This selenium is too low, this selenium is too high,

SOUTH DAKOTA SELENIUM IS JUST RIGHT

Lyman County farmer-rancher Steve Taylor knew the selenium-rich soils that underlie some of his fields and pastures could be a problem. Through the years he's occasionally had horses start to go lame and observed cows that have had trouble conceiving.

Those are symptoms of what scientists know now is selenium toxicity, first documented in 1860 in what would become South Dakota. The surgeon general of the U.S. Cavalry described the complaint in horses and cattle at Fort Randall, less than 100 miles as the crow flies from Taylor's ranch. Under Fort Randall are the same West River soils, formed from the parent materials soil scientists describe as Pierre shales and Niobrara marls, as on Taylor's farm.

But while too much selenium can be toxic to both animals and humans, some is necessary, and a growing body of research suggests selenium delivers real health benefits. That explains why, starting in the 1990s, Taylor began to reap some profits—literally—from those selenium-rich soils.

BUYERS FROM GERMANY AND AUSTRIA were glad to pay premium prices for wheat grown in Taylor's fields because it is considerably higher in selenium than ordinary wheat. The Europeans market it to health-conscious consumers in their home countries who are interested in selenium because of its role as an anti-oxidant that may have cancer-fighting properties.

"A lot of places in the world are low in selenium," Taylor explains. "There's a demand and I think there's a need for it."

Studies investigating the various ways selenium intake is related to human health are going forward in various universities. They have shown selenium can reduce the risk of heart disease by protecting against arterial deposits and helping regulate blood pressure. Other studies have explored the activity of selenium on the tumor-suppressing gene p53.

Selenium is found in nuts, vegetables, and whole grains, and wheat is thought to be the most efficient of the common cereal crops in accumulating selenium. So, as more becomes

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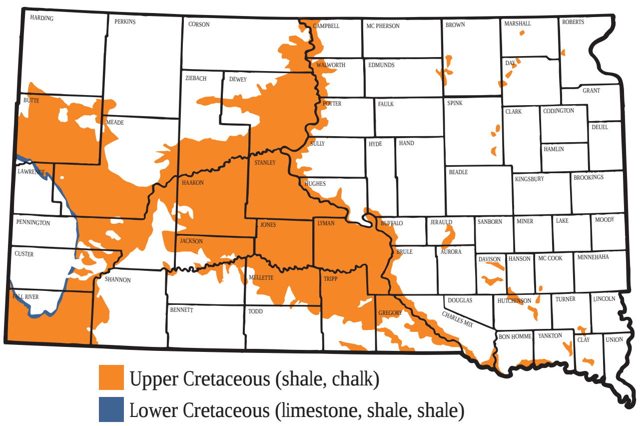

Location of marine shale deposits in South Dakota. Selenium-bearing soils form from these deposits.

known about selenium’s helpful effects when included in the right amounts in the diet, demand for selenium-rich wheat—such as that which grows on parts of Steve Taylor’s farm—is likely to increase.

Randy Englund, executive director of the South Dakota Wheat Commission, says South Dakota has long been known for top quality spring wheat and winter wheat. The possibility of being able to sell selenium-enhanced wheat from some parts of South Dakota would give buyers from selenium-deficient countries additional incentive to buy wheat from South Dakota, he says.

“Mother Nature has provided a potential marketing advantage for South Dakota if we can add that nutritional benefit to our high quality wheat.”

MOTHER NATURE IS ALSO HOLDING TIGHT to her secrets. There are many questions about what happens in the plant and in the soil to make plants take in selenium. Furthermore, selenium is not uniformly distributed across fields.

“A lot of people don’t understand that. They think if you’ve got a 100-acre field, you’re going to get 100 acres of wheat high in selenium. That hasn’t been my experience,” Taylor says.

After an earlier SDSU research project did a grid sampling to check the selenium levels of wheat in the dough stage on his land, Taylor was able to roughly map out selenium “hotspots” in his fields so that he could harvest those locations separately. Within a 300-acre field, Taylor calculates that he has about 10 acres quite high in selenium, and an additional 30 acres that are “fairly high.”

But Taylor still notes that the wheat harvested off those selenium-rich parcels will vary in selenium content, depending on the growing season. Taylor’s own experience in marketing selenium-rich wheat to European buyers tells him that from year to year, the same half-section of land will produce lots of wheat with selenium contents varying from 9 parts per million, 10- , 12-, and up to 20 parts per million.

