the treatment of psoriasis and malaria. Several podophyllotoxin preparations are on the market for dermatological use to treat genital warts. Since the total synthesis of podophyllotoxin is an expensive process, availability of the compound from natural renewable resources is an important issue for pharmaceutical companies that manufacture these drugs.

Currently, the commercial source of podophyllotoxin is the rhizomes and roots of *Podophyllum emodi* Wall. (syn. *P. hexandrum* Royle), an endangered species from the Himalayas. In recent studies, we concluded that the leaf blades of the North American Mayapple (*P. peltatum* L.) may serve as an alternative source of podophyllotoxin production. Since leaves are renewable organs that store lignans as glucopyranosides, podophyllotoxin can be obtained by conversion of podophyllotoxin 4-O-D-glucopyranoside into the aglycone using our buffer extraction procedure. This extraction procedure of *P. peltatum* leaves yields podophyllotoxin in amounts similar to the ethanol extraction of *P. emodi* rhizomes and roots.

Podophyllum peltatum accessions with podophyllotoxin-rich leaf biomass were identified and transplanted to different growing conditions by vegetative cuttings. Results indicate that the lignan profile in leaves does not change over time or due to environmental conditions. Podophyllotoxin and a-peltatin contents in the blades seem to be stable with an inverse relationship between these compounds. Podophyllotoxin-rich leaf accessions showed low biosynthetic capability to synthesize a- and b-peltatin and the opposite was also true, indicating that selection and cultivation of high-yielding podophyllotoxin leaf biomass may reduce production costs.

There has been an increasing interest in domestication and cultivation of *P. peltatum* for podophyllotoxin production. However, there remains a need for the confirmation of the most economical and available sources since podophyllotoxin is also present in other genera. Most importantly, feasibility will depend on the cost of *P. peltatum* cultivation and on the podophyllotoxin purification process.

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OILSEEDS - EDIBLE

CANOLA: AN EMERGING OILSEED CROP

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Canola is the second largest oilseed crop in the world providing 14% of the world's supply, yet it is still considered a NEW crop in the United States. Canola is new in the sense that it has a relatively short history in the United States. Significant domestic markets were not created until GRAS (Generally Recognized as Safe) status was granted by the FDA in 1985, allowing its oil to be used in foods marketed in the U.S. Early expectations were that canola would take the United States by storm as this new, improved, and a renamed version of rapeseed had done in Canada in the previous decade.

Many experts projected 8-10 million acres in the U.S. by the turn of the century with broad scale adoption in the Midwest and Southeast. Although the current canola acreage in the United States of 1.6 million acres falls far short of those original projections, these production levels would still lead you to believe that canola is probably the greatest new crop success in the United States since the development of soybean as an oilseed. Unfortunately, this is true in only one region, the Northern Plains. Of 1.6 million acres of canola produced this year in the U.S., 1.4 million were grown in North Dakota and most of those within a hundred miles of the Canadian border. Virtually all of the U.S. canola production can be viewed simply has an extension of Canadian production that is largely supported by Canadian infrastructure, Canadian varieties, and Canadian markets.

Several other production regions in the United States have demonstrated good potential for canola production, but they have experienced very little growth over the past fifteen years and are still struggling to develop or sustain viable canola industries. Introducing canola elsewhere besides the Northern Plains has been largely unsuccessful due to the host of problems that are all too familiar to those of us who work routinely with new crops. Absences of local markets, unavailability of locally adapted varieties, lack of registered crop protection chemicals, reluctance of farmers to adopt a new crop, various production challenges, absence of infrastructure, meager research funds, limited crushing capacity, and strong world competition combined with no incentives for domestic production have each played a role in stifling commercialization efforts in one or more regions.

Probably the most common constraint is the formidable "chicken or egg" dilemma caused by the large initial production level that is required for profitable commercialization. Fortunately, some of the many barriers that stifled early commercialization efforts in the U.S. have now come down. The "Freedom to Farm" philosophy reflected in the last farm bill removed many cropping restrictions and made it possible for producers to incorporate new crops, such as canola, into their production systems. Coverage of canola crops by Federal Crop Insurance, inclusion of canola and related oilseeds in the Commodity Loan Program at a favorable loan rate, registration of a host of new crop protection chemicals, and the development of better adapted varieties by publicly-funded regional breeding programs should greatly improve the chances of successful commercialization of canola in other regions of the U.S. over the next 10 to 20 years. Yet the harsh reality remains. Introduction of a new crop is a long-term undertaking, especially if attempted in the absence of a coordinated national policy that encourages and supports new crops research and development programs.

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FLAX UPDATE: NEW USES AND DEMANDS

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Recently, there has been a resurgence in the use of flaxseed for food and industrial uses. Flaxseed is produced primarily in North Dakota, South Dakota, Minnesota, and the prairie provinces of Canada. North Dakota is the leading producer in the United States with approximately 9.9 million bushels produced on 500,000 acres annually. The United States has not produced enough flaxseed in recent years (10.7 million bushels annually) to meet its domestic needs. Therefore, approximately 50 to 60 percent of the flaxseed is imported from Canada.

The major use of flaxseed still remains for linseed oil. Industrial linseed oil is extracted and used for paints and coatings, linoleum, oil cloth, printing inks, soap, patent leather, base oils, brake linings, and herbicide adjuvants.

A moderate resurgence for the food use of flaxseed has occurred both in the United States and Canada. Flaxseed and cold-pressed flaxseed oil can be purchased in many food stores in North America. Flaxseed has a pleasant, nutty flavor with few side effects. The principal benefits of flaxseed in both human and animal nutrition are the high levels of alpha-linolenic acid (ALA) in its oil, and the high content of both soluble and insoluble fiber in the seed. Flaxseed contains 55-58% ALA in its fatty acid profile. It is a widely known that the inclusion of omega-3 fatty acid into human diet has a very positive health benefit.

Research has been reported that the omega-3 fatty acids are associated with lowered risk of coronary heart disease by reduction of triglyceride levels in the blood. Other health-related research has shown that flaxseed lignin can aid in reducing the risk of hormone-dependent cancer such as breast, endometrial and prostrate as well as decreasing menopausal symptoms.

Flaxseed also is being used in swine rations to increase litter size and birth weight. Laying hens fed flaxseed in rations are now producing healthier omega-3 eggs for human consumption. Flaxseed is being used in early rations for feeder cattle to reduce shipping fever. In preliminary studies, flaxseed has induced immunity to a respiratory bacterial endotoxin in young feeder cattle. Gains in efficiency were greatest for cattle fed diets containing flax, and were substantially improved relative to diets containing full-fat soybeans or beef tallow. Death losses also were significantly lower for stressed cattle fed flaxseed as the lipid feed supplement.

Flaxseed stem fiber is now being processed and used for a number of products. In addition to cigarette paper, flax fibers are being used for pulp and paper, erosion control mats, reinforcing materials in plastics and particle composite products.

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SESAME: PROGRESS IN COMMERCIALIZATION FOR THE CONFECTIONERY AND OILSEEDS MARKETS

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Sesame is one of the oldest cultivated crops known to man. There are archeological remnants dating to 5,500 BC in the Indian subcontinent. However, sesame faces the following paradox: It is not a major crop because there is little research, and there is little research because it is not a major crop. In order to become a major crop, sesame has to be converted from a manual crop to a mechanized crop. There was some sesame grown in the U.S. in the 1950s and 1960s using binders, shocking, and combining. However, when the Brazero program was ended, there was no manual labor to do the shocking and the sesame program died.

In 1978, Sesaco was formed to try to completely mechanize the crop. For the past 60 years, the major obstacle has been the shattering of the capsule at harvest. Two genes have been discovered that keep the capsule closed – the indehiscent gene in 1943 and the seamless gene in 1986. However, these genes have not worked because there is too much damage to the seed when opening these capsules mechanically.

Sesame is over 50% oil, and thus must be handled very gently. Initial direct harvest in 1978 resulted in 90% seed losses. By 1982, the crop could be harvested completely mechanically by swathing the sesame, leaving it to lie horizontally, and then picking it up with a combine when dry. The initial variety was adequate with a 30% loss with no rain, but could lose as much as 60% with just a little rain on the drying windrow. From that time forward, there have been 24 varieties released, each with better shatter resistance. By 1989, there was enough shatter resistance to allow direct harvest when the plants were dry. In 1995 and even with rain, there was only a 30% loss. In 1997, the shatter resistance was good enough that the completely dry sesame stayed in the field for 6 weeks in the rain with only a 10% loss.

Along with improvements in shatter resistance, breeding has successfully incorporated resistance to aphid, white fly, and root rot. For the past 33 years, the breeding focus was to have the actual yields approach the potential yields by ameliorating yield preventers and yield reducers. The challenges for the future are (1) continue to improve potential yield, which was sacrificed for shatter resistance, (2) register herbicides, and (3) get crop insurance. World consumption of sesame continues to increase. With mechanized sesame, the U.S. can become one of the major producers of sesame.

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SUNFLOWER: NuSUN AND OTHER DEVELOPMENTS

Larry Kleingartner

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In 1995, the membership of the National Sunflower Association (NSA) determined that adjustments to the existing fatty acid structure of sunflower were needed to attract consistent domestic markets for the oil. All sectors of the sunflower industry were represented on a planning committee that laid out a strategy for converting the U.S. sunflower acreage to a mid-level oleic fatty acid sunflower seed (later to become known as NuSun). The decision to change was prompted by communication with major users of vegetable oil who reported concerns about the future use of hydrogenated oils, especially for frying. They indicated that a mid-level oleic sunflower oil might provide desired stability without hydrogenation.

A major initial hurdle was determining whether NuSun sunflower oil would indeed meet the needs of the domestic snack food frying industry. This was needed before the hybrid seed industry was willing to make investments in a new breeding program. An existing patent on high oleic sunflower seed was another complication for starting breeding programs. Generating confidence in industry members and farmers that NuSun sunflower had market potential was a critical factor throughout the first five years of the project.

The hybrid seed companies faced the major challenge. The new hybrids had to have all of the essential requirements of yield, oil content and the other agronomic characteristics found in traditional hybrids. The hybrids also had to meet the oleic content needs of the end user.

Farmers faced the challenges of switching to hybrids with limited testing and the necessity of keeping NuSun sunflower separate from traditional production. That required separate storage on the farm or immediate market outlets at harvest. Crushing plants provided a market incentive to farmers by paying a slight premium for NuSun. The first handler, the grain elevators, had to find a method to segregate NuSun from traditional hybrids and maintain separate storage. An instrument was identified that could provide a quick and inexpensive way to determine seeds high in oleic acid.

