Agricultural Adaptations to Water Needs

Q&A[1]

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Dave Warner: Hank, what is the efficiency of phosphorus recovery?

Hank Venema: When burning cattails in a conventional furnace it's not optimized at all for phosphorus recovery. Nevertheless, at first try, we recovered 90%, well actually 89%, of the phosphorus in the ash. The only gaseous form of phosphorus is phosgene, and we are not producing that. So, the phosphorus has nowhere else to go.

Venema: I have a question for Wes. What yields are obtained from perennial crops?

Wes Jackson: Perennials are low yielding, but, for instance, with Kernza™ we get an increase of about 100 pounds per acre per selection cycle. There's more total biomass in perennial wheatgrass than there is in annual wheat, but the harvest index is much smaller in the former; it's not around 0.5 as in wheat. So, breeding is mostly a matter of changing the harvest index, of breeding to alter allocation. The perennial captures more sunlight as it has a longer growing season. An important paper was published by David Van Tassel and colleagues on why our ancestors did not develop perennial grains. They point out that annuals tend to self-fertilize and, by selfing, they inbreed and so the genetic load does not build up. Herbaceous perennials tend to outcross and, therefore, have a great deal of heterozygosity and a rather high level of genetic load. The good thing about the

[1]The audiorecording, from which this written record was prepared, was of poor quality, rendering it impossible to accurately represent the dialogue in many places. Every effort has been made to provide a faithful transcription.

annual is that a desirable trait, like shatter-resistance, can be obtained relatively quickly. However, inbreeding results in only about half of the seeds being filled. The other seeds contain aborted embryos, essentially getting rid of the genetic load. The way we look at it is that, yea though we go through the valley of the shadow of death, we fear no evil, for the evolutionary force is with us, actually increasing the number of viable embryos. Now, imagine our ancestors, at the eastern end of the Mediterranean with annuals. We can do what they could not do, partly because of our knowledge of genetics, our computational power and the use of molecular markers. We argue that if you want high seed yields in the future, they will be achieved with perennials. Annuals have too many limits placed on them.

Venema: I appreciate your latter point. But if life-cycle sustainability, reduced greenhouse-gas emissions, and so forth, are part of our major objective here, why not focus perennials on fiber and fuel production where they're already extremely efficient and where we can displace very typically unsustainable value chains that have a heavy atmospheric load?

Jackson: First, a chief concern is soil erosion in annuals. According to a paper, of which Chris Field was an author, from 1700 to 2000 we have had three times the total agricultural acreage of the US—on a global basis—go out of production. We are losing our soils. The second part is to deal with the question of biofuels; a massive biofuels program won't do what a very modest conservation program will do. For instance, the average American consumes the equivalent of 26 gallons of gasoline a year in food calories. So let's say that we don't eat for a year and we turn all of our food into biofuels. That's 2 gallons a month per person. Now, let's say that we take all the wheat straw, peanut shells, and corn stalks, and so on, and turn them into biofuels—maybe another 2 gallons a month per person, depending on how you calculate it. Stop all exports—another 1½ to 2 gallons. So, at the most, 6 gallons a month per person. Our view is that, with a modest conservation program, we won't have to turn to our soils to produce biofuels.

Venema: A reflection on the afternoon with respect to sustainability. The hand-out package contains a white paper from NABC on climate change. An important observation is that we tend to look for single-issue solutions and, I know in my jurisdiction, historically we have too much water in the spring and there is overdrainage, and, of course, that vulnerability has been revealed many times because occasionally we have severe drought in our region as well. The likely impact of climate change will be more variability—both increased flood episodes and increased drought episodes. So, what we are really looking for is resilience to variability for sustainability rather than single-issue adaptation. I just want to throw that out there to get people thinking. The only robust prediction is increased variability.

Jackson: I think that it will come back to a natural ecosystem like the prairie. During the dust-bowl years, the wheat plants died in Kansas; the prairie came back. If prairie bottoms get flooded, they come back. If you flood soybean or corn, you kill it. So, if you

are talking about resilience and sustainability, there must be a pretty good reason why, when nature's ecosystems regenerate, they favor the perennial.

