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Project title: *Production and evaluation of biofuel from canola and mustard irrigated with agricultural water on the Westside of central California*

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Major Objective:

Growers on the Westside of the San Joaquin Valley have tried to reduce their production of Se-laden effluent and thus sustain their agricultural land in central California. The Water Management Research Lab has studied the reuse of drainage water for producing canola and mustard; hence reducing the volume of Se-laden agricultural effluent to dispose. In order for mustard and canola to be widely accepted as potential crop, and be used as practical tools to manage the volume and Se content in effluent produced in the Westside of the SJV, it is imperative that viable economical uses for the harvested plant product be created. After growing the crops with poor quality waters, we harvested the seed, and are currently processing the seed with our "oil mill". The canola and mustard oils are to be further processed (transesterified), blended with diesel, and used as a source of B20 biofuel for operating diesel-powered engines.

Thus the primary objectives of this multi-year study were:

1) Grow commercially viable acreage of canola and mustard as recipient crops for disposal of Se-laden effluent.
2) Extract canola and mustard oils seed from our "oil mill" at Red Rock Ranch.
3) Process the canola and mustard oils and bring them to ASTM quality.
4) Evaluate the effects of using B20 blends of canola and mustard oil in diesel-powered engines and evaluate performance and emission quality in biofuel-powered irrigation pumps.

Major Accomplishments:

Generally 40 ha plots were planted to canola and mustard at Red Rock Ranch on an annual basis (Figure 1). Both plantings received Se-laden water as the primary source of irrigation water, when available. Water quality consisted of an electrical conductivity of 5-7 dS/m sulfate salinity, 5-7 mg B/L and 0.15-0.20 mg Se/L Soil samples were collected to a depth of 0-90 cm at a preplant and at harvest for each respective crop and location.

Total plant biomass and seeds were harvested and yields recorded. Plant biomass values were as high as 5.5 tons/acre, while seed yields averaged 2 tons/acre for both canola and mustard. Both soil and all plant products were analyzed for Se content. Plant Se concentrations, including seeds, ranged from 2 to 4 mg Se/kg DM for all plant organs, while total soil Se concentrations averaged 1.5-2.0 mg Se kg^{-1} at 0-45 cm depth and 1.0-1.5 mg Se kg^{-1} at 45-90 cm depth, respectively, at the end of growing season.

Harvested canola and mustard seed were processed with our retrofitted extruder and horizontal press ("oil mill") located and housed at RRR (Figure 2). Extraction modifications to operate the "oil mill" were performed by personnel at RRR. Structural and mechanical changes were necessary for bringing the "oil mill" (for seed pressing) under compliance of the SJV Air Pollution Quality Control Board regulations. Because the manufacturer of the "oil mill" failed to inform us of many obstacles related to processing canola seed instead of soybean seed, John Diener's mechanical engineers continually retrofitted our oil mill components in conjunction with the designers of the equipment. With much added time and extra expense for John Diener, we had to acquire a used "shaker/sifter" that most importantly removed rocks from the seed before the seed was moved into the "oil mill." It is imperative for future efforts associated with oil pressing and biofuel production that manufacturers send their own personnel to initially set-up and operate "oil mill" under field conditions. We have processed over 300 tons of canola and mustard seed with our Model 2000 RC Dry Extruder with Top Feeder and a Model 1500 Insta-Pro Continuous Horizontal Press. The upgraded extruder and oil press processed between 15-20 tons of seed per day. We realistically extracted up to 90% of the available oil in canola and mustard seed (Figure3 and Figure 4). Extracted oil was processed (i.e., transesterfied by another company at no cost in Ventura, CA) and then the ASTM quality biofuel was mixed with diesel and the resultant BD 20 fuel was used to power diesel-powered stationary irrigation pumps on Red Rock Ranch under heavy irrigation load. We generally estimate that if we ideally achieve seed yields of canola/mustard as high as 4000 kg/ha, that we can produce a high of 7600 L of BD 20 fuel (80 % diesel and 20% canola oil) per ha, if we can extract at least 90% of the available oil (≈35 %) contained within the seed.

