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Program Abstracts

PLENARY SESSION

WELCOME TO CANADA

Peter McCann

FROM MEADOWFOAM TO CRAMBE - THE USDA SEARCH FOR NEW INDUSTRIAL OIL SEED CROPS

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In 1957, the Department of Agriculture in an effort to reduce crop surpluses entered into the new crops program. The initial program was shared by the Industrial Crops Laboratory at the Northern Regional Research Laboratory, Peoria, Illinois and the Crops Research Division in Beltsville, Maryland.

The program surveyed seeds sampled from around the world in an effort to find new and unusual seed oils or rich supplies of useful materials in seed oils that were only found in minor amounts in seeds.

The organization and the people were surprisingly successful in their goal. Seed from more that 8000 species of plants were examined from over fifty countries. The impact of the program is still being felt with emerging crops such as meadowfoam (*Limnanthes alba*), crambe (*Crambe abyssinica*), and jojoba (*Simmondsia chinensis*) a direct result of the effort. Species from genera such as *Cuphea*, *Vernonia*, *Euphorbia* and *Lesquerella* are poised to take their place in the agriculture of the United States and the world. In addition, the new crops program provided basic knowledge in new materials, new analytical methods, and new agricultural techniques.

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Top of Page

Return

NATURAL RUBBER & RESINS

INCIDENCE OF SPROUTINGS IN GUAYULE UNDER IRRIGATED AND DRYLAND CONDITIONS

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One of the most common kinds of vegetative propagation among plants is the production of shoots from underground stems. The guayule (*Parthenium argentatum* Gray) plant fits into this category and uses it for survival under adverse conditions.

The objectives of the present study were: to evaluate the incidence of sproutings in guayule under irrigated and dryland conditions, and to estimate biomass, main stem diameter, plant height, and rubber and resin content of the shrubs.

The study was carried out in the Experimental Field Buenavista at the University Antonio Narro in Saltillo, Coahuila, Mexico, in February 2002. Four parcels of guayule of 152 m² each were evaluated (16 × 9.5 m). The furrow spacing was 0.9 m, and between plants of 0.36 m, for a plant density of 30,864. The four-year-old plants, during their development, were under a watering treatment during the dry season (March-June) to promote plant growth previous to the rain season (June-September). Irrigation treatments were: T1, three; T2, two; T3, one irrigation, and T4, no watering at all. In the field, 50% of the plants of each parcel was evaluated by recording the number of sproutings per plant. Ten plants per parcel were collected and taken to the laboratory for evaluation of biomass, main stem diameter, plant height, and rubber and resin content.

Differences were not observed in the sprouting's development in the different watering treatments. The mean values were five sprouting per plant, which shows that they develop even in the treatment without watering. The four-years-old plants had a biomass of 631 g plant^{-1} (T1), 515 g plant^{-1} (T2), 441 g plant^{-1} (T3) and 191 g plant^{-1} (T4). The rubber content was similar in all parcels at 5.1% (T1) to 5.9% (T2) and the resin ranged between 10.7 (T1) at 14.3 (T3) .

The sproutings in guayule develop even under low-water, dryland conditions, which should be taken into account in the eventual reproduction of this shrub.

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GERMINATION OF GUAYULE (*Parthenium argentatum* Gray) SEED

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Guayule production is dependent, in part, on the quality of the seed used for stand establishment. The long-term objective of this research is the improvement of seed quality in guayule with the objective of the research reported here being the improvement of the germination percentage and rate.

Standard germination tests were performed with four 25-seed replicates used for each treatment. Seeds were placed in Petri dishes with two filter papers on the bottom moistened with water equivalent to 2.5 times the substratum weight (the two filter papers) and germinated at 25°C and 24 hours under fluorescent lights for two weeks. Seed coat color, seed size and germination were measured on all seeds, and the following preconditioning treatments were analyzed: PEG 8000, KNO_3, GA_3, NaOCl, and thiram.

Seeds characterized as black or dark in color tended to germinate at higher levels than the lighter-colored seeds, and the preconditioning treatments PEG 8000, KNO_3, GA_3 and thiram improved germination percentage and

rate. Results showed that germination is affected by NaOCl, and when added to seeds without initial presoaking in water decreased the germination percentage and rate. These results show that guayule seed germination differs depending on the seed color and pre-treatment, but not seed size.

In conclusion, our results indicate that dark seeds presoaked in water and treated with 2 to 3% of NaOCl for 2 to 4 min can be used to improve germination percentage and rate. Also, the preconditioning treatment standardizes the germination percentage and rate. Size and color are factors limiting commercial handling and performance of the seeds, respectively, and must be considered in future investigations.

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EFFECTS OF HERBICIDES ON DIRECT-SEEDED GUAYULE

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Recent studies have shown that guayule can be successfully direct-seeded. An effective preplant or preemergence herbicide is critical for optimum stand establishment. Several chemicals must be tested on different soil types across the potential guayule growing region (Texas, New Mexico, and Arizona). Guayule seedlings grow slowly and produce about 1 cm top growth and 5 cm root growth two weeks after emergence. Therefore, the young seedlings cannot compete against the faster growing weeds.

This study was designed to observe the tolerance of a direct-seeded guayule population to the following preplant incorporated herbicides: bensulide, DCPA, and pendimethalin.