Jim Doolittle, SDSU soil scientist, says research is beginning to look at the difference that agronomic practices can make in determining how much selenium plants take in. For instance, research at some universities suggests elevated sulfur content in the soil solution somehow inhibits selenium uptake.

Doolittle notes that phosphorus may have the opposite effect and actually increase selenium uptake. That was the focus of a greenhouse study Doolittle undertook with Sang-Hun Lee, graduate student, funded in part by the South Dakota Wheat Commission.

“We know that phosphorus plays a role. What’s currently thought is that it helps by competing for the adsorption sites on the soil,” Doolittle says. “Our premise was that phosphorus would displace some of that selenium on those binding sites, making it more available for plant uptake.”

Lee says that explains why selenium uptake by plants is not predictable based on total soil selenium concentration: Uptake is highly related to selenium’s association with other constituents in the soil. To complicate things even more, previous research has separated soil selenium into five fractions, two of which are unavailable to plants, two of which are available, and one which is conditionally available to plants.

Since the SDSU experiment called for fertilizing beyond what is needed for producing the target wheat yield or wheat

The selenium project of Jim Doolittle and and Sang-Hun Lee is advancing from greenhouse to sites along the Missouri River, with check plots back in Brookings. Results will better show how agronomic practices and environment affect the uptake of selenium in the plants.

goal that is usual in South Dakota, Sang Hun first did a greenhouse study to find if there was a toxicity or inhibitory response in the wheat when phosphorus was increased up to 1,000 parts per million. There was no detrimental effect from high levels of phosphorus, but yields did plateau after the initial response.

In the actual selenium study, Doolittle and Lee blended the selenium soil with perlite—a necessary step because seleniferous soils are fine-textured and easily become waterlogged—and then grew two spring wheat varieties (Oxen and Granger) and two winter wheat varieties (Arapahoe and Wendy). Phosphorus fertilizer was applied at three different levels: 0, 100, and 250 milligrams kg-1.

They found what they expected: Phosphorus fertilization increased the total amount of absorbed selenium in the grain and stem tissue of all wheat varieties tested.

The experiment showed, in addition, that only one of the selenium soil fractions changed significantly. What is called "ligand exchangeable" selenium significantly decreased as phosphorus applications increased.

That makes this selenium fraction in the soil the one that can be most readily incorporated into wheat if the soil conditions are favorable for it.

THE PROJECT IS STEPPING OUT of the greenhouse into "the real world."

Doolittle is planning a follow-up, outdoor study in selenium-rich soils along the west side of the Missouri River in South Dakota, with a replication on non-seleniferous soils on the SDSU campus in Brookings as a control. Two to three other sites will be on seleniferous West River soils.

With the roots of the plants able to explore greater volumes of selenium-rich earth, Doolittle says, the study will give a clearer picture of the difference that agronomic factors make in selenium uptake.

"We can produce wheat on seleniferous soils that's about 2 parts per million selenium. We're hoping that with the selenium-enriched grain that we want to produce, we're going to be in the area of maybe doubling that—4 or 5 parts per million.

"Doing the calculations with a 5 parts per million wheat, I believe a person can get anti-cancer benefits from two slices of bread made from that wheat."

Doolittle says selenium questions that still remain to be answered include the difference in selenium uptake due to the depth of the available selenium in the soil profile, rainfall during the growing season, or wheat variety. Wheat breeders think there may be varietal differences, he says.

An unrelated issue, Doolittle says, is the need for mapping of seleniferous soils so that growers know where they're located.

"Producers would like to know which of their fields have a potential to produce these selenium-enriched grains. We know in general terms where that parent material is. But it's still on a field-by-field basis where a soil high enough in selenium is."

Addressing at least some of those issues, the South Dakota Wheat Commission is putting $85,000 toward a broad-based selenium research project at SDSU in budget year 2006. Planned as a 3-year project, the work would include the variability in locations where selenium is available and conditionally available in selected selenium-rich fields. Also to be investigated are differences in selenium uptake in selected spring and winter wheat varieties as influenced by weather conditions and soil selenium.

Additional questions may lead to answers that determine the distribution of selenium within the kernel of wheat after milling; the bioactive form of selenium in selected wheat varieties; the total antioxidant activity of selected wheat varieties; and the antioxidant activity from selenium conjugates.◆

—Lance Nixon