Anna McClung (USDA-ARS, Stuttgart): Dr. Warner, has there been an attempt to define megaenvironments so to speak, or specific environments that one could develop specific traits for, and, if that's the case, have you looked at how those environments might be altered in response to climate change over the next few years? The package of traits today for a variety for a specific area or region may have to evolve over time to comprise different traits.

Dave Warner: The short answer is "yes." Our environmental modeling group collaborates with several NGO and academic agencies who are projecting where we need to be in 10 or 15 years. The rate of climate change is usually slower than how quickly we can adapt our breeding technologies. We are monitoring climate changes.

McClung: Do you want to comment on trends that you have identified?

Warner: This is a little bit outside my expertise. One of our breeders spoke to the Crop Science Society last fall about that, for which he produced a couple of slides that I wish I had brought with me. They showed shifts in the environments in the western part and center of the corn belt with higher temperatures moving north possibly expanding the corn belt. These are 20-year trends and beyond.

Andy Pereira (University of Arkansas, Fayetteville): Dr. Jackson, in the domestication of plants as crops, certain traits were selected for such as non-shattering pods, time to flowering and increased seed size. For perennials, a main objective is ensuring survival from year to year. How does this relate to grain yield?

Jackson: There are perennials that do have large seeds—trees for example—and have high yields and they have the same amount of sunlight striking them per square meter. The herbaceous perennials have not *had* to have large seeds because they have perennial tissue below, but it does not mean that they cannot be bred to have large seeds by changing the harvest index. Also, overall, photosynthetic capture is longer than for annuals. Therefore, more photosynthate is available for reallocation. The r and K[2] selection strategies do not apply absolutely in plants, if that is your concern. If you select for high seed yield—which is what we do—by increasing seed size and seed number and your total photosynthetic capture is longer, then the perennial has even greater potential for higher yield than the annual. The annual has a shorter photosynthetic capture period. For instance, our winter-hardy perennial sorghum has a full canopy three weeks before annual sorghum germinates.

[2]http://en.wikipedia.org/wiki/R/K_selection_theory.

Kelly Foley (Oregon State University, Corvallis): What's being done to help producers make the shift from annual to perennial crops?

Jackson: How are farmers responding to the shift from annual crops to perennials? We don't have any seed ready, so there's no response. But, you can imagine who won't be interested: the seed houses and the fertilizer people, especially if you have a legume in your system you will purchase less nitrogen. Perennials provide species diversity and chemical diversity, so it takes a tremendous effort on the part of an insect or a pathogen to produce an epidemic. So the pesticide people won't be much interested. The reward goes to the farmer and the landscape rather than to the suppliers of inputs, where most of the money is made in agriculture. Farmers don't have any problem with the concept. They are at us almost every day to give them seed.

Foley: Do you anticipate a backlash from a major switch from annuals to perennials?

Jackson: About like the switch from the Ptolemaic system to the Copernican system. Yeah, there will be a backlash because there's a lot on the line. You think about how humanity has 10,000 years of annuals that have been feeding us—and soil erosion has gone along with that—but we are in tune with the patterns that come with that kind of agriculture. However, we need to recognize that the plowshare is destroying the options of future generations. This is a psychological shift that comes from nature being subdued or ignored to nature being the teacher, with ecology overriding agronomy. Think how exciting that is.

Douglas Cattani (University of Manitoba, Winnipeg): Although I don't think there will be a mass acceptance, I think that a small group currently within the seed-production industry would be amenable to fostering adaption to farming perennials.

Ralph Hardy (National Agricultural Biotechnology Council, Ithaca): A broad-canopy question. In the area of societal benefits, in some cases the producer will see benefit. It may be with an organic crop for which a premium price may be charged. How do you see the societal benefits related to water having value-added for the producer to induce her/him to adopt them?

Venema: Can you give specific examples of potential benefits?

Hardy: Like less phosphate pollution, from which a farmer won't benefit directly, but society will.

