**NCERA 103 Agenda**

**November 16, 2017**

**Holiday Inn, Des Moines, IA**

Present:

Kurt Steinke – Michigan State University

Edwin Ritchey – University of Kentucky

Dorivar Ruiz Diaz – Kansas State University

John Sawyer – Iowa State University

Bijesh Maharjan – University of Nebraska-Lincoln

Dan Kaiser – University of Minnesota

David Franzen – North Dakota State University

Jim Camberato – Purdue University

Emerson Nafziger – University of Illinois

Matt Ruark (chair, operating secretary) – University of Wisconsin-Madison

Absent:

Carl Rosen (administrator) – University of Minnesota

Ed Lentz (secretary) – Ohio State University

Administrator Report

* A written report from Carl Rosen was provided and read by Matt Ruark

Rotation update

* Matt Ruark (UW) will be chair and Ed Lentz (OSU) will be secretary in 2017 and 2018
* Ed Lentz (OSU) will be chair and Maharjan (UNL) will be secretary in 2019 and 2020

State reports

* Given by each member. Detailed written reports are included below. The state reports constitute the majority of the meeting time which involve recaps of current product trials, identification of new products on the market and their potential effectiveness, and extension publications and programming in the area of non-conventional additives.

Old business

* Compendium website: Iowa State will update the template of the website, will add link to committee website. We are unable to track hits, this will be added after the update.
* Regional publications are still a priority for this group. Dan Kaiser is still interested in leading a regional publication on P extenders.

New business

* Discussion of NutrientStar and potential interaction. A few NCERA-103 members have interacted with this group in the past year. Still learning more about potential interaction.
* We will tentatively plan on November 15th as the meeting time for 2018

Adjorn

**State reports**

Iowa State University

General information:

*Main questions about these products are their potential usefulness/efficacy for crop production.*

*Anchor-N (from Altitude Crop Innovations, LLC) – Low rate DCD product for control of nitrification. Concern – while DCD is known as a nitrification inhibitor is the rate actually adequate to slow nitrification. Many products in the marketplace like this.*

*Proximus with Nutri-Guard (actagro) – Fertilizer additive to reduce nitrate leaching in soils. Concern – the product contains carboxlic acids and phenols which would be quickly degraded in soil and have not been shown to affect nitrification or nitrate loss.*

*Yeti Bloom (from growcentia) – A microbial biostimulant to unlock phosphorus and micronutrients. Concern – a product that supposedly contains beneficial bacteria but are they viable and can they compete (survive) with soil bacteria, and therefore have any efficacy. Depletion of soil phosphorus would be an issue if the product works.*

*PlantCatalyst company – Has a proprietary formula product to reduce dependence on fertilizer. Concern - Nothing provided about active ingredient or how the product works, or how it would replace fertilizer.*

*Fortalis with CaT technology (from Plant Impact) – Is a crop enhancement product that stimulates natural processes to enhance nutrient translocation and efficiency to improve soybean yield and consistency. Concern – unknown process of increasing nutrient mobility (and which ones) and response to plant stress signaling process. Product also contains calcium and zinc which are unlikely to be needed on most soils.*

*Agrho N-Protect (from Solvay) – Is a unique range of urease and nitrification inhibitors, with those being comprised of NBPT or DCD. Concern - those active ingredients are known to affect urease activity and nitrification. However, no active ingredient amount is provided and not really a new product. Likely another of the low active ingredient products.*

*L-CBF 7-21-3 MKP (from Midwestern BioAG) – A low concentration fertilizer with a molasses base. Concern – this is a fertilizer product but the fertilizer formulation is not new or different and inclusion of molasses would not affect nutrient supply to crops.*

*VeraShield (from elemental enzymes) – A proprietary platform for stabilizing enzymes, proteins, and peptides for delivery into harsh industrial or environmental conditions. Concern – there is little or no need for such a product in crop production systems and application of enzymes, proteins, and peptides to soils would have rapid degradation and be of no value to crops.*

Accomplishments:

*The compendium web site is being revised and updated, with progress underway. It will continue to be housed at Iowa State University, Department of Agronomy.*

Impact Statements:

*The compendium web site (Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production,* [*http://extension.agron.iastate.edu/compendium/index.aspx*](http://extension.agron.iastate.edu/compendium/index.aspx)*) has 235 research reports, with five new reports added in 2016-2017. Clientele use of the site was not tracked in 2016-2017.*

North Dakota State University

General information:

The most asked questions are about AgXplore’s line of products sold as nitrogen fertilizer additives, particularly the effectiveness of their ‘ContaiN’ urease inhibitor.