The experiment was initiated at the University of Arizona Maricopa Agricultural Center on May 14, 2002. The experimental design was a randomized complete block with four replications. Herbicide treatments consisted of single raised beds spaced 102 cm apart and 9 m long, treated with bensulide (2.2, 3.4, 4.5 kg ai/ha), DCPA (4.5, 9.0, 11.0 kg ai/ha), and pendimethalin (0.6, 1.1, and 2.2 kg ai/ha). Treatments were applied using a CO_2-powered backpack sprayer with a single-nozzle boom (Teejet 8002 flat fan nozzle) delivering 300 l/ha at 172 kPa. The herbicides were incorporated to a 10 cm depth with one pass of a tractor-driven tiller.

Conditioned guayule seed (selection AZ-2) was then planted 1 cm deep on each bed with a Gaspardo SV255 pneumatic planter. The seeding rate was 100 seeds/m. The study was sprinkler irrigated for 13 days, and maintained by furrow irrigation afterward. Evaluations were conducted at weekly intervals by counting seedlings in 1 m long subplots in each herbicide treatment.

Maximum seedling emergence occurred 10 days-after-planting. There were little differences between herbicide treatments 13 days-after-planting. Seedling mortality was noted and was probably due to salt damage by the sprinkler irrigation. Sprinkler irrigation should be discontinued 7-10 days-after-planting to minimize this problem. The number of seedlings in the medium rate of pendimethalin (1.1 kg ai/ha) was not different from the control. This rate corresponds to the recommendations for cotton. The preplant herbicides tested have good potential for weed control in direct-seeded guayule.

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SALT TOLERANCE STUDIES WITH GUAYULE

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Arid and semiarid lands, soils and water contain salts. The cultivation of conventional crops may partially or totally fail due to their low salinity tolerances. The pool of native desert plants might naturally exhibit a greater salt tolerance, which appears to be a tempting and convincing reason to select potential crops from this plant pool for cultivation in salt-affected areas. Guayule (*Parthenium argentatum* Gray) is native to the Chihuahuan Desert, producing natural rubber and resin. Previous studies have identified guayule as low salt-tolerant plant.

This preliminary study investigates salt tolerance levels of various guayule lines during germination and first-year of growth. Growth characteristics and rubber and resin production will be determined for each salinity level.

For the germination trials, five lines of guayule seeds were germinated in petri-dishes under one control and four salinity levels (2,500, 5,000, 10,000, and 20,000 ppm NaCl). For the plant growth experiment, six lines of guayule transplants have been exposed to one control and four salinity levels (2,500, 5,000, 10,000, and 20,000 ppm NaCl) under greenhouse conditions. Plant height and width have been recorded biweekly. Two harvests will take place after 140 and 280 days. determining Fresh weight, dry weight, root-shoot ratio, and rubber and resin contents will be determined.

All six guayule lines had delayed and decreased germination rates with increasing salinity levels. The six guayule lines in the greenhouse study tolerated salinity levels of up to 2,500 ppm NaCl with slightly stunted plant growth. Plants from all lines irrigated above 2,500 ppm NaCl died.

The hypothesis that salinity enhances production of secondary metabolites in guayule is still not proven. After plant analysis, more data will be available to test such hypothesis.

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GROWTH PATTERNS OF TRANSGENIC GUAYULE

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This study is being conducted to determine whether the insertion of genes that synthesize precursors in the rubber biosynthesis pathway can increase rubber production in guayule (*Parthenium argentatum)*, thereby increasing overall rubber yield. Three lines, AZ101, N6-5 and G7-11, had either farnesyl diphosphate (FPP) synthase or geranylgeranyl diphosphate (GGPP) synthase inserted using Agrobacteruim mediated transformation. Controls were the same lines transformed with the plasmid that lacked the genes for FPP synthase or GGPP synthase. The transformants were isolated on a kanamycin selection media. Plants were proliferated in tissue culture before being transferred to the soil, and then transplanted into the field at The University of Arizona, Maricopa Agricultural Center in May and October 2001. Beginning in November 2001, height and widths measurements were taken monthly. Stem samples for rubber and resin analysis were harvested 3 May 2002. Most plants had very little growth between November 2001 and March 2002, but significant increases in both height and width occurred between March and May 2002.

There were no significant differences between heights of the transformants and their controls, with the exception of the AZ101 transformants A1-4 e and A4-4 a, which were significantly larger. There were no consistent patterns in width between transformants and their controls. Rubber and resin contents for each transformant are currently being analyzed. It appears from initial growth data that most transformants are not responding to transformation with increased growth, with the possible exception of the AZ 101 transformants mentioned previously.

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FREQUENCY DISTRIBUTION ANALYSIS OF BIMONTHLY GUAYULE LATEX YIELD FOR SELECTING OPTIMAL HARVEST DATES

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Because guayule (*Parthenium argentatum*, Gray) is a perennial plant, harvesting for latex could conceivably be feasible throughout the year. Reports show that the rubber content increases during the cooler months, but this observation cannot be used as a guide for the optimum harvest period. Intuition would lead to the conclusion that harvest during the fall-winter months would be preferable to the summer months, but no evidence is available to support this type of harvesting scheme.