Extensive taste and performance testing of the NuSun occurred at private and public facilities as soon as sufficient oil became available in the l998-99. All of the research reports came back favorably. As early as 1999 several regional potato chip companies reported using NuSun and were pleased with the oil’s performance and consumer acceptance. One continuous theme repeated from research taste panels to industrial users was the excellent taste of the products produced in NuSun.

NuSun received a big boost in July 2000 when Proctor & Gamble announced that the company would be using NuSun in the production of Pringles chips. This provided a strong vote of confidence for the decision that was made in 1995.

Hybrid seed companies were making excellent progress with NuSun hybrids. By the 2000 season it was estimated that one-third of the U.S. oil-type acres were planted to NuSun. That was approximately 650,000 acres. Estimates are that 2001 NuSun acreage will approach about half of the U.S. sunflower oil-type acreage. The market and hybrid performance will continue to direct the rate of acreage conversion to NuSun.

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OILSEEDS - INDUSTRIAL I

CHIA SEEDS: NATURAL SOURCE OF w -3 FATTY ACIDS, ANTIOXIDANTS, AND DIETETIC FIBER

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Chia (*Salvia hispanica* L.) is a summer annual belonging to the Labiatae family. This species originated in the mountainous areas of west-central Mexico and northern Guatemala. Pre-Columbian civilizations used chia seeds as the raw material for making medicines as well as nutritional compounds. It was one of the main crops of the Pre-Columbian societies of the region, and was surpassed only by corn and beans in terms of significance. The city of Tenochtitlan received an annual tribute from conquered nations, a minimum of 4,400 tons of chia. Also, the city received annually chia produced by the Aztec intensive agriculture system, which utilized 9,000 ha of chinampas.

Chia seeds contain varying amounts of oil of between 32-39%, with the highest natural percentage of a-linolenic acid known (60-63%). Chia has been shown to hold significant potential in the food industry as a source of w-3 fatty acids. Hens fed chia seeds have produced eggs with up 59 mg of w-3 fatty acid/g of yolk. Milk from cows fed chia has 30% more w-3 fatty acid than milk from cows fed conventional diets. Chia-enriched broiler diet provides 2.7 to 3.5 times more w-3 fatty acids and a similar cholesterol content per edible portion of white and dark meat with skin, respectively, than an equal sized portion of canned tuna.

In addition to the w-3 content, extracts of chia seed have been shown to exhibit strong antioxidizing characteristics. The more important antioxidants isolated to date are: chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol flavonols. Chia seed contains 32-39% fiber, of which 5% is soluble fiber useful as a dietary fiber. In addition to the usefulness of the seed, chia biomass contains an abundance of essential oils, which are of significant commercial importance in the flavor and fragrance industries.

Thus, chia's chemical composition, and/or its nutritional value, gives it a very high potential for use within both food and medicinal markets.

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USE OF VEGETABLE OILS AS BASE FLUIDS FOR INDUSTRIAL LUBRICANTS

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There is growing interest in vegetable oil-based lubricants and functional fluids. Vegetable oils are renewable and biodegradable so they can be formulated to make vegetable-based or bio-based lubricants that are more environmentally sensitive than similar conventional petroleum-based products. Using an environmentally friendly product can save an equipment operator a substantial amount of money in terms of oil spill related clean up, fines and down time.

This presentation is about the formulation and use of vegetable oils in industrial lubricants and how developers of new crops and seekers of new uses can best interact with companies that develop and market specialty fluids. Topics will include a review of the current state of the art of vegetable oil formulations, their strengths and weaknesses, and the differences between various vegetable oil types.

Formulating with vegetable oils will be explored, with emphasis on lubricant characteristics, what formulators need to know about base oils to begin their work, especially in terms of preliminary testing and compatibility with chemical additives. By providing formulators with the required oil properties in the terms they understand, their interest can be maintained and development time reduced.

The major driving forces for bio-based lubricants will be discussed. What is the state of current and pending legislation and what other factors make people buy vegetable-based lubricants? While there is no universal definition of environmental preferability, many of the currently used definitions will be explained.

A brief overview of market opportunities will be explored including current bio-based oil purchasers, their needs and necessary performance specifications that must be met. Finally, a formulator's wish list will be outlined. This list is developed with the lubricant formulator in mind with the intention of guiding new crop developers to develop crops with the highest probability of commercial success.

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SELECTION FOR HIGH VERNOLIC ACID AND LOW FREE FATTY ACIDS IN VERNONIA

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MORPHO-PHYSIOLOGICAL DETERMINANTS OF SEED YIELD

IN FIVE SPECIES OF *LESQUERELLA*

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PERENNIAL *LESQUERELLA* FOR SEMIARID LANDS WITHOUT IRRIGATION

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GENETIC MECHANISMS UNDERLYING THE HIGH OLEIC ACID PHENOTYPE IN SUNFLOWER

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The high oleic phenotype in cultivated sunflower (*Helianthus annuus* L.) originated from a dominant mutation (*Ol*) in the cultivar Pervenets. *Ol* has been widely used in the development of high oleic inbred hybrids and is necessary for producing the high oleic phenotype. We previously showed that a seed specific D^{12} oleate desaturase gene (OLD-7) was duplicated and weakly expressed in *OlOl* homozygotes and the nucleotide sequences of the coding regions of wildtype and mutant oleate desaturase genes were identical, and speculated that the duplicated gene disrupted the OLD-7 promoter. To test this, our objective was to design oligonucleotide primers to amplify the DNA fragment hypothesized to reside between the tandemly repeated genes.

Using long distance PCR, a 3,000 bp fragment was amplified from the mutant line, whereas no fragments were amplified from the wildtype line. DNA sequencing confirmed that a 3,000 bp fragment resides between tandem repeats of OLD-7. We cloned upstream and downstream regions flanking the OLD-7 coding region in wildtype and mutant lines. Our aims were to identify the novel splice site, confirm that the promoter sequence is disrupted in the mutant line, and develop and map dominant and co-dominant DNA markers for OLD-7, specifically insertions-deletions (INDELs) and single nucleotide polymorphisms (SNPs).

We are using the PH-C × PH-D RIL population to identify candidate genes and QTL that interact with *Ol*. SNP or other markers for OLD-7 will be integrated with simple sequence repeat (SSR) markers on the genetic map to facilitate marker-assisted selection for the high oleic phenotype in sunflower. PH-C × PH-D, a recombinant inbred line (RILL) mapping population, segregated for *Ol* and quantitative trait loci (QTL.) affecting oleic acid concentration. The oleic acid distribution was continuous in two sites and two locations.

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FIBERS

CONNECTING A WORLDWIDE NETWORK OF NEW CROPS AND NEW USES RESEARCHERS, ENTREPRENEURS AND CORPORATIONS THROUGH AN INTERNET-BASED COMMUNICATION SYSTEM

Peter A. Nelson

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As an increasing priority for New Uses Council Inc., U.S. Dept. of Agriculture and other public and private entities, has been to develop an internet-based communications network for the variety of individuals with an interest in some segment of new uses, new crops and other biobased product technologies. A system, or combination of systems to connect the whole emerging industry is necessary for many reasons. These include the need for leadership, assist in developing a unified public policy voice and to participate with all those involved in their efforts to avoid reinventing the wheel when it comes to research priorities and applications.

As part of this broad effort, the U.S. Dept. of Energy has announced plans to develop a "Virtual Bioenergy Center" to connect those with a specialized interest in bioenergy and biofuels. There are similar efforts being developed around the world, with major networks in Canada, Europe and Japan. As a central catalyst to this effort, AgroTech Communications, Inc. has developed the Biobased Information System (BIS) to ensure multidirectional communication between a worldwide network of users.

The Biobased Information System (BIS) was created by AgroTech Communications, Inc. to sort and administer information flow between originators of biobased information, publishers of that information, and the thousands of individuals worldwide who benefit from the system. Originators create content for use on the system, while publishers are any website administrators in the world who would like to use biobased information in their own website. All the features of the system are available through a password-protected area of the website.

The implementation of the Biobased Information System (BIS) will continue to bring the entire biobased industry together to pool resources, avoid mistakes, develop a unified approach to public policy and other factors necessary to build a vibrant and fast-growing industry.

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NONWOOD FIBER CROPS AND INDUSTRIAL TECHNOLOGIES: CURRENT STATUS AND EXPECTATIONS IN THE 21ST CENTURY

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WOOD vs. AGRICULTURAL RESIDUES FOR PAPERMAKING: WHICH IS BETTER?

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The failure of many nonwood fiber pulp and paper projects is due to the inability to understand the suitability of wood as a papermaking raw material. Even agricultural residues, which have certain cost advantages compared to fiber-only crops, must be able to compete against the inherent advantages of wood.

Trees are a low-maintenance crop that is fairly insulated against environmental fluctuations. Wood has good bulk density and can be economically transported and stored. Wood is a clean material, with a low content of foreign materials, metals, and silica. The fibers from wood have a uniform, normal distribution, with a low content of parenchyma, pith, and unusable structures. Wood fibers have a wide range of lengths, but even the shortest lengths are useful for papermaking. Fiber wall thickness and integrity in wood fibers are sufficient to provide good strength and good recyclability, but still allow collapse into flat ribbons for papermaking.

Agricultural residues are derived from annual crops, which require significant maintenance during growth and harvest. Since annual crops are sensitive to environmental conditions such as drought or flood, some amount of material must be kept on reserve to provide a buffer. Residues tend to have a low bulk density, resulting in high storage costs and limiting the distances they can be transported economically. In addition to foreign materials entrained with the residues during harvest, many residues have a significant content of metals and silica. Some residues have a significant amount of parenchyma and pith, which cause problems in both pulping and papermaking. Most residues have short fibers with thin walls, producing adequate tensile strength, but poor tear strength and recyclability.

The most significant advantage of agricultural residues compared with wood is that they have a very open structure and have lignin that is not very condensed. These properties can cause residues to respond to very mild pulping processes (chemical and chemical-mechanical) in a way that wood cannot. Redesigning a pulp mill to take advantage of these properties may give residues the edge necessary to compete with wood.

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SUCCESSFUL UTILIZATION OF RYEGRASS STRAW AT WEYERHAEUSER'S SPRINGFIELD LINERBOARD MILL

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FRUITS AND VEGETABLES

NEW FRUITS FOR ARID CLIMATES

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Israel is a tiny country. Its domestic market is small – too small to warrant R&D activity – and in the world market it cannot compete against the large producers of common crops. However, if Israeli growers were provided with new crops for export, they could successfully aim for the lucrative exotic niche. This is the rationale that led us to initiate a program for domestication of new fruit crops 17 years ago. These totally new crops, which do not exist in Europe, the U.S. or Japan, are being introduced into the only open space available for agricultural development in Israel – the Negev desert.