Accomplishments:

1. Presentations
   1. December, 2016- Central Dakota Ag Day, Carrington, ND, assessing unusual products
   2. December, 2016- University of Minnesota Short Course, St. Paul, N additives
   3. January, 2017- Soil and Soil Water Workshop, Fargo, N additives
   4. February, 2017- ND Eastern Crop Scout School, Fargo, assessing unusual products
2. Peer-reviewed publications
   1. Nitrogen Additives and Amendments for Field Crops, NDSU Circ. SF1581 published

<https://www.ndsu.edu/fileadmin/soils/pdfs/Nitrogen_Extenders_and_Additive_for_Field_Crops_2017.pdf>

Impact Statements:

Farmers are guided through our publications and the website away from products with little value to those that have shown consistent benefit and a supported mode of action.

University of Minnesota

General information:

In 2017, I have not been fielding many questions related to non-traditional products which are likely a result of low corn and soybean prices. Products are still being marketed across the state but most of my questions have been regarding starter fertilizer products containing micronutrients. There seems to be some interest from farmers on biologicals due to increased sales from seed companies but little testing has been done on these products to my knowledge. I was at a recent trade show and there were booths for products such as Avail and Nutrisphere so it is likely there are still sales of the products in the state. The U of M is currently offering basic nitrogen education geared towards farmers. As part of this program we discuss inhibitors with the group and will be using materials generated from the NCERA-103 committee as handouts for the meetings.

Research on non-traditional products has slowed. I do not know of much testing going on by U of M researchers. I am working on a study comparing naked chelates to see if they have benefits for in-furrow application without a metal cation like zinc. I completed a greenhouse study comparing five chelates, EDDHA, EDTA, DTPA, citric-, and oxalic acid placed on the seed comparing among corn, soybean, and hard red spring wheat. A second study was completed comparing EDDHA, EDTA, and DTPA at 0, 0.2, 0.4 and 0.6 mol/ac. I have followed the greenhouse work with field studies on corn at two locations in 2016 and 2017. I also am planning follow up testing for a greenhouse study in winter 2017/2018.

University of Wisconsin-Madison

Accomplishments:

1. 2017 product trials
   1. Dow-Instinct on Potato (sandy soil)
2. Presentations given
   1. “Reviewing the benefits of soil biological additives” 2016 Soil, Water, and Nutrient Management meetings, 8 locations, 500 attendees
   2. “Assessing the quality of polymer coated urea” 2017 Wisconsin Agribusiness Classic, 1,500 attendees
3. Reports (proceeding papers, industry reports, etc.)
   1. Ruark, M and M. Naber. Assessing the quality of polymer-coated urea. Proceedings of the 2017 Wisconsin Agribusiness Classic, 10-12 Jan, Madison, WI.
4. Peer-reviewed publications
   1. The value of arbuscular mycorrihizal fungi for field crops (UWEX A4114-01, part of the Soil Biology Fact Sheet Series), G. Siemering, M. Ruark, F. Arriaga, E. Silva, and H. Johnson, 2016.
   2. The value of Trichoderma for crop production (UWEX A4114-02, part of the Soil Biology Fact Sheet Series), G. Siemering, M. Ruark, and A. Gevens, 2016.
   3. The value of bacillus amyloliquefaciens (UWEX 4114-03, part of the Soil Biology Fact Sheet Series), G. Siemering, M. Ruark, and A. Gevens, 2016.

Impact Statements:

In the past year, we have used two techniques, literature review and field testing of products, to bring information on the efficacy and value of alternative crop products to farmers, crop consultants, and fertilizer dealers. By reporting and presenting on the most up-to-date information, we have provided value to the fertilizer supply chain by giving decision makers knowledge about enhanced efficiency fertilizers, microbial inoculants, and organic soil amendments. These groups can then decide for themselves if the product is economical and worthy of investment.