The objective of this study was to apply the frequency distribution technique for the latex content data collected on a bimonthly basis to improve estimating harvesting times. Previously seasonal variations in latex content were noted, but the statistics used did not provide clear-cut differences that could be used to make recommendations on the optimal harvest period.

A three-year data set was used that included latex analysis for three guayule lines sampled bimonthly. The years were separated into three separate groups and the bimonthly samples divided within each year. In addition, the latex contents for each sampling date for each line were arbitrarily categorized as either “high” or “low” and the frequencies of such designations were noted to characterize the harvest date for each of the plant lines. The frequency distribution was then tested by appropriate statistical analysis.

Contingency table analyses indicate the appropriateness of the frequency distribution approach applied for the data set. The analysis indicated that the frequencies of high versus low yields are significantly dependent on the month of the year at the $P < 0.0001$. Thus, the frequency tables developed showed clearly that the months for latex harvest for Arizona is through the November and succeeding January through March periods. The May through July harvest period will have the low latex yields.

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Top of Page

Return

OILSEEDS

INFLUENCE OF CHIA ON TOTAL FAT, CHLORESTEEROL, AND FATTY ACID PROFILE OF HOLSTEIN COW’S MILK

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A feeding trial was conducted with multiparous lactating Holstein cows to determine the effect that feeding chia (*Salvia hispanica L.*), an emerging oilseed crop rich in w-3 a-linolenic fatty acid, would have on milk.

Total fat, cholesterol, and fatty acid profile were compared between two groups of cows fed a chia supplement,

and a control supplement, over a period of 94 days.

Milk production was not significantly different (P<0.05) between the two groups of cows. Cholesterol and total fat contents were lower in the milk obtained from the cows fed the chia diet. However, no significant differences (P<0.05) were detected. Oleic, linoleic (w-6) and linolenic (w-3) fatty acids were significantly higher with the chia diet than with the control diet, as was total polyunsaturated fatty acid. No significant differences in saturated fatty acids were detected between treatments. Significantly (P<0.05) lower SFA:PUFA and SFA:w-3 ratios in the milk were found as compared to those of the control diet.

These improvements would make milk more acceptable to health conscious consumers and could increase milk consumption, which has been decreasing in recent years.

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CHIA CONSUMPTION - EFFECT ON BLOOD CHOLESTEROL, HDL, LDL, AND TRIGLYCERIDE LEVELS IN HUMANS

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Coronary heart disease is a major health problem in the western world. A number of research studies have determined that diet can significantly reduce an individual's propensity to suffer from this disease as well as a number of other diseases. Consumption of omega-3 fatty acids has been shown as one way to reduce these risks. Chia (*Salvia hispanica L.*), an oilseed rich in w- 3 a- linolenic fatty acid, has recently been commercialized as a crop in South America.

The objective of this preliminary study was to determine the effects of eating chia could have on blood composition for people with high levels of cholesterol and triglycerides.

For the study, 16 subjects were selected. One group consumed 28 g of chia seed each day, the other a placebo. Duration of the trial was 28 days. Twenty days prior to initiating the trial, all subjects stopped taking all other medications, which were being administered for the purpose of regulating blood composition. Blood cholesterol, HDL, LDL, and triglyceride levels were measured at that time, and then again the day before the subject began consuming chia. Blood samples were also drawn at the end of the trial.

Results were inconclusive. Significant differences in mean cholesterol, HDL, LDL and triglyceride values between the two groups were not detected. An analysis of covariance, however, showed that HDL and triglyceride levels were different between groups, with the difference favoring the consumption of chia.

Clearly, additional studies using either a larger population or less diverse group of individuals are needed to verify the effects that chia consumption can have on blood composition.

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HARVEST DATE AND METHOD FOR *Cuphea* IN THE NORTHERN CORN BELT

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Cuphea (Lythraceae) is rather unique among plants that grow in temperate climates because its seed storage lipids are primarily composed of medium-chain triglycerides. Semi-domesticated genotypes developed from crossing *C. viscosissima* x *C. lanceolata* show good potential for commercial production. *Cuphea* has an indeterminate growth habit and flowering and seed maturation can occur over a 4 to 8 week period. Seed capsules that initially form during reproductive phase, by the end of the growing season, tend to split at the dorsal surface allowing seed to shatter. Little is known about when or how to harvest present *Cuphea* genotypes in order to maximize seed yield.

The present study was initiated in 2000 to determine the optimum period and method to mechanically harvest *Cuphea* in west central Minnesota. *Cuphea* (PSR-23) was sown in 61 cm spaced rows with a Marliss no-till grain drill at a rate of 6.7 kg of seed/ha on 15 May in 2000 and 10 May in 2001. Harvests were taken at weekly intervals between 23 August and 21 September in 2000 and 13 August and 23 October 2001. Methods of harvest that were evaluated included wind-rowing, defoliating with paraquat and combining, treating with Roundup and combining 8 to 14 days later, and straight combining.

Results clearly showed that greatest seed yields were obtained in late September to early October, corresponding with the average time when the first “hard” frost (i.e., ≤ -2°C) in this region occurs. Death and dehydration of plants facilitated by freezing aided seed harvesting. However, freezing also hastened seed shattering. During 2001, harvested seed yield increased almost 2.5-fold between 31 August and 11 October with a hard frost occurring 6 October. By 17 October, yield declined 63 %, likely due to seed shattering. Of the harvest methods evaluated, straight combining with a small grain header, typically used for soybean, gave the best results.