The aim of the program is to develop the know-how required for the production and marketing of exotic fruits, mainly for the export market.

We introduced over 40 different fruit-tree species and tested them in the five ecozones found in our desert. Many did not survive, some turned out to have no commercial value, but others seem very promising. Four species have already penetrated the European market. Among the failures were yehib, *Cordeauxia edulis* from the Horn of Africa, which proved highly sensitive to low temperatures, mongongo, *Ricinodendron rautaneni*, with low yields, and *Harpephyllum caffrum*, which produces tiny fruit with only a small edible portion. All the species that were successfully introduced into the European markets belong to the Cactaceae and hence are efficient water users. This is obviously a tremendous advantage for Israel, a country with severe water shortages. The cacti in question include *Cereus peruvianus*, trade name Koubo, an erect outdoor-grown summer-bearing plant; its smooth oval fruits are medium-sized, with a variously-hued red peel and white aromatic pulp. *Hylocereus undatus* and *H. polyrhizus*, also summer-bearing, have scaly fruits, and *Selenicereus megalanthus*, which is both winter- and spring-bearing, bears spiny fruit. All are epiphytic and have to be grown on trellises under shade (due to photoinhibition). However, they differ in sensitivity to high and low temperatures and requirements for shade and water. *S. megalanthus* also known as "yellow pitaya," has a delicious white- fleshed fruit with a yellow peel, with large thorns easily removed at harvest. *H. undatus* also known as Dragon fruit or white-fleshed red pitaya, bears beautiful large fruit (300-600 g) with green scales and a very mild taste. *H. polyrhizus* is similar to *H. undatus*, but has a strong color and a glowing, deep-purple pulp. Unlike the cactus pear, all have soft edible black seeds similar to those of kiwi fruit. Apart from their beautiful appearance, the main reason for their success was the special attention given to marketing. Other species considered to have potential as export crops are: marula, *Sclerocarya birrea* sbsp *caffra* from southern_Africa; *Vangueria infausta* (mmilo), *Strychnos cocculoides* and *Strychnos spinosa*,_also from southern Africa; and argan, *Argania spinosa*,_an oil-producing tree from Morocco. Argan and marula can tolerate the extreme temperatures and salinities that prevail in the Negev desert.

The main obstacle to introducing real new crops remains the marketing issue and the refusal of the establishment to support the newly emerging crop. There are many more fruit trees waiting for the scientific community and the granting agencies to explore their potential and give them a chance to become the crops of the future.

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THE NEW SALAD CROPS REVOLUTION

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Over the years since early historic times, the nature of salads has changed in both style and content. In the last quarter century, substantial changes have occurred on four main fronts: 1) the types of lettuces used; 2) the appearance and expansion of value-added products; 3) the addition of new or previously little used species; and 4) a growing interest in nutritional and health value of salad vegetables.

Different lettuce types have historically predominated in different regions of the world. In the US, until the early years of the 20th Century, we consumed several types of lettuces. With development of the Western shipping industry, iceberg lettuce became synonymous with salad. In recent years, the development of the salad bar and the increasing feasibility of shipping non-iceberg types long distances brought a resurgence in the use of romaine, butterhead, and leaf lettuces.

The value-added revolution started with shredding of lettuce, carrots, and red cabbage for institutional uses. Now, the shredding and chopping of several kinds of salad vegetables, combined in numerous ways in small family-size plastic packages, are a major force in the produce industry and have contributed to a radical shift in home food preparation.

Spring mix or mesclun, the combination of young small leaves of various kinds, is in the throes of extremely rapid growth over the last few years. We have been introduced to a bewildering number of new leaves: arugula, tat soi, frisee, beet tops, and many others.

The last change is incipient. It is a growing interest in the nutritional value and antioxidant capacity of the various kinds of lettuces, as well as the other species now being consumed in our salads. This interest may stimulate a corresponding interest in breeding for increased content of beneficial compounds.

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NEW OPPORTUNITIES IN *VIGNA*

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The genus *Vigna* (Leguminosae) contains several species that are of considerable economic importance in many developing countries. Cowpeas (*V. unguiculata* [L.] Walp.), mung beans (*V. radiata* [L.] Wilczek), and urd beans (*V. mungo* [L.] Hepper) are key dietary staples for many millions of people. Additionally, adzuki beans (*V. angularis* [Willd.] Ohwi & Ohashi), bambara groundnuts (*V. subterranea* [L.] Verdn.), mat beans (*V. aconitifolia* [Jacq.] Marechal), and rice beans (*V. umbellata* [Thunb.] Ohwi & Ohashi) are important in the diets of many societies. Many of these *Vigna* species are also valued as forage, cover, and green manure crops in many parts of the world. Annual worldwide production of the various *Vigna* species probably exceeds 20 million hectares, and virtually all of this production is in developing countries.

The economic *Vigna* species exhibit a number of attributes that make them particularly valuable for inclusion in many types of cropping systems. They can be grown successfully in extreme environments (e.g., high temperatures, low rain fall, and poor soils) with few economic inputs. Many of these species produce multiple edible products, and these products provide subsistence farmers with a food supply throughout the growing season as well as harvested seeds that are easy to store and transport. For example, tender shoot tips and leaves of cowpeas can be consumed as soon as the plants reach the seeding stage and immature pods and immature seeds can be consumed during the fruiting stage. Harvested dry seed of all of the *Vigna* crops can be consumed directly, and seeds of several of the crops are commonly used to make flour or produce sprouts. Plant residues and haulms can be used as fodder for farm animals. *Vigna* food products exhibit many excellent nutritional attributes and these products provide a needed complement in diets comprised mainly of roots, tubers, or cereals.

Except for cowpeas, which were heavily researched in the U.S. early in the 20th century, there has been little research on any of the *Vigna* species until recent decades. Although there are appreciable efforts in the international research arena at present directed toward cowpeas and mung beans, many of the *Vigna* species are still largely ignored by the scientific community. However, plant explorers and the plant germplasm preservation community long ago recognized the potential importance of the economic *Vigna* species. These people have done a commendable job of collecting and preserving *Vigna* germplasm, and appreciable collections of *Vigna* germplasm are held by various national and international agencies. All of the economic *Vigna* species have potential for introduction or increased production in the U.S. The introduction or expansion of the culture of *Vigna* species in the U.S. would create new opportunities and provide alternative crops for American farmers, give American consumers access to new and novel foods, and increase the bio-diversity of crops used in American agriculture.

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SCREENING MELONS (*CUCUMIS MELO*) FOR ADAPTABILITY IN NORTH CAROLINA AND FOR COMMERCIAL MARKETING POTENTIAL

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Profit margins for traditionally grown agronomic crops such as corn, soybean, and small grains have been minimal the past several years. This coupled with nearly a 50% reduction in the tobacco quota in the past four years, a primary source of revenue for North Carolina farmers has caused growers to search for alternative agricultural enterprises which are profitable. Warm season vegetables such as muskmelons or cantaloupes are grown profitably by several growers throughout North Carolina. Besides cantaloupe, there is a great diversity of melon (*Cucumis melo*) types with unique flavors and appearance that could provide crop alternatives and profits for growers.

One objective of this program was to screen advanced lines or cultivars of the different melon types and determine their adaptability (i.e. yield, disease resistance/susceptibility) to North Carolina growing conditions. The second objective was to take promising melon cultivars/types and test market them for buyer and consumer acceptance. A third objective is grower participation in the marketing development and economic analysis of the specialty melons.

Each year, specialty melons for field testing are obtained by contacting international and national seed company representatives, and individual plant breeders. Melons for testing include juan canary, Japanese, oriental-crisp-flesh, Galia, Christmas, rochet, charentais, and honey dew types. In 10 to 12 m long rows, melons are evaluated for horticultural qualities such as yield potential (number and weight), fruit shape and size, sugar content, flavor, flesh texture, optimum time to harvest, and shelf life. Based on these criteria, melon cultivars that show potential for commercial production are included in the screening trial the following season. Those melons only suited for local sales (highly perishable or low yielding) are typically not included in the screening trial the subsequent year. After one to two years of field trials, melon cultivars or types which show high potential are test marketed. Test marketing is done several ways; sampling product to local grocery store chains as well as independent grocers, sampling a few boxes, which are add-on items as part of a trailer load with grower cooperators, and via consumer surveys. If the particular melon type is well received, a few growers volunteer to produce small acreage (0.5 to 1 acre) of the melons during the third year in order to provide some volume for continued test marketing. If there is buyer acceptance of the melon, increased grower participation along with increased acreage occurs the fourth year. Continued support is provided through extension programming and marketing by the North Carolina Cooperative

Extension Service and the North Carolina Department of Agriculture and Consumer Services, respectively.

Several melons show good potential as a specialty item. For example, a crisp-flesh-oriental melon has garnered market acceptance. Approximately 10 growers are now producing this crisp flesh melon commercially and have shipped between 60 to 70 tractor trailer loads in 2001. A number of other melon types are being tested on-farm to evaluate their commercial potential. These melons were originally screened on the research station and determined to be well adapted to North Carolina environmental conditions.

This program is only four years old and has provided consumers with new crop items and growers with new opportunities along with educational program support. At least one-half of the growers shipping the oriental crisp flesh melon are tobacco growers that are using this additional income that was lost due to reduced tobacco acreage.

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CEREALS AND PSEUDOCEREALS

PROGRESS WITH PROSO, PEARL, AND OTHER MILLETS

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Paniceae is the largest tribe of the Gramineae family, with more than 1,400 species. This summarizes the advances in cultivar development, management, and utilization for the most economically important species of this tribe, which include proso millet (*Panicum miliaceum* L.) foxtail millet (*Setaria italica* L. Beauv.) and pearl millet (*Pennisetum glaucum* L.R. Br.). Recently, grain types of pearl millet and proso millet have been released and U.S. acreage has continued to increase, especially for proso millet.

Advanced lines of foxtail are being tested for grain yield potential in the High Plains region that have been selected for improved resistance to wheat streak mosaic. Foxtail millet lines are also being developed to better meet the market for individual heads for caged birds and for forage production. Proso millet germplasm is being developed with starch characteristics unique to the U.S. market and may improve the export potential of the crop. Recent releases of pearl millet for forage based on manipulation of the photoperiod response are starting to be marketed. Management research has been limited, but new herbicides have been labeled that help in controlling weeds in all three crops. These millets reliably produce grain and forage under the most adverse conditions around the world. They have the potential to improve our cereal food supply, produce forage for livestock production and provide for the leisure activity of feeding birds.