University of Nebraska

General information:

1. *Neptunion and Cybelion- drought tolerant products from the Plant Response*

*I tested these products in the field trial.*

1. *Plant Catalyst product- claimed to work wonders on crops. The rep did not share how it functions. The rep shared positive data from some countries in Africa. After questioning how it might work and having proposed for a trial in Nebraska, I never heard back.*
2. *Inhibitor products from Solvay. I tested the products.*

*In Nebraska Panhandle, folks are asking about coal combustion residue from the local sugar processing plant. Since that by-product has high carbon content, a common question is on how that might benefit soil and eventually, crop yield.*

Accomplishments:

1. 2017 product trials – (with short description of experimental design)
   1. *A trial was conducted to evaluate Plant Response products, Neptunion® and Cybelion® on irrigated maize and soybean production on University of Nebraska research facilities near Scottsbluff, Nebraska. This experiment used a split-plot randomized complete block design with irrigation levels as the whole plot and Plant Response products as sub-plot treatments with 4 replications. The irrigation levels were*
2. *75 % (10.5 inches)*
3. *100 % irrigation (15 inches).*

*Plant Response products treatment in both irrigation regimes included:*

1. *4.5 fl oz foliar spray Neptunion® (at V6 in maize or at R1 in soybean)*
2. *Seed treatment Neptunion® 3ml (1g/Kg)*
3. *Seed treatment Neptunion® 3ml (1g)/Kg) + 4.5 fl oz foliar spray Neptunion® (at V6 in maize or R1 in soybean)*
4. *control (no Neptunion® treatment)*

*Following additional treatments were added in 100 % irrigation level in four replications in soybean. They were initially meant to be added only in 100% irrigation level in maize as well. By mistake, they were added in both irrigation regimes in maize but in two replications.*

1. *4.5 fl oz foliar spray Cybelion® (at V6 in maize or R1 in soybean)*
2. *9 fl oz foliar spray Cybelion® (at V6 in maize or R1 in soybean)*

*Seeds were treated with the products at suggested rates for seed treatment plots. Foliar treatment plots were sprayed with backpack sprayer. Best agronomic practices including fertilization, insect scouting, and other were same all across the plots. Crop yields were measured with hand harvest from two rows of 10 ft length each to evaluate effects of these treatments.*

* 1. *This project was conducted to evaluate effects of different inhibitor products in reducing ammonia volatilization loss and greenhouse gas emission in sprinkler-irrigated corn on University of Nebraska research facilities near Scottsbluff, NE. This experiment used a split-plot randomized complete block design with nitrogen levels as the whole plot and nitrogen fertilizers as sub-plot treatments with three replications.*

*The Nitrogen levels were*

* 1. *80 %*
  2. *100 % of recommended rate (160 kg N per ha)*

*Nitrogen fertilizer treatment in both irrigation regimes included:*

1. *UAN (no inhibitors)*
2. *UAN + Solvay @ 1.9 l/ton UAN (S1)*
3. *UAN + Solvay @ 3.9 l/ton UAN (S2)*
4. *UAN + Solvay @ 6.6 l/ton UAN (S3)*
5. *UAN + Agrotain Plus @ 6.8 kg/ton UAN (Aplus)*
6. *UAN + Agrotain Advanced @ 1.05 l/ton UAN(Aadv)*
7. *UAN + Instinct HL @ 24 fl. oz/ac (INST)*
8. *Control (0 N)*

*Field measurements of nitrous oxide (N2O) emissions and ammonia (NH3) volatilization were carried out at 100 % N level from all N treatments except S2. Standard static chamber method was used to measure N2O emissions by collecting air samples twice a week for two months after N fertilization and weekly thereafter during the season with total of 27 sampling days. Air samples were generally collected during 1000 to 1200 h local time when the soil temperature in the upper 10 cm is close to its daily mean value. One stainless steel circular chamber anchor (25 in diameter) was installed in each plot between corn rows. On sampling day, insulated and vented chamber tops were secured to anchors, and samples were collected at 0, 20, and 40 min using 12-mL polypropylene syringe. Samples were transferred to glass vials with rubber septa and analyzed using gas chromatograph.*

*Ammonia volatilization was measured by acid-trap method using PVC tubes installed in all plots from where N2O emissions were measured. Ammonia traps were foam disks soaked in dilute phosphoric acid and glycerol solution. Traps were installed in the interior of installed PVC tubes in each plot and collected every 2 days in the first month after N fertilization and every 3-7 days for another month with total of 9 sampling days.*