Initially, funds were available on a delayed basis for this project. This delay resulted in a late ordering of analytical equipment necessary for emission evaluation, and a late arrival of the equipment. In conjunction to this delay, the dynamometer and the diesel engine at CSU Fresno were not in certifiable condition for performing emission analysis of biofuel consumption. Because of this, we were unknowingly redirected into the new construction of our mobile emission lab (Figure 5). NO_x, CO/CO_2 analyzers were bought and we evaluated the initial ability of these NO_x, CO/CO_2, and SO_2 analyzers to analyze standard gases under controlled laboratory reproducible conditions, before we tested emission quality from biofuel-powered irrigation booster pumps under field conditions. The pretesting allowed us to determine the capability of our emission equipment to simultaneously analyze a range of concentrations of the above gases. The analyzers were eventually placed inside a mobile trailer to potentially analyze emissions emitted as exhaust from biofuel-powered irrigation booster pumps operating under heavy irrigation load under field conditions. The mobile analyzing trailer allowed us to easily travel onto any field site to perform the emission analysis. Preliminary emission testing of the canola-based BD 20 biofuel under field conditions on the Cummings 5.9 L diesel irrigation booster pumps used at Red Rock Ranch showed average reductions of CO (14%), CO_2 (13%), and THC (11%) compared to emissions emitted from the same booster pumps operating on petro diesel. Reductions in NO_X were not clearly observed. Significant NO_x reductions (>100%) were measured after injectors within the diesel engine were cleaned when operating on diesel. This observation clearly shows the importance of maintaining properly tuned engines. Data obtained from the gas analyzers have shown us the limited capabilities of these analyzers even under a controlled environment to simultaneously measure NO_x, CO, CO_2, and PM. Hence, we must realistically analyze each component separately. These extra steps will increase the time it will take to measure the volatile emission gases under field conditions (work is still in progress).

In light of the extremely poor air quality in the central SJV, a decrease in petrodiesel consumption and a potential decrease in emissions of CO, CO_2, and THC with increase usage of biofuel consumption could give the agricultural community the first-hand ability to reduce air pollution by partially switching from petrodiesel to blended biodiesel in irrigation booster pumps (note: there are over 5,000 such pumps in operation in central California). Presently, Red Rock Ranch (4,500 acres or 1,875 hectares in size) consumes about 250,000 gallons (950,000 liters) of diesel per year on site. Reducing this consumption by even 20%, with the production and use of Red Rock-produced BD20 biofuel, certainly adds a commodity benefit to the Se phytomangement strategy, as well as its contribution to improving the overall air quality in the SJV.

Our testing up to early 2010 at least demonstrated that the coupling of Se phytomanagement (using plants as recipients of Se-laden waters) with biofuel production may provide growers with a unique opportunity to increase environmental sustainability in areas with high Se conditions and reduce some usage of petro-diesel in sensitive parts of California. However, we importantly emphasize that good quality soils and waters should not be utilized for growing oil-producing crops that will eventually be used for

producing biofuels. Most important, other sources of energy, e.g., gasification, will be essential for operating larger-scale oil presses, since the costs to utilize electricity from the "grid" can be exceedingly high. Moreover, more acreage planted to *Brassica* oil crops on "non-food producing soils" is essential for operating the oil press on a sustained basis. This will require the formation of developing co-ops and increasing the planted acreage of oil producing crops. In regards to effects of biofuel consumption on air quality, more research is needed "under load" situations to determine if sustained reductions in NO_x production is possible when unregulated irrigation booster pumps are operating on BD 20 biofuels. Other benefits that may be just as important as the production of biofuel, are the supplemental usages of the residual seed meal (after oil extraction). These uses are currently under investigation and hopefully the remaining monies from this project (circa $13,000) can be used in a subsequent DWR agreement to investigate these usages of Se-enriched meal. These include; using the seed meal as a supplemental source of organic Se for maintaining animal nutrition, and as a biofumigant for preventing weed emergence and reducing root knot nematode infestation. These works have been initiated but their continuation is dependent upon using the residual DWR monies to continue their investigation.

Importantly, we were able to organize a special conference on the "Role of Selenium in Human Health and the Environment" in Suzhou China (September 2009), and highlighted this DWR funded research, that was also sponsored by the ARI and USDA. The conference was a huge success, and attracted major attention for researchers working in Se-rich regions of China and India, especially where the production and use of biofuel is strongly advocated. Work with the *Brassica* plants has led to the future evaluation of new oil-producing plant species, e.g., camelina, jojoba, that are currently being evaluated for their salt and B tolerance, Se accumulation, and oil production capabilities in our drainage-impacted soils of the Westside of the SJV. If cultivation of biomass crops for fuel production becomes widely practiced in California, additional studies such as those described here will be needed to optimize their rotation with the high-value specialty crops which are important and unique to California agriculture. One thing is certain-if biofuel crops become a major part of the agricultural landscape in California, scientists and growers will be looking carefully at crop sequencing with the idea that employing their residues as soil disinfectants and sources of organic Se can provide additional measures of usefulness and sustainability to their cultivation.

Publications

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Figure 1 Mustard grown at Red Rock Ranch

Figure 2 Oil press at Red Rock Ranch

Figure 3 Extracted oil from canola seed

Figure 4 Residual seed meal after oil extraction

Figure 5 Measurement of emissions from biofuel-powered tractor