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AMARANTH PROGRESS AND PROBLEMS

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Amaranth has been a "New Crop" in the United States since the late 1970s. It is grown for grain, leafy vegetable, forage, and ornamental use.

Amaranth grain is an international commodity exported from Peru, the United States and other countries. It is used in health-food breakfast cereals and other high-value food products. Amaranth grain brokers estimated grain prices in July 2001; farmers were paid $1.30 to $1.80 per kg for certified organic grain and $0.90 to $1.10 per kg for conventional grain. With average U.S. yields of 670-1,340 kg/ha, organic growers can gross $870-2,410 per ha. Grain amaranth production in the United States is at levels similar to the 1990s, estimated at 400-2,000 ha per year. Improved varieties and cultural methods could help the industry by lowering production costs. Plant breeding work in progress is intended to reduce seed shattering during late-season storms, and to increase yield potential.

Amaranth is under investigation as a forage crop internationally. Forage is the main use for the 60,000 ha of amaranths grown yearly in China. Amaranth can yield 12,400-kg/ha dry weight of forage that is very digestible and contains 25% protein. Nitrate can reach toxic levels. These nitrate levels diminish in older plants, and are influenced by genotype and environment.

Vegetable amaranths are adapted to warm-humid summer growing conditions in the United States. They are an excellent source of dietary carotenoids and iron. Immigrant populations from countries where amaranth vegetable use is important continue to purchase vegetable amaranths in the U.S. Dietary iron could become a marketing advantage in the U.S. where iron deficiency is common.

Ornamental amaranths are commonly used as bedding plants in the United States. The popular *Amaranthus tricolor* types could be improved by breeding for improved resistance to *Phomopsis amaranticola* leaf and stem blight. Other ornamental types such as ‘Elephant Head’ are attractive, easy to grow and should be promoted.

Amaranths are desirable because they add to farmer and consumer options, offering good performance for crop rotations. The amaranth community is making progress with the problems that limit amaranth’s use.

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OILSEEDS - INDUSTRIAL II

PRODUCTION OF UNUSUAL FATTY ACIDS WITH INDUSTRIAL VALUE IN TRANSGENIC PLANTS

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THE SUNFLOWER AND COMPOSITAE GENOME INITIATIVES

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Our laboratory conducts research on sunflower (*Helianthus annuus* L.) focused on the development of enhanced germplasm and genetically superior inbred lines, the development of genomics and molecular breeding tools, and genetic and functional genomic analyses of economically and biologically important traits.

My aims are to describe genomics and molecular breeding tools for sunflower, review the aims of the Compositae Genome Initiative (CGI), and describe the development of the sunflower and lettuce expressed sequence tag (EST) databases. The specific topics to be covered are: the development of 1,100 simple sequence repeat (SSR) markers for sunflower, an analysis of the extraordinary allelic diversity of SSRs in exotic and elite sunflower germplasm, the discovery and analysis of single nucleotide polymorphism (SNP) markers in sunflower by cloning long PCR amplicons and sequencing alleles from diverse genotypes, the development of a genome map for sunflower comprised of DNA markers for high-throughput genotyping, initial analyses of 100,000 ESTs from sunflower and lettuce, the discovery of SSRs and SNPs in the sunflower EST database, and an overview of functional genomic and molecular breeding analyses of a variety of economically and biologically important traits in sunflower.

CGI is a collaborative research program between OSU, University of California, Davis (Richard Michelmore, Kent Bradford, and Louise Jackson), Indiana University (Loren Rieseberg), and University of Massachusetts, Boston (Rick Kesseli). The Compositae is a family comprised of 20,000 species and an enormous number of economically important crops, e.g., safflower and noug, several new crops, e.g., guayule, *Calendula*, and *Grindelia*, and ecologically important species. One of the rationales for the CGI was to create a public EST database that could be mined for genes involved in secondary chemistry, biotic and abiotic stress, and disease resistance.

The tools and resources developed by the CGI should accelerate the discovery of genes underlying economically important traits, biochemical pathways, and developmental and physiological processes in the Compositae.

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SYNTHESIS AND PHYSICAL PROPERTIES OF CUPHEA OLEIC ESTOLIDES

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Cuphea is a new crop that has been grown throughout the Midwest. Cuphea produces medium chain fatty acids similar to those produced by coconut and palm kernel oils. The development of a new crop often depends on the synthesis of novel compounds. Estolides are one such derivative of new crop oils which show promise in industrial applications.

The synthesis of complex and oleic estolides will be compared to the cuphea oleic estolides. Estolides are formed when the carboxylic acid functionality of one fatty acid links to the site of unsaturation of another fatty acid to form esters. Estolides were derived from a number of unsaturated fatty acids in the presence of varying equivalents of acid with no solvent with varying temperatures. The estolides were converted to their corresponding hydroxy fatty acid and the degree of polymerization was determined by GC analysis.

The free acid estolides were then converted to the esters under standard conditions. Physical properties (pour points <-40^{o} C, viscosities) of these estolide acids and esters were compared to previous reported estolides, which have current industrial applications as a potential hydraulic fluid. The oxidative stability of the complex estolides was measured and formulated (~2%) to exceed commercially available products.

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ROOTING CHARACTERISTICS AND WATER REQUIREMENTS OF CUPHEA

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Seed oil of Cuphea contains saturated fatty acids that are only commercially available through import of coconut and palm kernel oils. The potential value of Cuphea for American agriculture thereby demands a thorough understanding of physiological processes that will improve domestication and production of Cuphea. Native plant surveys suggest that Cuphea may be vulnerable to water stress due to a shallow root system.

This study evaluated rooting characteristics and water use of Cuphea sown on various dates and at different plant densities in the northern Corn Belt. Cuphea was sown biweekly beginning 3 May to achieve a plant population of 328000, 164000, and 82000 plants ha^{-1}. Row spacing was 0.6 m within 4 row by 2 m plots. Rooting depth and density were assessed at flowering. Crop water use was determined by assessing changes in soil water content to a depth of 1.5 m using neutron attenuation. Cuphea was hand harvested when the bottom pods began to shatter (beginning 24 August).

Rooting depth varied with sowing date; the earliest sown plants had the deepest (0.4 m) roots. In addition, rooting density was about 2 m m^{-3} greater near the soil surface in the early sown than late sown crop. Rooting density was also greater at higher plant populations. Similar trends were found in seasonal water use with water use being greater for the early sown (evapotranspiration was 33 cm) than late sown crop (evapotranspiration was 26 cm). Plant population, however, had no influence on water use. Total above ground biomass and seed yield was greatest for the middle sowing date (6000 kg ha^{-1} biomass, 450 kg ha^{-1} seed) and least for the late sowing date (5000 kg ha^{-1} biomass, 350 kg ha^{-1} seed). Biomass and yield declined with a decrease in plant population. Water-use efficiency ranged from about 15 kg ha^{-1} cm^{-1} for the middle sowing date to 10 kg ha^{-1} cm^{-1} for the late sowing date. Water-use efficiency also declined with a decrease in plant population. Water stress was observed near the time of harvest, but only for the late sowing.

This study indicates that Cuphea production diminishes as sowing date is delayed beyond mid-May in the northern Corn Belt due to shallow rooting characteristics and increased water stress later in the growing season.

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GROWTH AND DEVELOPMENT RESPONSES OF *CUPHEA* TO TEMPERATURE

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Recently developed semi-domesticated *Cuphea* (sp.) genotypes show good potential for commercial production of medium-chain fatty acids used in industrial chemical manufacturing. Successful crop management and production will depend on a basic knowledge of *Cuphea*'s response to environmental growth-limiting factors. Little is known about the growth and development responses of *Cuphea* to temperature.

We conducted a study using controlled-environment chambers to test the effects of temperature on the growth and development of a semi-domesticated genotype, *Cuphea viscosissima* x *C. lanceolata*, developed by Dr. Steven Knapp at Oregon State University.

Plants were grown under daily sinusoidal temperature regimes with daytime-maximum and nighttime-minimum temperatures of 18/12, 24/18, 30/24, and 35/27°C.

The life cycle, growth rate, and biomass accumulation of plants increased considerably up to a daytime maximum temperature of 30°C, but declined sharply at 35°C. Photosynthesis at growth temperature was less responsive than growth and development over the range of 18/12 to 35/27°C. The apparent temperature optimum for photosynthesis, about 23 to 24°C, was 3 to 4°C lower than that for growth. Seed mass decreased by 50% between 18 and 30°C, whereas plants under the 35/27°C regime failed to set seed.

Water use efficiency of CO_2 gas exchange in upper canopy leaves also declined sharply with temperature, decreasing as much as 70% between 18 and 35°C daytime temperature. Although *Cuphea* appears to adapt well to cool to moderate temperatures, it also has a relatively high water requirement for growth. In the absence of irrigation, production of current semi-domesticated genotypes of *Cuphea* may be best suited for areas with cool to moderate growing season temperatures and high annual precipitation.

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COMPOSITION OF CHILEAN JOJOBA SEED: COMPARISON WITH WORLDWIDE COMMERCIAL JOJOBA PRODUCTION

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Cuttings from 19 jojoba mother plants were collected from abandoned jojoba plantations in various regions of Chile. All 19 were grown at an experimental research station in Chile. These plants were continuously monitored for three years based on vigor, foliage color, and several other standard selection criteria. A comparison between seeds from these plants and seeds grown in several different geographic regions could help predict the seed characteristics of future jojoba crops.

The objective of this study was to compare the seeds of 19 Chilean jojoba plants with each other and to seeds grown in other major jojoba-growing regions of the world.

Seeds from these 19 jojoba clones were analyzed for oil content, weight per 1000 seeds, and protein content. The compositions of the wax-esters, fatty acids, and fatty alcohols were determined by gas chromatography and correlations among these components were analyzed.

The results of the chromatographic analyses were used to correlate wax-ester composition and average molecular weight of the Chilean seed oil and the commercially grown jojoba seed oil of all the major jojoba-growing regions. The analysis of variance and t-test of the wax-ester compositions showed evidence of systematic differences between the Chilean seed oil and oil from the US, Israel, and other South American countries. These same statistical analyses showed evidence of systemic differences between the average molecular weights of the Chilean seed oil and the U.S. and Israeli seed oils. Differences, however, are not supported between the average molecular weight of the Chilean seed oil and the oil from other South American seed oil.