Initial results indicate that when planted in early to mid-May, the best time to harvest *Cuphea* in west central Minnesota is late September to early October, similar to the time frame used for soybean production in this region. The best mechanical harvesting method appears to be combining with a small grain header.

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PRODUCTION AND SEED YIELDS OF LESQUERELLA

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Seed yields are critical in determining the economic success of lesquerella. There have been reports of yield potential based on individual plants and on small-plot estimates. A decade ago, attempts were made to produce lesquerella on farmers’ fields to increase seed to measure seed yields. The objective of this study was to determine the amount of progress made since then in breeding and agronomy of lesquerella by again planting on farmers fields. Seeds from the newer released germplasm selections were used. and yields, oil content, and oil quality were measured.

We planted lesquerella on two farms in Texas and two in Arizona in the fall of 2001. The two Texas plantings were sown on the flat in 20 acre fields, one with a center pivot irrigation system and one with flood irrigation. One of the farms in Arizona was 25 acres, planted on raised beds with furrow irrigation, and the other was a 5 acre, flat field with flood irrigation.

The germination was uniform at the flood-irrigated Texas farm, and less uniform at the farm with the center pivot. However, it was necessary to abandon both Texas fields because of an unusual fall-occurring hailstorm that destroyed many of the seedlings. Germination of the Arizona 25 acre field was limited to the sides of the beds and in the furrows. Germination did not occur on the top of the beds, presumably due to salinity. A uniform stand was obtained at the Arizona flat 5 acre field. Weeds were controlled by a preplant application of Treflan followed by Goal and Fusilade.

The seed yields from the combine in the 5-acre field were 1,507 kg per ha (1687.5 lbs per acre). Hand harvested

plots from this field were 1549.2 kg per ha (1735.5 lbs per acre). The seed yields from the combine in the 25-acre field were 950 kg per ha (1064.8 lbs per acre). The hand harvested plots were 980.5 kg per ha (1098.2 lbs per acre). Yield estimates from previous experiments on farmers' fields ranged between 714 and 1071 kg per acre (800 and 1200 lbs per acre).

These results indicate that lesquerella yields have improved due to improved breeding lines and agronomic practices. Seed yields from flat fields were more than 60% greater than yields obtained from raised beds.

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PHYSICAL PROPERTIES OF LESQUERELLA OIL ESTOLIDES

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Lesquerella fendleri is a winter annual seed oil crop native to the desert southwestern United States and is currently undergoing an intensive research effort for its successful introduction into agriculture. Lesquerella produces a small seed that has 25 to 30% oil which contains 55 to 64% lesquerolic acid.

Triglyceride-estolides were synthesized from the hydroxy moieties of lesquerella and castor oils with a series of saturated fatty acids and oleic acid. Estolides where one hydroxy moiety is esterified, and estolides where all the hydroxy moieties are esterified were made. Typical reactions required stoichiometric amounts of fatty acid to oil and were run in the absence of catalyst or solvent. The reactions were performed either under a vacuum or under a nitrogen blanket depending on the chain length of the capping fatty acid. Complete esterifications were possible under these conditions in 24 to 48 h at 200°C.

Pour points, viscosity, viscosity index, and oxidative stability were determined on both castor and lesquerella estolides. The triglyceride estolides had pour points between -15 to -39°C and cloud points between -5 to -45°C. Viscosities ranged between 100 to 216 cSt at 40°C with viscosity indices between 115 to 191. Rotating Bomb Oxidative Stability (RBOT) of the triglyceride estolides were compared with and without anti-oxidant present and correlated to the iodine value of the material. Lower iodine values gave longer RBOT times than their more unsaturated counterparts.

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DESCRIPTION OF *Vernonia galamensis* SEED OIL: EFFECTS OF SELECTION ON LOW FREE FATTY ACIDS AND HIGH VERNOLIC ACID CONTENT, AND OIL DEVELOPMENT PATTERNS

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The seed of *Vernonia galamensis* contains an epoxy fatty acid, 12,13 epoxy-*cis*-9-octadecenoic acid, which is a valuable industrial oil. Steady progress has been made on improving vernonia as a viable crop to be grown in the United States and elsewhere. The oil has many applications including the production of plastics, protective coatings, and lubricants. Alternative products derived from vernonia oil include dibasic acids and secondary amines. While epoxidized linseed and soybean oils meet current epoxy oil needs, vernonia oil is considered more suitable for many applications due to its lower viscosity.

This study was conducted to determine potential improvement in oil quality by selecting for low levels of free

fatty acids (FFA) and high levels of vernolic acid in vernonia seeds. Our research also included a study of oil development in vernonia seed. Vernonia oil has long been recognized as having a high percentage of FFA in extracted oil. Poor seed handling and oil extraction techniques can compound this problem. Several researchers have proposed inactivating lipase in seeds prior to oil extraction, but our research found that several agronomically desirable accessions have >5.0% FFA in intact seeds, which is greater than the generally accepted standard of 0.5%.

