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FREQUENCY OF NUTRIENT DEFICIENCIES IN CORN PRODUCTION

By Robert O. Miller, Affiliate Professor – Colorado State University

Nutrient management in the Midwestern United States relies heavily on soil testing to assess crop nutrient sufficiency levels. Diagnostic nutrient analysis of plant tissue is much less common, and interpretation data is limited across crops and growth stages. Plant tissue analysis can be useful in confirming nutrient deficiencies, toxicities and imbalances, evaluating fertilizer programs, and determining the availability of nutrients not reliably assayed by other testing methods (Jones, 1976). Micronutrient and sulfur deficiencies are more accurately identified by plant tissue analysis than by soil testing (Schulte and Kelling, 2013).

There is limited information on corn tissue nutrient diagnostic criteria at early growth stages, with more substantial data for ear leaf nutrient levels provided by Land Grant Universities, regional work groups and published literature (Jones, 1997; Reuter and Robinson,

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ACHIEVING NUTRIENT AND CARBON REMOVAL THROUGH AN INTEGRATED DAIRY MANURE TREATMENT PROCESS

By Erik R. Coats[1] and Kevin Feris[2] – [1]University of Idaho, Department of Civil Engineering; [2]Boise State University, Department of Biological Sciences

The estimated 9 million dairy cows in the U.S. generate in excess of 249 million tons of wet manure annually. Dairy operations also produce significant quantities of carbon dioxide (CO_2) equivalents (largely as methane associated with manure degradation). Recognizing the need to reduce these greenhouse gas (GHG) emissions, in January, 2009 the Innovation Center (IC) for U.S. Dairy announced a voluntary goal to reduce dairy GHG emissions 25% by 2020, and established a formal relationship with the USDA to "reflect the commitment of the Parties to take steps aimed to create a sustainable future for the dairy industry." The relationship was renewed in 2013. Beyond GHG emissions, manure nutrient management (nitrogen, phosphorus) is also a challenge to which a solution is needed.

Current manure management practices rely largely on lagoon storage and land application, while composting and anaerobic digestion (AD) are utilized to a much lesser degree. Considering the challenges of manure management, and depending on the lens through which the associated emissions are viewed, one can see either a regulatory problem or

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Head Editor – Amber Moore, University of Idaho; Guest Editor – Tim Hartz, University of California–Davis

Frequency of Nutrient Deficiencies in Corn Production, cont. from pg 1

Table 1. Incidence of corn nutrient deficiency in Indiana, as diagnosed by ear leaf nutrient concentrations.

	Deficiency Threshold [1]	Percent of Samples Deficient [2]		
Nutrient	< Less than	2011	2012	2013
N (%)	2.76	5.0	33.1	10.5
P (%)	0.25	1.1	20.4	2.7
K (%)	1.75	15.3	57.3	17.9
S (%)	0.16	0.1	8.1	2.4
Mg (%)	0.16	6.2	1.7	13.2
Ca (%)	0.30	0.0	0.8	0.6
Zn (ppm)	19	7.2	0.6	6.6
Mn (ppm)	19	1.2	2.7	0.9
Fe (ppm)	50	0.0	0.0	0.4
B (ppm)	5	7.1	2.8	11.1
Cu (ppm)	3	0.0	2.7	10.5

[1] Source: https://www.extension.purdue.edu/extmedia/NCH/NCH-46.html
[2] 1,623 samples over three years

2008). Betsy Bower, an agronomist with Ceres Solutions in Indiana, conducted a 3 year survey (2011-13) of corn ear leaf tissue collected at growth stage VT-R1. Potassium was the predominant nutrient deficiency, based on Purdue University deficiency thresholds (Table 1). Potassium deficiency was especially common in 2012, which was a year of drought in the Midwest. The incidence of nitrogen deficiency varied across years from 5 and 33% of samples, with phosphorus deficiency observed in less than 3% of samples in non-drought years. Incidence of magnesium deficiency was lower in the drought year, as was the case for zinc and boron. Zinc and boron were the most common micronutrient deficiencies observed.