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ORNAMENTALS

DEVELOPMENT OF *PHALAENOPSIS* ORCHIDS FOR THE MASS-MARKET

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During the Victorian period, orchids were popular house plants. At the turn-of-the-century, orchid use shifted from potted-plants to cut-flowers. Recently, potted-plants have become popular again. The goals of breeding have changed over time to fit consumer preferences. The first hybrids were developed as potted-plants. Later, hybridization goals changed focus to cut-flower types. Today, hybridization is concentrating once again on potted-plant types.

Phalaenopsis is the most widely grown orchid throughout the world. Their production is globally connected. For example, in one cooperative venture hybrids are created in the United States and selected clones are sent to Japan to initiate tissue cultures. Primary tissue cultures are then shipped to the People's Republic of China for mass propagation. The resulting plantlets are next sent to The Netherlands for growing. Nearly mature plants, are finally returned to the U.S. and Japan for finishing.

During the last five years, worldwide sales of *Phalaenopsis* have increased at a very fast rate. In the US, there has been a 57 % increase in sales of orchids, most of which are *Phalaenopsis*. The current rate of increase in production is expected to continue for at least the next five years.

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ORNAMENTAL GRASSES AND SEDGES: NEW ORNAMENTALS AND LANDSCAPE PLANTS

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Interest in and use of herbaceous perennials as landscape ornamentals has swept the North American landscape industry in the past few decades. Ornamental grasses and sedges are a major component of the plant taxa that have fueled that development. The genetic diversities that exists in these taxa have just begun to be tapped for horticultural development. Current trends suggest continuing strong interest in, and growth of this component of the ornamental industry.

Ornamental grasses and sedges offer numerous characteristics that are attractive to the landscape nursery industry, to site owners and to landscape managers. Most taxa are easy to propagate, either by seed or vegetatively, and relatively fast to grow to saleable size. In the landscape, these plants have relatively low maintenance requirements, and the maintenance that is needed is typically simple to perform. Pest and disease problems are few. Grasses and sedges provide a unique visual character, particularly in terms of texture that isn't available from other species. Some species are particularly effective at continuing that unique visual quality into the dormant season. Some ornamental grasses and sedges that are North American natives provide site owners the philosophical appeal of using indigenous species. Finally, this plant group has members which are tolerant of a wide range of sites, environmental conditions, and fit into many of the functional landscape categories.

As this plant group has gained popularity and wider use, some concern has grown over the potentially invasive nature of some, especially the nonnative taxa. While this is not a unique issue to ornamental grasses and sedges, it may mean that the pace of future developments will be moderated by efforts to forestall introduction of nuisance species.

Current trends in this plant group that will be discussed and illustrated include:1) New species introductions from worldwide plant collecting, 2) New cultivar introductions from breeding programs and selection among variants in wild populations, 3) Continuing development of annual grasses as an aspect of the bedding plant industry, 4) Increasing emphasis on native species, and 5) Increasing emphasis on sedges for shady landscapes and as alternatives to traditional turfgrasses.

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FOLIAGE PLANTS: NEW CULTIVARS, NEW PLANTS, AND NEW USES IN FLORIDA

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Florida leads the nation in the production of containerized tropical ornamental foliage plants. According to the USDA National Agricultural Statistics Service, the national wholesale value of foliage plants in 2000 was $574 million with Florida accounting for $394 million. In addition to its favorable climate, Florida dominates the foliage market because Florida foliage growers continually introduce new foliage plants and new cultivars of standard interiorscape plants, which dramatically expand the way foliage plants can be used for interiorscaping.

Historically, new foliage plants or cultivars were introduced into the foliage industry by tropical plant collectors or isolated from mutations of established cultivars. Although collectors still introduce new plants to the industry, most new cultivars now originate from plant breeding programs and/or tissue culture activities. Breeding has provided the industry with new colors, shapes, and forms of standard interiorscape plants. Using tissue culture methods, a new cultivar can be rapidly increased to commercial production levels within 1 to 2 years, instead of the 5 to 7 years required with standard cutting or division techniques. Tissue culture has also become an important avenue for new cultivar development when somaclonal variants are selected or existing mutants are uncovered during micropropagation. The importance of breeding and tissue culture in contributing to the development of new aroid ornamentals will be discussed.

The increased new cultivar and/or plant introduction provides interiorscapers with more options to use plants in unique and interesting ways. These new uses include dwarf *Ficus*, *Schefflera*, and *Dracaena* cultivars presented as Bonsai to create dramatic miniature settings; indoor-flowering *Anthurium* and *Spathiphyllum* cultivars integrated into colorful interior designs; *Anthurium* and *Aglaonema* leaves utilized as cut greens; and chill resistant *Aglaonema* and *Schefflera* cultivars used for interiorscaping where cooler temperatures occasionally occur.

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POT PLANTS AND LANDSCAPE PLANTS FROM THE ZINGIBERACEAE FAMILY

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Many ginger plants in the Zingiberaceae have unique foliage and colorful, long-lasting inflorescences, a 90 to 100 day production cycle and few pest problems. These gingers have great potential for use as flowering pot plants, both indoors and as patio and landscape plants. They are herbaceous perennials with short fleshy rhizomes and tuberous roots, often with a dormancy period. Inflorescence stalks arise either from a short pseudostem or independently from buds on the rhizome. The inflorescence of most species is a compressed spike of colorful long-lasting bracts subtending 2 to 7 true flowers. Some ginger species, however, have short-lived flowers with attractive, colored/patterned leaves that vary in size and shape.

There is little information on the optimum production environment, postproduction longevity and landscape survivability of commercially available gingers. The objectives of this research were to determine the optimum cultural practices for producing quality pot plants of several ornamental ginger, their postproduction longevity and landscape quality. *Curcuma* spp., *Globba* spp. and *Kaempferia* spp. were grown from rhizomes and the effects of temperature, light intensity, photoperiod, plant growth regulator application, postproduction longevity and landscape quality were studied.

Length of storage time and storage temperature of rhizomes of all species tested affected days to emergence and flowering. *Curcuma* spp. grow best under high light intensities of approximately 9,000 fc, whereas *Globba* spp. and *Kaempferia* spp. grow better under lower light intensities of approximately 4,500 fc. Plant-growth retardant application is necessary only on *Curcuma alismatifolia* unless other *Curcuma* species or *Globba* species are grown under lower then recommended light levels. Drenches of 10 mg a.i./pot Uniconizole or over 20 mg a.i./pot Paclobutrazol are recommended for height control. Rhizome dips of gibberellic acid concentrations up to 600 ppm will delay emergence and flowering of *Curcuma* species and do not promote or enhance flowering of any of the species tested. Ginger requires greater than 12 hours of light to prevent dormancy. Postproduction longevity of flowers of *Globba* and *Curcuma* was greater then 3 and 4 weeks, respectively. These gingers are hardy to USDA Zone 7 and require soil temperatures of greater than 70 F for emergence.

Studies conducted on *Curcuma* spp., *Globba* spp. and *Kaempferia* spp. have provided much needed information on production and landscape usefulness of these gingers. More research needs to be conducted on these and many other species in the Zingiberacea family. These plants however, are highly recommended as an alternative pot plant and landscape plant.

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OTHER NEW CROPS

FLOWER-STALK REMOVAL INCREASES LEAF BIOMASS PRODUCTION IN *HESPERALOE FUNIFERA*

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Hesperaloe funifera (Agavaceae) is under investigation as a potential new crop producing very high performance fibers for the pulp and paper industry. High biomass yields will be needed to keep feedstock costs low. The plant is a perennial, flowering usually in the third to fifth year of production. Biomass harvests are recommended after the first five years of growth; subsequent harvests can be made every three years thereafter. Flowering is indeterminate with a long flowering season during which the three to five meter-tall stalks produce thousands of flowers, requiring significant amounts of carbohydrate, both from storage and from the current year's photosynthesis.

We hypothesized that removing flower stalks early in their development would result in increased relative growth rates of plants and increased biomass production of the stand.

We tested this hypothesis at the Maricopa Agricultural Center by removing all flower stalks from all flowering plants from nine randomly selected plots for two years; there were nine randomly selected control plots from the same field. Over 70% of the plants in both control and treatment plots flowered during the 1999 or 2000 growing seasons. Aboveground fresh weights of all plants in the 18 plots were estimated at the end of 1998 (before removal), 1999 (after removal), and 2000 (after removal). Estimated fresh weights of plants at the end of 1998 were 2555 g and 2468 g in the control and treatment plots, respectively ($F = 1.24$, $p > 0.05$); after two years of flower-stalk removal estimated fresh weights at the end of 2000 were 5606 g and 7159 g, respectively ($F = 55.6$, $p < 0.001$). Relative growth rates for the 1999 growing season were 0.695 in the control plots and 1.023 in the treatment plots ($F = 71.6$, $p < 0.001$); for the 2000 growing season, they were 0.423 and 0.540, respectively ($F = 13.8$, $p < 0.001$).

These and other results support the hypothesis that removal of flower stalks redirects available carbohydrate from reproductive growth to vegetative growth, increasing leaf biomass production of both individual plants and of whole stands.

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INCREASES IN THE GUM CONTENT OF *PROSOPIS* POD AS A CONSEQUENCE OF INSECT ATTACK

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SALICORNIA BIGELOVII (CHENOPODIACEAE) – A SEAWATER-IRRIGATED CROP WITH VERSATILE COMMERCIAL PRODUCTS

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Finding enough land and water to support the world's food needs is an urgent growing global problem. Over the next 30 years, an additional 200 million ha of new cropland will be needed to support population growth in the tropics and subtropics. Yet only 93 million ha are available, and much of that land is forested and should be conserved. Furthermore, finding enough high-quality water to increase the acreage of irrigated agriculture will be difficult, as the world's freshwater resources are being stretched thinner and thinner. On the other hand, saline land (coastal deserts, inland salt basins, and secondarily salinized farmland) and salted water (seawater and other saline water sources) are abundant and currently underutilized on the earth. In order to exploit these resources for sustainable food production, our research over the past 20 years has successfully domesticated *Salicornia bigelovii* Torr., a wild succulent euhalophyte (naturally salt tolerant plant), as a new crop that grows with seawater irrigation in coastal deserts and can produce multiple products. This paper reviews the progress in the development of its commercial products and agronomic techniques.