Vernonia seeds were collected over two growing seasons from accessions provided by the U.S. Water Conservation Laboratory in Phoenix, AZ. Eighty-four half-sib families were evaluated during the first growing season and selections were made. Progress was evaluated in the second growing season. To study oil development, capitula were tagged on the first day of anthesis and collected at intervals throughout both growing seasons. All constituent fatty acids from the oil were quantified for each growing season. Oil and FFA were separated using solid phase extraction columns. The oil fraction was transesterified with its constituent fatty acids quantified and identified using gas chromatography. FFA was quantified using colorimetric assay.

Measurements from the first growing season show that the accessions used for this research contain considerable variation for levels of vernolic acid, total oil, and FFA. Total oil ranged from 20.3% to 53.6% with vernolic acid ranging from 12.7% to 42.9%. The FFA content ranged from 4.2% to 25.4%. After ranking all three variables together, the top 14% of accessions were selected for evaluation the following growing season. Results from this study and for the oil development study will be presented. Continuing improvement of vernonia will hopefully encourage commercialization of the crop providing alternatives to farmers in the United States and abroad.

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Top of Page

Return

GENERAL CROPS

THE PENDING ENERGY BILL COULD LAUNCH COMMERCIALIZATION OF ENERGY CROPS IN THE UNITED STATES

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It is technically feasible to use a wide range of plant biomass, including both herbaceous and woody material, to produce energy as either liquid fuels (such as ethanol, methanol, and bio-diesel.) or electric power. Consequently, the U.S. Department of Energy has been funding research on the development of energy crops since 1978. This work has been directed out of Oak Ridge National Laboratory in Tennessee, but to date the only commercial energy plants that have been built to process crops are ethanol facilities that use corn grain as a feedstock. Federal subsidies are necessary to make ethanol-from-corn competitive with gasoline, and with the pending ban on MTBE as an octane enhancer in gasoline in many states, demand for ethanol as a replacement is expected to rise sharply.

The pulp and paper industry is probably the largest current producer of power from biomass, because this process is economical within the industry as it eliminates the need to dispose byproducts such as bark. Pulp mills also use the power they generate internally, thus saving the retail price, instead of selling power at the wholesale price, which is usually about one-third of the retail value. Even though a 1.5 cents/kwh tax credit for closed loop biomass power systems has been available for over a decade, no new independent biomass power plants have been built in the U.S. Part of the reason for this is the high capital cost associated with such facilities. Co-firing biomass with coal at existing coal-fired power plants avoids the need for major capital equipment, but under current regulations this technology does not qualify for the tax credit.

The Senate Version (which is already passed) of the pending Energy Bill currently being considered in Washington D.C. contains a 1.5 cents/kwh tax credit for co-firing biomass from energy crops with coal to produce electricity. It also requires utilities to produce 10% of their power from renewable sources by 2020. These sources include hydro, wind, solar, geothermal and biomass. However, in regions such as the Southeast, biomass is the only realistic option.

The significance of the 1.5 cents/kwh is that it amounts to about a $30/ton subsidy on biomass. Therefore, if a farmer delivers biomass to a power plant at $50/ton, the price paid by the utility is $20/ton. At 10% moisture, biomass contains about 14 million btu/ton, which, at $20/ton, translates to $1.43/million btu. This price is highly competitive with coal, which usually costs $1.50 to $1.80/million btu. In addition, co-firing biomass with coal offers distinct environmental benefits, especially reductions in CO_2, SO_x, NO_x and mercury emissions. It is concluded that if the 1.5 cents/kwh tax credit remains in the final version of the Energy Bill, along with the 10% (or some modification thereof) renewable energy requirement by 2020, commercialization of large scale energy crop production will almost certainly be initiated in the United States in the near future.

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A HARVESTING SYSTEM FOR *Hesperaloe* LEAVES

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The long, strong, thin fibers found in the Arizona native plant, *Hesperaloe*, can be used to produce an ultra-light-weight coated paper used for magazines, catalogs and newspaper inserts. *Hesperaloe* may also be used as a strengthening pulp in recycled papers.

Hesperaloe is grown on beds spaced 1 m apart. The succulent leaves of *Hesperaloe* plants are very difficult to harvest as they grow 1 to 2 m tall and have an oblong base of 2 × 5 cm. Each mature plant has a 30 cm diameter rosette base from which up to 100 leaves emerge. Plants are ready for harvest when five years old with a yield expectation of 220 t/ha. There were four objectives in this study. The first objective was to develop a mechanized system to cut the leaves close to ground level and to windrow them. Objective two was to remove the leaves from the field without disturbing the bedded rows. Opening or cracking the heavy cuticle of the leaves to allow drying was the third objective. The fourth objective was to compress the dried leaves into convenient sized packages for shipment to a pulping plant.

A harvesting machine was developed to cut the leaves 5 cm above ground level with two counter-rotating 60 cm diameter saw blades. The cutting mechanism was mounted on a modified cotton picker chassis and utilized the existing picking-head height sensor to control the leaf cutting height. Approximately 25 kW of power was used to drive the cutting blades and a forward speed of 1.2 km/h was achieved. The cut leaves were manually loaded into tractor drawn carts, each holding up to 350 kg. Canvas slings were placed in the carts before loading and were used to transfer each load to the crushing unit feed table. A 60-cm wide roller mill was mounted on transport wheels and fitted with a feed table and appropriate shielding. The *Hesperaloe* leaves were fed by hand between the crushing rolls. A week of field drying reduced the water content of leaves to less than 10 %. A three-wire commercial hay baler was modified to compress the dried leaves into 85 kg packages for shipment.