*Best agronomic practices including fertilization, insect scouting, and other were same all across the plots. Crop yields were measured with hand harvest from two rows of 10 ft length to evaluate effects of these treatments.*

1. Reports (proceeding papers, industry reports, etc.)

*Reports on their product tests were submitted to Solvay and Plant Response.*

1. Grants (non-gifts)

*Grant worth US$47,240 was received to evaluate effects of coal residue on soil properties, environmental nutrient losses in fertilized soil, crop yield and nutrient management in manure.*

University of Illinois

General information:

The product Fortalis (from PlantImpact a UK company) was heavily promoted early in the 2017 growing season. A quote from the company website: “Fortalis® uses a new formulation to further increase yield by improving the mobility of calcium throughout the plant to improve fixation of flowers and pods” [in soybean] – only if used with a foliar fungicide.

Proximus from Actagro LLC, Biola, CA: purports to “reduce nitrate leaching in soils,” and in a phone conversation I was told that it stimulates microbial growth that then sequesters N. The label says it’s “9% carboxylic acids and phenols.”

Accomplishments:

1. 2017 product trials – (with short description of experimental design)
   1. We did two replicated studies with and without foliar fungicide in soybeans, in combination with and without Fortalis. We saw no effect of Fortalis by itself or in combination with fungicide.
   2. We tested the Koch Industries urease inhibitor (now with the trade name ANVOL) in two replicated studies in Illinois, comparing N rates applied as surface-broadcast urea treated with Anvol, Agrotain Advanced, or untreated.
   3. Our N research trials at four Illinois sites include treatments comparing corn yields with and without Agrotain, N-Serve, SuperU, and Nutrisphere added to or comprising the N source.

1. Presentations given – none specifically, but Fortalis results were presented a couple of times as part of longer presentations.
2. Grants (non-gifts) – support from Koch industries for the inhibitor study. N research including inhibitor comparisons is funded by NREC (IL fertilizer checkoff.)

Impact Statements:

Lower prices for corn and soybean have dampened producer enthusiasm, if not marketing efforts, in the use of non-traditional products. Our findings on “inhibitor” effects on both yield and soil N provide support to decisions regarding their use, and in evaluating their possible effects on N loss.

Purdue University

General information:

CleanGreen Liquid Calcium Ag-USA, 300 times more available than gypsum or ag lime!

Questions are in general about biologicals (mostly bacteria-based products) and humates.

Accomplishments:

1. Product trials
   1. Large-plot replicated corn trials at 4 locations with 3 bacterial-based in-furrow treatments, an in-furrow seed growth regulator, and a seed-applied combination bacteria-fungi treatment. More or less a repeat of a similar set of trials in 2016 and similar trials intended for 2018.
2. Publications
   1. Lee, J., J.J. Camberato, and R.L. Nielsen. 2017. Plant growth and yield response of maize to in-furrow biological and plant growth regulator products. *In* Agronomy Abstracts 215-9.

Impact Statements: Results from multi-location, replicated large-plot corn trials have been used to caution farmers about the limited potential for grain yield response to ‘biologicals’

University of Kentucky

General information:

Most of the products I have included came from questions that extension agents send our way.

1. SymTRX, Southern States is the sole dealer (I think or trying to be in KY). Question came from extension agent. Nathan Slaton in Arkansas tested and no difference in yield with product, but sulfur is not limiting on those soils. He said that probably a good S fertilizer if S is needed, but no better than other S fertilizers.

[http://www.anuviaplantnutrients.com/product/agriculture/](https://urldefense.proofpoint.com/v2/url?u=http-3A__www.anuviaplantnutrients.com_product_agriculture_&d=DwMFaQ&c=7ypwAowFJ8v-mw8AB-SdSueVQgSDL4HiiSaLK01W8HA&r=aqGNgECtwY8ZriSfYWon4w&m=yPFXOWpF_DDR98_E7zx1dSlJGHGsyNHe9aX48BcuEUI&s=ahGx_MI3Vk6xlDuiKWrD8PPjl_IjwSVz2cRf6nmHKh0&e=)