S. bigelovii is a leafless, annual plant and thrives in coastal salt marshes and inland salt basins in North America. R & D has identified versatile commercial products from this halophyte crop, such as food, fodder, timber, bio-fuel, fire logs, chemical compounds, and cosmetic products. Moreover, this crop has proven to be environmentally useful in remediation of air (CO_2 sequestration), water (disposal of aquacultural effluents and agricultural drainage waters), and soil (removal of heavy metals, e.g., selenium). As a fresh organic vegetable for human consumption, *S. bigelovii* can be harvested in the vegetative phase. Nutritionally, its green tips provide a good source of minerals (2.6 g), protein (1.4 g), and vitamins A (2400 IU), C (10.7 mg), B1 (270 µg) B2 (45 µg), and niacin (1.5 mg), with a total energy of 30 calories per 100 g fresh tips. Vegetable yield can be as high as 8-9 Mt/ha on our seawater-irrigated farms in Mexico. *S. bigelovii* is primarily being cultivated as a new oil-bearing halophytic crop, since the seed contains high levels of oil (30%) and protein (35%). The oil is edible with a mild nutty flavor and is rich in polyunsaturated fats (90%), particularly linoleic acid (ca. 70%). The meal left from the oil extraction process is a good source of protein supplementation for animal diets and is rich in sulfur-containing amino acids and orthophosphates. *S. bigelovii* straw after seed threshing is used as forage, fire logs, or made into particle board. In addition, R & D has exploited some value-added products from this crop. For example, a line of skin care products with a brand Seaphire™ has been created based on special properties of the oil. On our farms, this halophytic crop yields 12 – 20 Mt/ha shoot biomass and 1.2–1.7 Mt/ha oilseeds.

In the commercial production of *Salicornia*, the most significant expense comes from the cost of pumping. In order to reduce pumping cost, an integrated seawater farming system has been developed and implemented in Mexico and Eritrea. This system consists of seawater-based aquaculture (shrimp and finfish), agriculture (*Salicornia*), and coastal wetland development (other halophytic species). Continuous efforts have also been made in the breeding improvement of *S. bigelovii* cultivars and hybrids, the development of agronomic expertise necessary for a profitable crop, the development of seawater irrigation technology, and the exploitation of value-added commercial products. In addition, field trials of *S. bigelovi* as an alternative crop to reuse agricultural drainage waters in saline land (5,000 – 20,000 ppm TDS) are under way.

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HEMP - A NEW CROP WITH NEW USES FOR NORTH AMERICA

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The ancient cultigen hemp (*Cannabis sativa* L.), grown under commercial license in Canada since 1998, is the most publicized "new" crop in North America. For the past decade, remarkable progress has been made in Europe with respect to breeding cultivars, harvesting, and processing technology, and new uses for industrial hemp. Commercial cultivation in the U.S. is opposed by the government, although several agricultural organizations are lobbying for an American system that would regulate hemp cultivation as in most other Western nations. Biased evaluations by hemp proponents and detractors have made it difficult to evaluate the potential of hemp in North America.

Both in Canada and the U.S., the most critical problem to be addressed is the drug abuse and food toxicity potential of tetrahydrocannabinol (THC). In Canada, 25 mostly European cultivars known to be low in THC are authorized for cultivation, but most of these have limited suitability for Canadian conditions. The future development of hemp in North America is dependent on using European cultivars and germplasm collections to breed suitable varieties. For the last two years, we have carried out comparative analyses of agronomic characteristics and THC content of about 200 of these collections. The Canadian system forbids commercial cultivation of plants testing above 0.3% THC, and on this basis about one-half of the European material would be of doubtful suitability for breeding.

Although hemp was once the world’s leading textile and cordage fiber plant, and was cultivated mostly for these purposes, the North American market is most receptive to the following: oilseed products, particularly salad oil (hemp has an outstanding healthy fatty acid profile), processed foods, nutraceuticals and dermaceueticals/cosmetics, special-purpose industrial oils; fiber products, including thermal insulation materials, molded panels for the automobile and other manufacturing sectors, geotextiles, animal bedding, specialty pulp products (cigarette paper, bank notes, technical filters, and hygiene products), high-strength building materials (fiberboard, fiber-strengthened synthetics), biodegradable horticultural products. Much less certain in North America are the prospects for specialty woven textiles, biomass (fuel and pulp), and essential (floral) oil.

Both the European and Canadian experience suggest that the following classes of hemp cultivars may be successful in North America: (1) Dual-usage (for fiber and oilseed products). Most European and Canadian cultivation is of this type. (2) Oilseed cultivars, particularly fast-maturing, short plants for northern regions (such as ‘Finola’) and cultivars with oil profiles suitable for health and industrial applications. (3) Cultivars for limited-extraction (chopped stems) fiber applications.

Although strongly handicapped by the reputation of its drug cousin, hemp has excellent agricultural, industrial, and ecological properties. With appropriate long-term development it could contribute to relieving the glut of subsidized unprofitable major crops in North America.

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NITROGEN USE EFFICIENCY AND NITROGEN REMOTION BY SEVEN ACCESSIONS OF *GRINDELIA CHILOENSIS* AND *GRINDELIA CAMPORUM* (ASTERACEAE)

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TRANSPLANTING SWEET SORGHUM, AN ALTERNATIVE CASH CROP FOR TOBACCO

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During the past few years, the interest in producing sweet sorghum for syrup has greatly increased. With the loss of income from growing tobacco, many small farmers are turning to sweet sorghum to replace some of their income. Sweet sorghum for syrup is an excellent supplemental crop for tobacco as the net returns per acre are very comparable to tobacco.

Many of the newer varieties of sweet sorghum (*Sorghum bicolor)* are late maturing and must be planted quite early in the upper south or lower Midwest to mature before frost. The system of transplanting tobacco by growing them on float beds appeared to have a good potential for sweet sorghum. There would be several advantages to transplanting sweet sorghum: 1) utilize land that is too wet to direct seed early, 2) increase date of harvest up to 3 weeks, 3) make weed control easier, and 4) spread out the harvest season.

The objective of this research was to determine the proper number of seeds to plant per cell to transplant from 18 to 24 inches apart which is the same as most tobacco is transplanted.

Several float trays were seeded with sweet sorghum seeds with 2, 3, 4, and 5 seeds per cell. The seeds were placed in a 200-cell tobacco transplant tray with the nutrient fortified soil that is used for tobacco seedlings. The plants per cell were transplanted at 6, 12, and 24 inches apart in the row. A check of direct seeding was used to compare with the hill plots. The cultivars Simon, Sugar Drip, Della, Dale and M81E were all evaluated for 3 years. The juice was extracted and weighed to evaluate the relationship of yield and number of plants per hill.

The results were somewhat variable from year to year and between cultivars. Tillering was more in some years that other years. There was very little difference in juice yield between 3, 4, and 5 plants per hill and the juice yield was nearly the same for all spacings between hills. The final conclusion was that 4 plants per hill was best for hill spacings of 12, 18, and 24 inches.

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RESEARCH & DEVELOPMENT OF SEA BUCKTHORN IN CANADA

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Sea buckthorn (*Hippophae rhamnoides* L.) is a hardy, deciduous shrub that belongs to the family Elaeagnaceae. It bears yellow or orange berries and has been used for centuries in both Europe and Asia for food and pharmaceutical purposes. Sea buckthorn has been cultivated across Canada as a new alternative crop, it can be used for many purposes which has considerable economic potential.

Berries persist on the branches all winter due to the absence of an abscission layer and attaching the berry firmly to the fruiting branch providing for difficulties during berry harvesting. It was estimated that the total labor cost for harvesting a sea buckthorn orchard of 4 ha to be 58% of the total cumulative production costs over 10 years. In Canada, the most successful methods of mechanical harvesting have involved shaking the individual branches of the shrub *in situ* to dislodge the berries causing them to fall into a catcher placed around the base of the tree.

Berries yield 60 to 85% juice, which is very high in organic acids as reflected in the low pH of 2.7. The protein levels are fairly high for a fruit juice and this probably reflects the fact that sea buckthorn juice is a cloudy or opalescent product. The vitamin C and E contents are as high as 600 and 160 mg per 100 g of fruit, respectively. Its pulp and seeds contain triglyceride oils important for its medicinal value such as superoxide dismutase activity in mice, enhanced the activity of NK cells in tumor bearing mice.

There are two sources of oil in sea buckthorn fruit, seed (15%) and pulp (20%). The oils from sea buckthorn vary in their Vitamin E content depending on whether derived from seed oil (64.4 to 92.7 mg/100 g seed), juice oil (216 mg/100 g berry) or from the pulp after juice and seed removal (481 mg/100 g berry). Carotenoids also vary depending upon the source of the oil.

Phytosterols can also be extracted from sea buckthorn. The major phytosterol in sea buckthorn oil is sitosterol, with 5-avenasterol second in quantitative importance. Other phytosterols are present in relatively minor quantities. The total quantity of phytosterol is quite high in sea buckthorn and may exceed soybean oil by 4-20 times. Clearly, as a source of dietary sterols, sea buckthorn is worthy of further consideration.

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QUINOA SAPONINS: CONCENTRATION AND COMPOSITION ANALYSIS FOR FORAGE DEVELOPMENT

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Quinoa (*Chenopodium quinoa* Willd) is a plant resistant to low temperature that may be grown in poor soils at high altitudes (2,000-4,000 m). The seeds contain essential amino acids yielding good quality protein (14-18 % dry basis) that is receiving attention in Europe as human and animal feed. The main problem is the bitterness of the seed cover due to saponin concentration. Considering the low growing requirements, quinoa is a possible commercial crop for the arid and semiarid regions.

The objective of this paper was to study saponin composition and concentration of two quinoa varieties during the growing cycle subjected to three soil moisture conditions, and to evaluate the protein and biomass production for forage.

Quinoa was seeded in the locality of Maguey de Ferniza, 20 km from Saltillo, Coahuila, on February 14, 2000. A split plot design with four replications was used. The main plot consisted of three watering treatments: high, medium and low. The subplots had two varieties, 'Sajama' and 'Chucara', obtained from the experimental station of Patacamaya La Paz, Bolivia. Plant sampling was performed during five growing stages (early vegetative, branching, panicle, flowering, and start of grain-fill). Plants were collected from 2 m^2, transported to the laboratory, cut in a chipper, oven-dried, milled, and homogenized for analysis. Fresh and dry weight, saponins concentration, protein content, and yield were determined. Soil moisture was monitored during the experiment. The saponins concentrations were determined by Soxhlet extraction with butanol following successive extractions with solvents of different polarities. Butanol extraction was evaluated after 24 h and 72 h. Protein determination was carried out by the Kjeldahl technique.