The cutting and baling components of the system have performed adequately. However, the removal or picking-up of the leaves in the field and the crushing process are too labor intensive for a viable commercial operation. A machine that will pick up the cut leaves, masticate or shred the leaves and load them into a self-unloading wagon for removal from the field is being investigated. It is possible to mechanically harvest and package *Hesperaloe* successfully. Although current methods are highly hand-labor intensive, more labor efficient machines are being actively developed.

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INDIAN RICEGRASS: A GLUTEN-FREE CEREAL

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Celiac disease is a genetically inherited, medical condition in which the absorptive surface of the small intestine's mucosa is damaged by the protein, gluten. As a result, the body cannot absorb nutrients. The celiac, when exposed to gluten can show a wide array of symptoms: anemia, bloating, chronic diarrhea, cramps, fatigue, flatulence, irritability, severe weight loss, and intense skin rashes. It is estimated that one in two hundred North Americans is affected to some degree by Celiac disease. Symptoms are variable and the disease can only be determined by intestinal biopsy. There are no cures for celiac disease. The disease can, however, be managed by diet. Diets specifically exclude common cereals containing gliadin proteins such as wheats, barley, rye and oats. A search was initiated at Montana State University to determine whether there were cereals with properties conducive to baking and similar products. Indian Ricegrass (*Oryzopsis hymenoides*) had been, and still is, utilized by early Native American societies in the western states and prairies of North America as a cereal. Testing of the flour derived from Indian Ricegrass (IRG) showed that it was gluten-free and suitable for most baking and related products.

Indian ricegrass is a hardy, perennial grass inhabiting much of the prairie from Canada to Arizona. It is one of the most water efficient cereals known.

The objective of this study was to determine best production practices in perennial cultivated IRG. Best practices are to be determined for use in maximizing biomass production, seed yield, protein content and test weight of 'Rimrock' IRG.

Rimrock' IRG was planted 10 November 2001 at the Northwest Agricultural Research Center in Creston, MT on a Creston loamy sand soil. Treatments included nitrogen at 45, 90 and 135 kg/ha, irrigation using a line source system and seeding rate at 6 and 12 kg/ha. Stands of IRG were estimated at 90% with some losses due to spring snowmelt. With full stands established, nitrogen rates were applied on 10 May 2002 in three replications. The irrigation plots were applied perpendicular to the fertility and parallel to the seeding rates. Irrigation applied was measured via rain gauges at two-meter intervals through the plots. Biomass and seed yields were not affected by fertilization or irrigation in this study. Protein and test weight data indicate some improvement in cereal quality with fertility but little impact from irrigation. Biomass was affected by seeding rate as expected since IRG is typically a slow growing bunchgrass.

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Top of Page

Return

POSTERS

NEW LUBRICANTS VIA MONO-ESTOLIDES

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There has been an increased interest in vegetable oil-based lubricants and functional fluids over the past few years. Vegetable-based oil derivatives have many advantages over petroleum-based products, such as wear properties and biodegradability. Some of the main problems with current vegetable-based fluids are its cold

temperature properties, pour and cloud points, and cold temperature storage properties, which limits the geographical area that vegetable-based fluids may be used. Estolides are one such derivative from new crop oils that show promise in industrial applications as functional fluids. Estolides have excellent low temperature properties compared with mineral and vegetable-based materials.

The objective of this study was to synthesize a novel series of mono-estolides and to compare the cold temperature properties with commercially available mineral and bio-based materials.

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 low equivalents of acid with no solvent followed by the addition of 2-ethylhexanol *in situ*. The estolides were converted to their corresponding hydroxy fatty acid and the degree of polymerization was determined by GC analysis. In some cases, the mono-estolides were distilled from the larger poly-estolides.

The mono-estolides were then evaluated as potential lubricants and functional fluids. Physical properties (pour points, viscosities, color, OSI and RBOT) of these novel estolides were compared with previously reported estolides, which have current industrial applications as a potential functional fluid. The mono-estolides were found to have low temperature properties that exceed the normal vegetable and mineral type fluids. A series of mono-estolides was formulated to the standards as a biodegradable fluid and exceeded the ones currently in the market.

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EFFECTS OF PLANT DENSITY AND IRRIGATION ON SUNFLOWER (*Helianthus annuus* L.)

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Comarca Lagunera, located in the southwest of the Mexican state of Coahuila, is the main Mexican milk producing region based on irrigated agriculture. The present strategy consists in identifying more efficient water management practices for alfalfa production than traditionally used. Sunflower (*Helianthus annuus* L.) represents an alternative for forage production in this region.

The objectives of this study were to determine the production of dry matter, grain yield and oil and protein contents in sunflower variety SANE 23578 under two population densities and three irrigation time schedules.