1. Alltech Crop Science Products. They have numerous products that are largely by-products of their primary business, animal nutrition and health products. I don’t know of any work done to test these products, but their claims seem a bit hard to believe. Most products contain microbial inoculants, micronutrients and fermentation products. Contribute SR, Soil Set, Crop Set, Grain Set (these were what I was questioned about, the others I just found on their website when investigating). Nature Basics 2X, Turf Set, Liqui-Plex Bonder WP, Liqui-Plex Cu (also have Liqui-Plex Mn, Zn, and ZnMnB), Galvanize Caontact, and Galvanize Soil. They are based in Lexington KY. On a side note, they do make a good beer if you can afford it (Kentucky Bourbon Barrel Ale ($~12/4pack). <http://ag.alltech.com/crop/en/products/explore>
2. Agricen (A Loveland Products Company). I had questions on AccomplishLM, SoilBuilder, and Titan XC. I noticed the Extract, NutriLife, and SoilLife AF. Not tested, but claims are a bit out there “ innovative fertilizer products that enhance plant health and nutrition to help…industries get the most out of their plant nutrition programs.” <https://www.agricen.com/products#ag>
3. Agrian (Loveland Products). This was not on the other webpage, but Maximum N-Pact 24-0-0. 33% of N is marketed as slow release. I got this question I think because it was not registered for use in Kentucky (and 4 other states). “More efficient in uptake vs. other nitrogen sources”. <https://lovelandproducts.com/product/maximum-n-pact>
4. Monty’s Plant and Soil Products. Pretty much all of them, but the newest question was for Hay-Now, a foliar applied liquid fertilizer containing N, P, K, S Fe, and Zn. “Works on all grasses and legumes, enhance growth and root development, apply 1-2 quarts per acre spring through fall”. <http://www.montysplantfood.com/products/hay-now/>
5. Here is a link to their other products, enjoy the read. <http://www.montysplantfood.com/montys-products/>
6. Cocoa Compost Fertilizer. This came from an agent in the southeastern part of the state. They had an interesting angle. They make certain claims on their website, then cite refereed journal articles that discuss composts in general (e.g. Singer, J.W., C.A. Chase, K.A. Kohler. 2010. Profitability of cropping systems featuring tillage and compost. Agron. J. 102:450-456). Not sure who was carrying this product, the agent just told me that he had a few producers ask him about it. Claims to be superior to 98% of all other composts, I suspect it will produce similar results as most well composted products. “Cocoa is a fertilizer, soil amendment, and crop protectant.” <http://www.cocoa-corp.com/cocoa-compost-fertilizer/disease-suppression>
7. AgriCal by AgriGro, This one is interesting. Last year Josh got a few questions on the eastern end of the state about this being used for a lime product, but is actually Calcium chloride. I can’t seem to find that on their webpage, but we found it last year or the year before. Josh wrote a blog article about this not being a liming material, since it can’t neutralize soil acidity. That blog was picked up several places. Fast forward to last fall, I got a call from an agent asking me about the product. It sounded familiar and ended up being the product Josh wrote about. However, they had since dropped their claim as a liming product. Now it is just being touted as a Ca product since Ca is needed and their product is a soluble form. (I would call this a success story!) I have attached a link to the original blog and to their website. <https://graincrops.blogspot.com/2015/04/buyer-beware-when-it-comes-to_8.html#more> their website: <http://www.agrigro.com/products/crops/agrical/>
8. Ag PhD- many of the questions that I get come from something they have said. I try to catch some of their shows to see what they are pushing. Soil test for Cu, since it is limiting in many areas. Maybe in some areas, but not aware of an issue east of the Mississippi River on mineral soils. They were also pushing Agro Liquid products. Cation balance ratios for potassium. Other things are covered that you all are probably well aware of if you listen to them.

These are the biggest ones that come to mind. The Avail and Nutrisphere questions have died down. They are both still available at Southern States, but not hearing as much about them. At one point, John Grove said that some small stores in the east only carried Nutrisphere treated urea, unless you requested non-treated urea. I don’t know if that is still being practiced in those areas.

Finally, one thing that we are dealing with is the NBPT products. None or few really put the concentration on their label. So just because it contains NBPT, does it reduce ammonia volatilization? John Grove has been working with NRCS on many of these products and often the concentration is not adequate.