Saponin content was in general low for the two varieties that may be considered as "sweet." The ‘Sajama’ variety had lower saponin concentration at the low moisture treatment up to the flowering stage compared with the high and medium moisture treatments. At the beginning of the grain-fill, the two varieties had the lowest saponin concentration in the low moisture treatment. The protein content decreased with increasing age and increased with moisture reduction. Biomass yield at the start of the grain-fill stage was 13.8 t/ha for the high moisture, 9.9 t/ha for the medium and 8.1 for the low moisture treatment in ‘Sajama’ variety and 13.1 t/ha for the high moisture, 9.5 t/ha for the medium and 6.9 for the low moisture treatment in the ‘Chucara’ variety. The results suggest that these varieties are potentially useful as forage.

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NATURAL RUBBER & RESINS

REGROWTH AFTER HARVEST OF ONE- AND TWO-YEAR OLD GUAYULE PLANTS

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Allergies to latex products have become a serious health problem. Guayule (*Parthenium argentatum* Gray) is a source of hypoallergenic latex. One method of harvesting guayule is to allow for regrowth for subsequent harvests, thus eliminating replanting costs and reducing production costs. Data is lacking on the regrowth of new germplasm lines.

The objective of this experiment was to evaluate regrowth of three new germplasm lines (AZ1, AZ2, and AZ3) and an unreleased breeding line (G7-14) following the harvest of one- and two-year old plants.

Lines were transplanted in the spring of 1995 and 1996 at the University of Arizona Maricopa and Marana Agricultural Research Centers. Initial harvests were in the spring of 1997. Lines were monitored monthly for plants with regrowth, plant height, and plant width.

All lines had good regrowth, except AZ1. No differences were observed between locations or plant ages for number of plants with regrowth. The greatest differences for plant height and width occurred between locations with no differences between plant ages. Regrowth of plants of AZ1 was smaller than the other lines.

These results demonstrate that at least two harvests from a single planting of these new germplasm lines should be possible. Multiple harvests should reduce production costs to the grower.

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COMPARATIVE QUALITY TESTING OF ALLERGENIC (*HEVEA BRASILIENSIS*), HYPOALLERGENIC (*PARTHENIUM ARGENTATUM*) AND NONALLERGENIC (SYNTHETIC) LATEX MATERIALS

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Guayule latex (Yulex™) proteins do not cross-react with antibodies raised against latex proteins found in commercially-available products manufactured from *Hevea brasiliensis* latex. Thus, guayule latex is a promising raw material for the manufacture of hypoallergenic latex products, safe for use by people suffering from IgE-mediated Type I "*latex allergy*." Also, guayule latex is a low protein material unlikely to cause widespread sensitization.

We report results from various tests of latex and films made from *Hevea* and guayule as well as from synthetic materials. These tests include (1) a comparison of protein levels in guayule latex and in different types of *Hevea* latex and purified rubber particles, (2) comparison of the hole size caused by hypodermic needle punctures through films from new and aged guayule, *Hevea* and synthetic gloves, and (3) viral barrier test results for new and aged guayule glove and condom films.

The results show that guayule latex consistently contains a very low level of protein compared with *Hevea* latex, and that *Hevea* latex treated with enzymes to reduce protein levels retains high levels in whole latex. The enzyme treatment did greatly reduce the protein level in purified *Hevea* rubber particles, however. Also, using two sizes of needles, needle punctures through guayule latex films consistently resulted in smaller holes than punctures through new or aged *Hevea* or synthetic films. Guayule latex films taken from prototype hand-dipped gloves and condoms provide effective barriers to virus transmission, a property that remains (at least in condoms) during long-term storage (four years).

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SEASONAL EFFECTS ON GUAYULE LATEX CONTENT AND YIELD

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Reports indicate that the rubber content in guayule (*Parthenium argentatum* Gray) is higher in the winter than the summer months. This information can be used for scheduling harvest. Historically, rubber in the plant was extracted by a flotation process, which actually is water-based, but where the extracted rubber is allowed to coagulate. More recently, rubber was obtained with an organic solvent extraction process. In either case, we refer to such extracted rubber as solid rubber and relate it to its use in making tires and other solid rubber products. Interest has now focused on the latex form of rubber to make medical products. This latex rubber is presently obtained on a water-based extraction process and where the rubber particles are not allowed to coagulate.

Past reports on solid rubber yields may not give a true picture of latex yields. The objective of this study was to determine seasonal latex content of guayule to optimize latex yield and relate it to the timing of plant harvest.

The latex contents of four lines (11591, G7-11, G7-15, G7-11 TC) were determined every two months for a period of approximately three years. Field-grown, whole plants were harvested and chipped within three hours after sampling. Latex was removed from the plant using a water-based extraction procedure. The whole plant was ground in a hammer mill chipper where the chipped material could be immediately immersed in a pH-adjusted solution (pH = 11) containing an antioxidant (0.1% sodium sulfite). The chipped material in the solution was further ground in a blender. The latex in the homogenate was separated by coagulation and centrifugation based on a standard procedure.

The latex contents of the various lines were similar. However, the biomass of the various lines was different (G7-11>G7-15>11591>G7-11 TC). Because the latex yield is based on the product of the latex concentration and biomass, the faster growing, larger-size lines would be preferred to obtain the greatest yield. Variations were present for latex content with season, the highest occurring between March through April, but for practical purposes harvest could be done throughout the year without drastically reducing latex yields.

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GUAYULE PRODUCTION: RUBBER AND BIOMASS RESPONSE TO WATER APPLICATIONS

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Rubber and coproduct yields of guayule (*Parthenium argentatum*, Gray) depend on geographic and climatic conditions as well as irrigation frequency. Reports indicate that biomass and rubber yields are increased with an increase in fertilizer and water applications.

The objective of this paper was to study the agronomic management of plants grown in arid and semiarid regions of northern Mexico where water is scarce and rainfall occurs in erratic and short periods of time. The results may help to integrate an alternative income source to maize for potential producers in this region.

Guayule plants were transplanted in the experimental field of the University at Saltillo, Coahuila. in June 1998. Four parcels, one per treatment consisting of 170 m^2 (15 x 11.3 m) with 0.9 m between rows, 0.36 m between plants, and plant density 30,000 plants/ha were evaluated. The four treatments consisted of different number of water applications during the dry season (March-June) to promote plant growth previous to the rainy season (June-September). Treatments included three water applications (T1), two water applications (T2), one application (T3), and no watering (T4). Sampling was carried out two or three times during the year to monitor the biomass, rubber, and resin yields. No fertilizers were applied considering economic reasons.

Differences among the treatments were found. The plants with more water applications were taller and wider than those receiving less or no water. The rubber and resin contents were also affected by season and age.

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COMPARISON OF DIRECT-SEEDED AND TRANSPLANTED GUAYULE

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The commercialization of guayule depends on economical plant production. Direct-seeding has been successful and can reduce establishment costs when compared with seedling transplanting. Most economic and yield analyses have been based on transplants. The performance of direct-seeded and transplanted shrubs grown under the same field conditions, and analyzed by dividing each plant into branch and root sections has never been compared. Our study was designed to determine the productivity of direct-seeded and transplanted guayule over a three-year period. For this purpose, five guayule lines were established by direct-seeding and transplanting, and their biomass, rubber and resin content, rubber and resin yield were compared (branch, root, and total plant samples).

An experiment was initiated on a Delnorte very gravelly loam on 17 and 18 May 1994 at the Texas Agricultural Experiment Station near Fort Stockton, TX. Guayule selections AZ-R2, AZ-R3, 11605, CAL-6, and UC-101 were direct-seeded and transplanted on raised beds spaced 1 m apart. Six plants from each line/replication were harvested on 6 March 1996 and 11 March 1997. Each plant was divided into branch (clipped 10 cm above the soil surface) and root (10 cm of lower branches plus approximately 15 cm of roots) sections.

Guayule branch biomass was greater than root biomass at both harvests. Direct-seeded branch, root and total biomass was significantly lower than transplanted biomass in 1996. After 34 months at the 1997 harvest, no significant differences were observed between direct-seeded and transplanted shrubs. Resin and rubber content (%), and resin and rubber yield (kg/ha) were significantly greater in transplants versus direct-seeded shrubs in 1996, but not in 1997. Thus, direct-seeding would be a viable system for commercially establishing guayule stands. Line AZ-R3 exhibited the least potential of the five lines to overcome the initial growth advantage of the transplants. Lines AZ-R2, 11605, and CAL-6 are recommended for cultivation in western Texas and southern New Mexico.

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MICRO-QUANTIFICATION OF LATEX YIELD IN LIVING GUAYULE USING SCANNING ELECTRON MICROSCOPY

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Guayule (*Parthenium argentatum* Gray) rubber particles are formed in bark parenchyma cells and latex yield determinations have required the destructive harvest and extraction of branches which severely limits the frequency of yield determinations. This limitation, coupled with the relatively slow growth rates in the greenhouse and field, has hampered development of new higher-yielding lines of guayule by preventing early screening of new germplasm and the determination of treatment effects.

We have shown that latex yield may be accurately quantified, without causing permanent damage to the plants, in even the youngest of stems. Quantification is performed by excising small sections of bark, freezing, and fracturing the tissue, and then counting the rubber particles in different bark parenchyma cells under a scanning electron microscope (SEM). The method was tested over a wide range of latex concentrations, established by testing young, middle-aged and old stems from greenhouse-grown guayule lines, the hybrid line AZ101, *P. tomentosum*, and *P. incancum*. In each case, a section approximately 5 x 2 mm was excised and examined. The 5-cm length of stem on both sides of the excision (a 10-cm length, with the excision in the middle) was homogenized and the latex content determined using standard techniques. Additional excisions were made so that the recovering of the stem post-excision could be followed.

Twenty-one samples, with a latex content ranging from 0.73 to 39.45 mg/g dry weight of shrub (standard quantification method), generated a correlation coefficient of 0.85, d.f.=19 with the SEM quantification method. All plants survived the excision and the affected branches continued to grow.

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MEADOWFOAM AND OTHER NEW CROPS

THE MEADOWFOAM GENOME AND GENOME MAP

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Meadowfoam (*Limnanthes alba* Benth.) is a predominantly allogamous, self-compatible, diploid with a small haploid chromosome number (x = 5), the same as *Arabidopsis*, a model species with a physically small genome (1.50 pg). One of the goals of our laboratory has been to develop a dense genetic map for meadowfoam comprised of sequence-based markers for mapping economically important trait loci and accelerating the development of superior genotypes through molecular breeding. The physical and cytological characteristics of the meadowfoam genome have not been described, and the present genetic map of meadowfoam is solely comprised of amplified fragment length polymorphisms. Our specific aims were to describe the karyotype and physical size of the meadowfoam genome and develop a simple sequence repeat (SSR) map for meadowfoam.