Sunflower was seeded on 29 July 1999, in the Experimental field “El Retiro” of the Universidad Autónoma Agraria Antonio Narro in Torreón, Coahuila, using a randomized block design with three replications. The treatments were two population densities; 52,000 representing the normal density (ND) and 104,000 plants per ha, the high density (HD). Three irrigation schedules were selected, namely C1 (irrigation at 59 DAS); C2 (irrigation at 49 DAS) and C3 (irrigations at 49 and 59 DAS). The evaluated variables were, total dry matter, panicle dry matter, leaf area index, and oil and protein contents.

The analysis of variance did not show differences among the population densities, nor for irrigation dates or for production of dry matter. The dry weight accumulation rate for both densities was 0.13 g day^{-1}. The panicle weight represented 50% of the amount of the plant’s total dry weight. For grain yield, differences ($P \leq 0.05$) among population densities appeared, as well as for irrigation time schedules, and (D × C) interaction.

Sunflower dry matter production had a similar behavior, both for the densities of 52,000 and 104,000 plants per ha and independent of irrigation applied at 49 and 59 DAS.

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AGRONOMIC AND QUALITY BEHAVIOR OF INTERMOUNTAIN-CARGILL CANOLA GENOTYPES IN SOUTHERN SONORA, MEXICO

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EFFECTS OF CLIMATE ON THE RESPONSE OF QUINOA (*Chenopodium quinora* Willd.) var. CHUCARA AS RELATED TO SOWING TIME AND SOIL WATER DEFICIT

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Quinoa (*Chenopodium quinoa* Willd) is a traditional Andean pseudocereal increasingly attracting attention as an alternative forage crop in the semiarid areas of Mexico because of its adaptability to unfavorable soil and climatic conditions, and for its high nutritional value. The objectives of this study were to evaluate the effects of climate on the dry matter production and protein and saponin contents in quinoa (var. Chucara) under two soil-water deficit and two development stages, and to determine the water-use efficiency on dry matter and protein yields.

The experiment was carried out in two localities of the Municipality of Saltillo, Coahuila, México and in four sowing dates, one in the Jagüey of Ferniza (03/14/2000-spring 2000) and three in Buenavista (03/13/2001-spring 2001; 06/11/2001-summer 2001 and 09/03/2001-autumn 2001). A randomized block design was used, with two soil water deficit treatments, and four replications. The water deficit treatments consisted of: TI, 40%-50% available soil moisture, and TII, 10%-20% available soil moisture. Cuts were made in the panicle forming and flowering stages. The evaluated variables were production of dry matter, protein and saponin contents, and water-use efficiency.

The analysis of variance indicated significant differences ($P \leq 0.01$) for sowing dates in the production of dry matter and saponin concentration. Also, the soil water deficit treatments had significant differences ($P \leq 0.01$) for dry matter production. The highest dry matter yields occurred in the spring and summer 2001 in the TI treatment in the flowering stage. The saponin concentration was smaller (0.46%) in the TII of the spring 2000 sowing. The protein content did not show differences in the sowing dates. The best climatic conditions (temperature, precipitation, insolation) were present during the spring-summer 2001 sowing that favored a higher production of dry matter.

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AUTOCLAVE PECTIN EXTRACTION OF LEMON (*Citrus aurantifelia*) POMACE CHARACTERIZED UNDER LABORATORY CONDITIONS

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The extraction process is the key operation for obtaining pectin. For the industrial scale, the pectin is extracted by chemical methods where strong acids are used, but have some disadvantages. Investigations have begun to develop alternative processes. The autoclaving process has been used for extraction of potato pulp pectin, but the extraction period is still too long.

The objectives of this study were: to develop a laboratory method for the preparation of lemon pomace or pulp by the autoclave pectin extraction process with and without citric acid; to minimize the extraction period; to evaluate the physics and chemistry of the extraction process; to evaluate the recycling of depectinized pomace to obtain pectin for sequential extraction, and to compare the laboratory extracted materials with those obtained by industrial procedures.

Lemon (*Citrus aurantifolia*), 6 kg, was cut in half and the juice extracted manually. The weight of the seeds, bagasse, and rind was measured> The rind was then scalded with water vapor in an autoclave and then washed, and dried, milled, and stored. The pomace fractionation was carried out in a vibrating system RO-TAP using 10-, 25-, 50-, 80-, 100-, and 140-mesh screens. The galacturonic acid (GAA) content was quantified as well as the Total Sugars (TS) in the lemon pomace for the different particle sizes. For pectin extraction, lemon pomace, of 25 mesh was used with a 30% galacturonic acid (GAA). For the sequential and comparative extractions, a 5 min period was used with citric acid. For comparison, pomace from Tecomán, Colima; Apatzingán, Michoacán, and Argentina were used.

The rind yield was 26%. The relationship between the humid pomace/wet rind was 19.80%. Retention frequency in mesh 10 (42.5%) was greater than mesh 25 (26.75%). The GAA contents, as an index of pectin extracted, were significantly greater in the larger size mesh particles than the smaller size. Similar behavior was observed for the AT contents.

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CHARACTERIZATION OF LEAF AREA DYNAMICS IN FLAX (*Linum ussitatisimumj* L.)