Accomplishments:

* + 1. 2017 product trials – (with short description of experimental design)

I tested a product by Tessenderlo Kerley, INC. It was ammonium thiosulfate (Thio-Sul, 12-0-0-26S). I looked at it at two on-farm locations in large plots (3 reps) and then at UKREC (10 reps). We went in after corn was planted but before germinated and applied to 40 ft plots, 300 ft long. Potassium was confounding the one location that had a 9 bu/A increase over the check. Potassium averaged 80 for ATS treatment, 111 and 102 for treated UAN and untreated UAN. Not significantly different from treated UAN at 90% CI, but both were better than untreated UAN. Treated UAN was (Agrotain plus with NBPT and DCD). Both on-farm locations showed ATS and treated UAN with similar yields in an environment that favored denitrification. Nothing present at the UKREC location.

Impact Statements:

1. Avail and Nutrisphere calls have drastically decreased in Kentucky. Not sure what sales are doing, but hearing much less. I think this indicates less is being used.
2. AgriCal changed their marketing from a liming material to a Ca product. Calcium still isn’t needed in most KY soils, especially if producers are following proper pH management. Just good to see that someone heard the blog.

Michigan State University

General information:

Fewer inquiries and less marketing with low commodity pricing. Foliar micronutrients in relation to tissue testing getting more attention but little regard for likelihood of responsiveness nor crop-specific sensitivity to a response. Boron applications to wheat being discussed more frequently due to consistently low tissue test in Michigan but wheat has been classified as non-sensitive to B applications in the past. Other forms of slow-release N that have been primarily aimed at the turf market including sulfur coated urea and methylene ureas are being looked at for the agricultural markets. Marketing has shifted towards biologicals and or including biologicals with starter nutrient applications.

SymTRX20S (16-1-0-20S) and SymTRX12S (16-20-0-12S) are two N, P, S replacement products that were tested on S-deficient sugarbeet soils with STP of 23 ppm (below critical threshold). The two N, P, S replacement products evaluated resulted in non-significant yield, recoverable white sugar per ton, and recoverable white sugar per acre as compared to P applied individually and the P and S combination using MAP and AMS as the P and S sources, respectively.

Liquid carbon-based fertilizer (L-CBF) is apparently made from cane molasses and contains different levels of sucrose. Multiple formulations are then combined with different starter fertilizers (7-21-3, 10-14-1, etc) with the idea that the sucrose will stimulate the soil biology to enhance nutrient uptake. Products were applied as either in-furrow or 2x2 applications. Low initial soil test phosphorus readings (i.e., 23 ppm) likely explain the non-significant sugarbeet yield increases and significant gains in RWSA realized from both the IF and 2x2 P2O5 applications when compared to the N only standard. Among treatments receiving IF or 2x2 nutrient applications, very few differences were observed.

Planttuff aglime or silica-based fertilizer. Labelling depends on whether listed as fertilizer or soil conditioner for a specific state. CCE of product quite high but ECC appears quite low due to particle size. No significant yield differences across wheat, soybean, corn, and sugarbeet.

Slow-release K and N fertilizers from ICL (0-0-58) (Agrocote K) and Agrocote N with 4-6 month release blends available (release at 70 degrees F). Positive slow-release K results on potato in 2016 but non-significant results in 2017 (greater number of leaching events in 2016). Price difference for the slow-release K is 3-4x that of potash thus return on investment thus far quite low.

Stimulate in-furrow microbial inoculant. Product contains 29 strains of “highly beneficial microbes”; No significant yield differences in 2017 across corn, wheat, or soybean.

Accomplishments:

1. Product trials
   1. Agrocote N and Agrocote K (slow-relase N and K)
   2. Simultate microbial inoculant
   3. Methylene ureas, humic-coated urea
   4. Instinct, Agrotain dry, SuperU, Limus, UltraMateLQ
   5. SymTRX20S and SymTRX12S
   6. Liquid carbon based fertilizers (L-CBFs)
2. Presentations
   1. Twelve presentations involving at least some product testing data
3. Publications
   1. Steinke, K. and C. Bauer. 2017. Enhanced efficiency fertilizer effects in Michigan sugarbeet production. Journal of Sugarbeet Research 54:2-19.
   2. Swoish, M. and K. Steinke. 2017. Plant growth regular and nitrogen applications for improving wheat production in Michigan. Crop, Forage, and Turfgrass Management, Vol. 3, doi:10.2134/cftm2016.06.0049.