The physical size of the meadowfoam genome was estimated using flow cytometry of nuclei isolated from leaf, root, and stem samples of OMF40-11 stained with 4,6-diamidino-2-phenylindole (DAPI) or propidium iodide (PI). The DNA content of the diploid nuclear genome was estimated to be 5.48 pg; thus, the meadowfoam genome is ca. 3.65 times larger than the *Arabidopsis* genome. Karyotype analyses were performed using metaphase root tip chromosomes of OMF86 stained with 2% aceto-orcein. The nucleolar organizing regions (NORs) were highlighted on mitotic metaphase chromosomes by *in situ* hybridization with radio-labeled *Arabidopsis* 5.8, 18, and 26S rDNA probes. The genetic map was constructed by genotyping 94 (OMF40-11 x OMF64) x OMF64 BC1 progeny with 112 SSR markers and was comprised of 90 SSR loci dispersed among five linkage groups with 12 to 25 SSR loci per linkage (12 SSR loci segregated independently).

The five linkage groups presumably correspond to the five haploid chromosomes of meadowfoam. The map was 970.2 cM long with a mean density of ~10 cM and minimal clustering of loci. The map is a powerful tool for molecular breeding and genomics research in meadowfoam.

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MAPPING GENETIC FACTORS UNDERLYING LOW ERUCIC ACID CONCENTRATION IN MEADOWFOAM

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The consumption of erucic acid (22:1D^{13}), a fatty acid present in the seed oils of meadowfoam (*Limnanthes alba* Benth.), rapeseed (*Brassica napus* L.), and several Brassicaceae, has been linked to increased risk of heart disease. Because low erucic acid phenotypes have not been discovered in meadowfoam, we developed an induced mutant (LE76) with low erucic acid and are developing low erucic acid cultivars. The erucic acid concentrations of wildtype lines typically range from ~8.5 to 23.2%, whereas the erucic acid concentration of LE76 typically ranges from ~2.8 to 3.9%. The official industry standard for the low erucic acid designation in rapeseed is 5.0% or less. The erucic acid distributions of F_2 progeny from crosses between LE76 and three wildtype lines (OMF86, OMF40-11, and OMF64) were continuous and complex. Because LE76 was developed by chemical mutagenesis, we presumed that the low erucic acid phenotype was caused by a macromutation; however, the mutation(s) present in LE76 did not produce discrete, non-overlapping phenotypic distributions and must be mapped as quantitative trait loci (QTL).

We developed F_2 and $F_{2:3}$ progeny from the cross between LE76 and OMF86 and constructed a genetic map using 120 simple sequence repeat (SSR) markers. QTL affecting erucic acid will be mapped and described. The cross between LE76 and OMF64, an *L. alba* ssp. *versicolor* line with 22.0% erucic acid, failed to produce low erucic acid progeny; the lowest concentration was 5.8%. Conversely, crosses between LE76 and wildtype *L. alba* ssp. *alba* lines (OMF86 and OMF40-11) produced progeny with low erucic acid (~3.5%). We speculate that OMF64 and other *L. alba* ssp. *versicolor* lines carry a linked mutation (natural allelic variant) that interacts with the low erucic acid mutation(s) in LE76.

The development of near-isogenic lines (NILs) and low erucic acid cultivars should proceed more rapidly and efficiently by using flanking DNA markers to introgress the underlying mutation(s). The development of low erucic acid cultivars may be essential for the development of pharmaceutical and food markets for meadowfoam oil.

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INTRODUCTION AND ESTABLISHMENT OF MEADOWFOAM AS A NEW CROP IN VIRGINIA - LESSONS LEARNED

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The meadowfoam research in Virginia had its beginning with a small observation plot, which was planted at the Randolph Farm of Virginia State University in 1992. This effort led to the commercial production of approximately 120 commercial acres in Virginia during the 1998-1999 season with the assistance of Oregon Meadowfoam Growers Association. Seed yields up to 800 pounds/acre with an oil content (dry weight basis) varying from 21 to 25 percent have been obtained. The oil contained approximately 93% long chain fatty acids (20- and 22-carbon). The current meadowfoam production recommendations in Virginia include planting with a grain drill with approximately 7-inch row spacing in early December with about 25 pounds of seed per acre. The nitrogen needs of meadowfoam are minimal and approximately 30-40 pounds of N per acre is optimum. Currently, there is a complete lack of approved herbicides for weed control in meadowfoam in Virginia. The commercial production of meadowfoam in Virginia is in limbo due to many factors especially the lack of site-specific production technology and uncertain marketing. Lack of locally-adapted weed management system has also played a major negative role. Starting with the 2000-2001 season, a concerted effort is underway to facilitate development of meadowfoam as a new winter oilseed crop in Virginia. The history of meadowfoam introduction and establishment in Virginia, over the last several years, has been educational.

The lessons learned have indicated that, for such efforts to succeed, a knowledgeable person, such as a breeder, should be heavily involved in commercial production efforts at least during earlier stages of crop adoption. A locally-adapted production system should be developed with close interaction between early producers and the researchers and an operational system. The role of extension personnel in such efforts is crucial, but they need to work very closely with the researchers. This presentation will discuss these issues to provide a general protocol for introduction and establishment of new crops.

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MEADOWFOAM GROWER SKILL SETS

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Excess production capacity, surplus quantities of agricultural commodities, and globalized agriculture have kept recent crop prices low, forcing farmers off the land. In those countries where these commodity prices were once cushioned by government subsidies, tariffs and crop production controls, markets may now be vulnerable. Profitable new crop options are needed, and aggressively being sought around the world. However, overproduction of a new crop product can easily and quickly destroy stable embryonic demand-price structure, and wipe out the new industry.

New crops are particularly vulnerable to free-riders, profit-takers, and pirates who have little regards for the long-term potential of a grower industry and rural economies. Therefore, farmers need new mindsets and skills to survive. Economic survival depends on skills to reduce risk and increase profits. Farmers have high skill levels in crop production technologies. They are being challenged to gain skills to form new mutually beneficial alliances and participate more actively in their farm products' value chains. Such skills may require behavioral changes, which are difficult to assimilate -- particularly in agriculture, and other industries dominated by commodities. Relational skill development is vital for nurturing trust among cooperators, such as growers, scientists and even administrators in the public sector, so they can make profitable commitments together.

Such an approach is being followed with the meadowfoam industry. It was launched in 1984 as an association of farmers in the Willamette Valley of Oregon. Now, the Meadowfoam Oil Seed Growers Cooperative (OMG), with membership open to all producers, grows the crop under contract, with the central objective of seeking sustainable economic returns for primary producers by balancing product supply with demand. An OMG subsidiary buys the seed, then extracts, refines, and markets the oil worldwide. OMG seeks multi-faceted positions to shield grower risk capital exposure from: (1) growers, who seek nonexclusive rights to grow meadowfoam varieties separate from the OMG cooperative, (2) non-grower opportunists who seek to divide and prevent unity which is inherent in a grower cooperative, and (3) attempts to set farmers bidding against each other to lower the market price of oil. The former seeks economic advantage by behaving as though the crop was a commodity.

The study objective was to foster new skills through encouraging more grower involvement in meadowfoam industry leadership. Both university-directed small-plot, replicated yield trials and grower-designed and managed replicated agronomic studies were conducted in growers' fields. The study increased trust and agronomic and economic understanding for some growers, enabled frustrations to be shared, and encouraged growers to contribute to the industry. The total package of factors involved in the meadowfoam industry and the perspectives of 80-100 growers are very complex. We seek expertise to support this type of rural development. Relational skill development for farmers, scientists and administrators is an overarching necessity. We believe it will reduce the transactional costs of carrying out the increasing number of tasks critical to farm success, reducing the risk in the process.

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RAPD-PCR ANALYSIS AS A TOOL IN *SALICORNIA* BREEDING

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Salicornia bigelovii (Chenopodiacea) is a leafless, succulent, annual salt marsh plant that completes its entire life cycle on undiluted seawater. It colonizes shifting mud flats in coastal estuaries through its prolific seed production. *S. bigelovii* can tolerate salinity up to 80,000 ppm in sandy soil and produce versatile commercial products. For example, the seed contains superior quality of edible vegetable oil for human consumption. The meal contains high levels of protein (40%) and relatively low levels of salts (7%), making this a desirable feed for animal consumption. Thus, *S. bigelovii* is an ideal new oilseed crop for coastal deserts and salinized lands, provided that its seed yield and undesirable traits can be further improved.

In order to assess the genetic variability and yield potential of *S. bigelovii*, 20 wild populations of *S. bigelovii* were collected from seven geographically distant regions across North America. These populations are serving as a basis for a systematic breeding to improve traits. In the present study, samples from the population groups were subjected to the random amplified polymorphic DNA (RAPD) analysis, with an attempt to investigate the genetic diversity and population structure in this species and to identify molecular markers associated with economically important traits.

Based on all loci produced by tested RAPD primers, the analysis of POPGENE (Yeh et al. 1999) showed that the gene diversity in *S. bigelovii* was 0.27 ± 0.18 (mean ± SD, $n = 45$) and the percentage of polymorphic loci averaged 77.8%. However, different native populations differed in the RAPD variation. Populations collected from Texas (USA) and La Paz (Mexico) appeared to display large variation. In contrast, most of the RAPD loci in a population from California coast remained monomorphic. According to Nei's genetic distance (1978), a dendrogram of genetic relatedness showed that fifteen native populations grouped into three main clusters, which were in agreement with their geographical distribution. This revealed that spatial effects might lead to the genetic differentiation in *S. bigelovii*. Using the Analysis of Molecular Variance (AMOVA, Excoffier 1996) to assay the partitioning of molecular variance in this plant, 50.37% of the RAPD variation was found among populations and 49.63% within populations, suggesting the necessity of widely collecting *S. bigelovii* germplasm (more wild populations and more samples within a population as well) for the breeding program. In addition, correlation analyses of RAPD loci to important traits revealed a molecular marker associated with the content of saponins (a major anti-nutritional factor) in *S. bigelovii* seeds.

To sum up, the results obtained from this research showed that the RAPD-PCR analysis would be used as a powerful tool in the development of *S. bigelovii* as a profitable oilseed halophyte crop.

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BORAGE AGRONOMY ON THE BLACK SOIL ZONE OF ALBERTA, CANADA

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