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CHEMICAL COMPOSITION AND POTENTIAL USE OF THREE SPECIES OF *OPUNTIA* FROM THE CHIHUAHUAN DESERT REGION OF MEXICO

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Opuntia imbricata (Haw.) DC. or “coyonoxtle” grows on the plains, hills, and grasslands and pinyon-juniper woodlands from Colorado, Arizona, New Mexico, Texas, Oklahoma, and Kansas of the United States, to Chihuahua, Coahuila, Nuevo León, Zacatecas, San Luis Potosí, Querétaro, Hidalgo, and Distrito Federal in Mexico. *Opuntia leptocaulis* DC. or “tasajillo” inhabits the plains and hills from Arizona, Oklahoma, Texas, and Baja California, Sonora, through the Chihuahuan Desert, to Puebla (Mexico). *Opuntia stenopetala* Engelm. or “nopal serrano” or “nopal colorado”, is common on the hills with pinyon woodlands from Coahuila, Nuevo León, Tamulipas, Zacatecas, San Luis Potosí, Querétaro, and Hidalgo.

The objective of this study was to evaluate the chemical composition, and the potential use of three species of *Opuntia* inhabiting the Chihuahuan Desert Region in Mexico.

The coyonoxtle and tasajillo collections were made on 6 September 2001 at San Juan del Retiro in the state of Coahuila 36 km from the University Antonio Narro. The mountain nopal (nopal serrano) was collected in San José's mountain in the State of Nuevo León 47 km from the University. The samples were taken to the laboratory and separated into stems (cladodes), and fruits (tunas), dried, milled, and prepared for analysis. The analyzes included crude protein, fat, ash, manganese, iron, and zinc contents and *in vitro* digestibility.

The fruits of the three species of *Opuntia*, in general, had the largest chemical composition, the nopal serrano with protein (6.41%), fat (11.62%), and ash (87.56%), larger than the tasajillo with protein (5.54%), fat (5.69%), and ash (77.9%), and the coyonoxtl with protein (6.15%), fat (4.65%) and ash (84.89%). The stems of the *Opuntia* had protein contents of 2.21% (nopal serrano), 3.8% (tasajillo), and 5.39% (coyonoxtle). The fat contents were similar ranging from 1.49 to 1.9%, and the ash contents varied from 60 to 70%.

The fruits of coyonoxtle, tasajillo, and nopal serrano, because of their chemical composition, can have a wide variety of nutritious, medicinal, and industrial applications that would provide added value, profitable for the inhabitants of the Mexican desert region.

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INDUSTRIAL, NUTRACEUTICAL, AND PHARMACEUTICAL USES OF CASTOR GENETIC RESOURCES

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Castor (*Ricinus communis* L.) is a plant used in the industrial, nutraceutical, and pharmaceutical areas. Modern agricultural research is now encompassing new crops such as castor due to discoveries and identification of phytochemicals in castor for preventing certain ailments and for medical applications.

The objective of this study was to identify various phytochemicals from castor genetic resources conserved at the USDA, ARS, Plant Genetic Resources Conservation Unit. Castor’s unique usefulness for these phytochemicals including their current or future uses will be discussed.

Several novel phytochemicals have been discovered and identified in castor with application in the nutraceutical and pharmaceutical industries. Phytochemicals such as beta-sitosterol, chlorogenic acid, ellagic acid, and many more have been found to be antileukemic, cancer preventive, antitumorous, and pesticidal.

Nutraceutical and pharmaceutical phytochemicals will help people with certain ailments and improve their added value use as an alternative crop.

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PORTABLE STEAM DISTILLATION UNIT FOR ESSENTIAL OIL PRODUCTION IN ALBERTA

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In Alberta, significant efforts are underway to enhance the agriculture and agri-forestry sectors in value-added production and processing. The Essential Oil Industry encompasses aromatherapy, perfumery, fragrance and/or flavoring, medicinal, and related health and wellness products. Essential oils can be derived from a variety of cultivated and noncultivated crops. In the commercial forest regions of Alberta, spruce, pine, poplar, fir, larch and related species can be used for essential oil production. Global market opportunities exist for essential oils, but producers and harvesters are limited in ability to process crop materials at the site.

The objectives of this project were to design and construct a mobile distillation unit and deliver a technology transfer and training program.

The portable steam distillation unit was designed and manufactured by the Agricultural Value-Added Engineering Centre. The unit is trailer mounted and consists of a: 4 hp low pressure propane fired boiler, 250 liter steam jacketed stainless steel distillation vessel, water-cooled, parallel-piped multi-tubular stainless steel condenser, and a stainless steel receiver for separating and collecting the essential oil. The distiller requires a potable water supply of at least three gallons per minute and a standard 120 V, 15 A electrical service.

Several training workshops were held in 2001 and 2002 to train operators and producers in distillation techniques and operating procedures. The workshops covered the basics of steam distillation, theory and the actual use of the unit. An operating manual and resource guide were prepared to assist producers in steam distillation of essential oils.

Samples of essential oil were analyzed with a gas chromatograph to identify components and constituents of the various oils. A database of Alberta essential oil information is being generated from the results.

A prototype steam distillation unit was designed, constructed, and demonstrated to help Alberta growers and producers develop the essential oil industry. The unit continues to provide Alberta producers the opportunity to gain hands on experience in essential oil production.

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Top of Page

Return

Top of Page

Return