PHYTOMANAGEMENT OF SOLUBLE SELENIUM AND PRODUCTION OF BIOFUEL AND BIOFORTIFIED NEW PRODUCTS

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ABSTRACT

In many areas of the western US, excessive concentrations of soluble selenium (Se) in the environment can cause Se toxicity to biological organisms. The use of green plants to manage the soluble Se content in soils by plant uptake and biological volatilization has been considered as a cost-effective strategy. Importantly, the development of economically feasible remediation systems will encourage more widespread implementation of an integrated phytomanagement technology. The objective of this presentation is to firstly discuss the use of salt and boron tolerant crops grown for the management of natural-occurring Se in soils and waters in the Westside of central California and secondly to discuss the derivation and novel production of Se-fortified products and other potential by products that were primarily developed from Brassica plant species.

INTRODUCTION

The use of green plants and associated microbes for environmental remediation has been called *phytoremediation.* This green technology is being developed for the management of metal(loid) contaminated soils and waters via the processes of phytoextraction, phytovolatilization, and phytostabilization. Based upon these processes a plant management remediation strategy for selenium (Se) has been developed for the Westside of central California (Bañuelos et al., 2002; Lin et al., 2002; Zayed et al., 2000). Bañuelos (2009) concluded that using a plant-based system for field phytoremediation on a sustained basis will eventually require the production of viable plant products from the cropping systems. Bañuelos et al. (2002) initially hypothesized that harvesting Se-enriched crops may produce products of potential economical importance for growers. These include; Se-enriched plant material for humans and animals, biodiesel made from extracted canola and mustard oils, and seed meal used as a biological herbicide, and a Se feed supplement. The objective of this presentation is to report on different plants grown for the management of soluble Se in central California soils and on the derivation and novel utilization of potential bio-based products.

METHODS

Long term multi-year field studies were conducted with *Brassica napus* var. Hyola (canola), *B. juncea* (mustard), and *B. oleracea* var. Marathon (broccoli), on field sites in central California. Water used for irrigation had a range of Se from 0.100-0.150 mg L^{-1}, B from 4-7 mg L^{-1}, and has a sodium sulfate-dominated salinity (EC) of 5-8 dS m^{-1}. Canola and mustard plants were harvested for leaves and seeds, and broccoli for florets. Seed was mechanically processed onsite for its oil, and residual seed meals were collected. Oils were further processed to ASTM quality, and B20 biofuel blends were produced for diesel-powered engines. Residual mustard seed meal was applied to soils, and its herbicidal effects was evaluated in strawberry production, while canola seed meal was used as Se supplement in dairy feed. All samples were analyzed for Se by ICP-MS (Agilent 7500cx, Santa Clara, CA) after digestion with HNO_3, H_2O_2 and HCL.

RESULTS

The multi-year field studies showed that these Brassica crops were moderately more effective for managing soluble Se to a depth of 50 cm than irrigated unvegetative sites. Losses of soil Se occurred primarily via accumulation, biological volatilization, and leaching from the upper soil profile. Brassica seed yields were between 3 to 3.5 metric tons ha^{-1}. Preliminary oil yields extracted from both seed types ranged from 570-600 L ha^{-1}, which were available to be used for producing a B20 biofuels (20% oil blended with 80% diesel) after transesterification. The residual Se-enriched canola seed meals (approximately 1.85 mg Se kg^{-1}) added daily to animal feed rations for 8 weeks increased milk Se concentrations to 65 ~µg L^{-1} from 37 µg L^{-1} in Holstein and Jersey cows. Mustard seed meal incorporated at 4 Mg ha^{-1} into strawberry production prevented the emergence of at least 12 different types of weeds in a sandy loam soil. Moreover, Se concentrations were as high as 3.5 mg Se kg^{-1} in broccoli, and resulted in Se-biofortified florets.

DISCUSSION/SUMMARY

Coupling phytomanagement of Se with the creation of new biofortified and byproducts, e.g., Se-enriched vegetables, animal feed, biofumigants, and even a byproduct like biofuel, may provide California growers unique opportunities to increase the environmental and economic sustainability of a plant Se-management system, while supporting the agriculture community in central California. These on-going field studies show that the phytomanagement of Se-contaminated soils by canola, mustard, broccoli, not only remove soluble Se that has accumulated on the soils, but harvesting these crops produces cash value bio-based products. As Se is an essential trace element in animal and human nutrition, Se deficiencies are generally a far greater problem than Se toxicities in livestock animals. In addition to utilizing the vegetative parts of the plant for animal forage, Se-enriched seed meal, a major by-product resulting from the oil extraction process of seed crushing, pressing, and extruding, is of high nutritional quality for use as part of a feed ration. The more bioavailable forms of Se in the canola seed meal and its low glucosinolate content are important qualities for using this seed meal in animal feed. In contrast, the higher glucosinolate value in the mustard seed meal is likely the family of compounds, primarily responsible for exerting the observed herbicidal effects. Lastly, the use of blended biofuels on farm sites may result in a reduction in certain atmospheric pollutants (e.g., particulate matter, carbon monoxide, volatile organic compounds). If this multi-faceted phytoremediation system proves to be sustainable and is accepted by growers, there could be long term economic benefits, as well as improved water and air quality associated with agricultural production in the SJV. Moreover, sustained production of canola and mustard crops may offer Westside growers a holistic phytoremediation system for managing contaminants, like Se, and transforming them into valuable biofortified products and byproducts.

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