Venema: It's funny because I have gone through a similar evolution in thinking. I started in my position about six years ago, and the narrative at the time was about payments to farmers for ecosystem services, which was appealing to growers in Canada, that they would be compensated for certain practices—or in some cases, certain non-practices—that had

associated public benefit. I think that that's valid. Public benefits from some agricultural practices are significant, but are not felt on-farm, so there should be a compensation mechanism. What that means is, from sustainable development first principles, you subsidize "goods" not "bads." A public subsidy is justified if there's a positive public externality. What we shouldn't be doing is subsidizing agricultural practices when there is definitely a negative public externality. That's illogical. Now, all that said, if we get negative subsidies out of the system that might be enough to start encouraging positive public externalities, but I'm not sure that will be the case. I am not convinced that there are enough resources to provide subsidies for public benefits even if we get the negative subsidies out of the system.

Bill McCutchen (Texas A&M University, College Station): Wes Jackson and others are working on 200-year sustainability projects and I'm wondering if Dave Warner and Randy Allan could talk about feeding the world of 9 billion people here in the next 15 to 20 years. How can industry and academia work more closely together to help make that happen? I know we are going to use annuals for a while—I accept that fact—but how can the technology that is being developed at Oklahoma State, at UC Davis or at Cornell be more efficiently utilized by companies such as Pioneer and Monsanto? There's a large gap there. Many technologies being developed in academia are sitting on the shelf; they can't be transferred because of regulatory hurdles. A lot of things are happening on the major row crops, but not on the specialty crops.

Warner: At Pioneer, we work closely with many academic organizations and NGOs on a lot of this technology and we license many genes from various sources, including academic sources. The biggest challenge for academics in small organizations with transgenes in particular is that the USDA requires extensive multi-year testing to document safety. It can take millions of dollars to usher a new product to the market place. That's why a small organization may license a new technology to a company like ours to take it to market.

Venema: The fraction of the US domestic corn crop eaten as food is about 2%. From the perspective of world food security, the elephant in the room is the enormous amount of cereal used for livestock production. It's a difficult question. I'm an omnivore like most of us, but that's the reality. A solution is to go from cereal production directly to food consumption rather than through the inefficiency of livestock production.

Hardy: It is my recollection that China now eats twice as much meat as the United States. This issue has to be considered on a global scale.

Audience member: Are we approaching a point where we will legislate what people can and can't eat?

Jackson: It's the language of the industrial hero who is forever asking how we are going to feed 9 billion without asking the next question: then what? 12 billion? 15? Whatever?

We do have a population problem, but what is not factored in often enough, is dealing with the question: what do people, deer, cars and houses and deep freezers and pop-up toasters have in common? They are all members of populations and they all occupy space and they are all dissipating structures. So, yes, we have a population problem. There are too many people, too many cars, too many houses, too many pop-up toasters, and so on. The more that we accumulate, the more regulations we will need or the planet will regulate us. It will regulate our behavior. It will regulate our numbers, and so on. We all know that. This is one reason people are starting to look more at the structure of the human brain as a product of the Paleolithic past. Is the neuro-network hard-wired? How much of it is amenable to learning new things? We need to think about what stands in our way of learning and changing. Kittens that are blindfolded at birth and kept that way for 6 weeks never learn to see; the neuro-network doesn't develop. So, in a certain sense, we are all blind kittens as a result of our experiences; it doesn't seem that our education in primary schools, high schools, and universities prepares us for overcoming our cultural and regional history. Until we come to terms with that neuro-network and the knowledge that this is part of what it takes to be a primate then we are going to get where we are going. The advertising industry knows one big thing: we are animals. And they also know that the rest of us don't know that. They are on to it, though. Consequently, we go merrily along depleting our resources and breeding. We must move into new territory in the sciences that is uncomfortable to us.

Veneman: I have a somewhat similar answer. In Canada, we have significantly higher fuel taxes than in the United States, and in Europe there are far higher fuel taxes yet than in Canada. And that is because they are attempting to internalize the public cost, since many externalities result from the use of fossil fuels. I am being slightly facetious, but only slightly: a tax on meat would, to some degree, provide invisible-hand moderation and might free up cereals for human consumption.

Rick Bennett: Josef Stalin said, "It's better to kill 1000 people in one day than 1 a day for 1000 days." That may have worked for him as a dictator, but it didn't work for him in Uzbekistan when he directed that the Aral Sea be exploited to grow irrigated cotton, which illustrates what we have been talking about: it's going to take societal and broad institutional changes and adoption of sustainability practices. It's going to take good science, the kind in progress on transgenic crops. And it's going to take good, solid policy.