Farther west, John Menghini of Midwest Laboratories, Omaha, Nebraska, compiled another data set on corn ear leaf tissue collected at growth stage VT-R1 in 2011-13 (Table 2). These data, representing a larger geographic area, showed nitrogen and potassium were the most commonly deficient nutrients. Incidence of potassium deficiency was highest in 2012, again associating potassium deficiency with drought stress. Nitrogen deficiency varied between 15 to 24%, whereas phosphorus and sulfur averaged 7 and 8%, respectively, across the three years. Magnesium deficiency incidence was again lowest in the drought year, and 12 - 13% during years with adequate spring moisture. Calcium deficiencies averaged 10%.

These corn ear leaf surveys showed that potassium is the most commonly deficient nutrient in Midwest corn production, and that it is particularly problematic in drought years. Nitrogen and magnesium deficiencies are the next most common, followed by zinc and boron. Phosphorus, copper and calcium

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Frequency of Nutrient Deficiencies in Corn Production, cont. from pg 2

deficiencies were uncommon.

What can Western corn growers deduce from these results? While it is true that Western soils have higher soil test K levels on average than soils of the Midwest (Fixen et al., 2010), it is also true that in Western states crops remove much more K than is applied as fertilizer or manure (Mikkelsen and Fixen, 2003). With each passing year, more Western soils will approach K deficiency status. Prudent growers will pay attention to soil test K levels, and consider plant tissue testing to document crop K sufficiency and general macro and micro nutrient levels.

Table 2. Incidence of corn nutrient deficiency in the Midwest, as diagnosed by ear leaf nutrient concentrations.

	Deficiency Threshold [1]	Percent of Samples Deficient [2]		
Nutrient (%)	< Less than	2011	2012	2013
N	2.80	23.1	15.3	24.2
P	0.25	7.5	5.3	4.2
K	1.75	17.3	29.3	20.4
S	0.16	7.3	5.4	10.5
Mg	0.16	12.0	7.5	12.7
Ca	0.37	9.0	8.4	11.6

[1] Source: Midwest Laboratories, Omaha, Nebraska
[2] 9,623 samples over three years

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Achieving Nutrient and Carbon Removal through an Integrated Dairy Manure Treatment Process, cont. from pg 1

a business opportunity. Choosing the positive viewpoint, an opportunity exists to capture value from the manure resource. After all, the manure carbon and nutrients, in their elemental form, are quite valuable. In this regard, our research team is conducting collaborative research to advance an integrated system of manure utilization technologies that will collectively reduce manure GHG and nutrient emissions. The process involves fermentation, anaerobic digestion, production of bio-plastics, and algae production. Ultimately, these integrated processes will be optimized to maximize manure resource recovery.

Interesting developments of our research to date include:

- Manure processed in a fermenter produces a liquid effluent that contains significant quantities of organic acids such as acetate and propionate. The organic acids from the fermenter can be used to produce a biological, biodegradable plastic known as polyhydroxyalkanoate (PHA, Fig. 1). We estimate that our technology can produce up to 0.5 pounds of plastic per gallon of thickened manure. The PHA can be sold commercially as a substitute for conventional plastics.
- Residual solids from the fermenter effluent can be used to produce methane-rich biogas in an anaerobic digester (AD). The methane-rich biogas can then be burned to produce electricity and heat. Fiber from the AD can be used for bedding material, or alternately marketed as a peat moss replacement.
- Liquid effluent from the bioplastic system can be used to culture to algae, which consume residual nitrogen and phosphorus. Using CO_2 emissions from the AD, we can produce approximately 0.1 lbs of algae for every gallon of manure fed into the system. Potentially the algae could be used as a fertilizer, or a biofuel.

Our integrated processes can achieve 50-80% overall manure nitrogen removal (exhausted as nitrogen gas after denitrification). We estimate that our integrated technology can capture approximately 6-10% of the manure carbon through bio-plastic and algae production, while also reducing GHG emissions associated with manure degradation by 84%. Biogas production is estimated at 20 to 25 cubic feet per pound of dry manure applied to the digester. We are continuing to research the various processes both in the laboratory and at a pilot-scale level (Figs. 2-3). Research is also being expanded to identify opportunities to capture the nitrogen and phosphorus in a solid fertilizer form.

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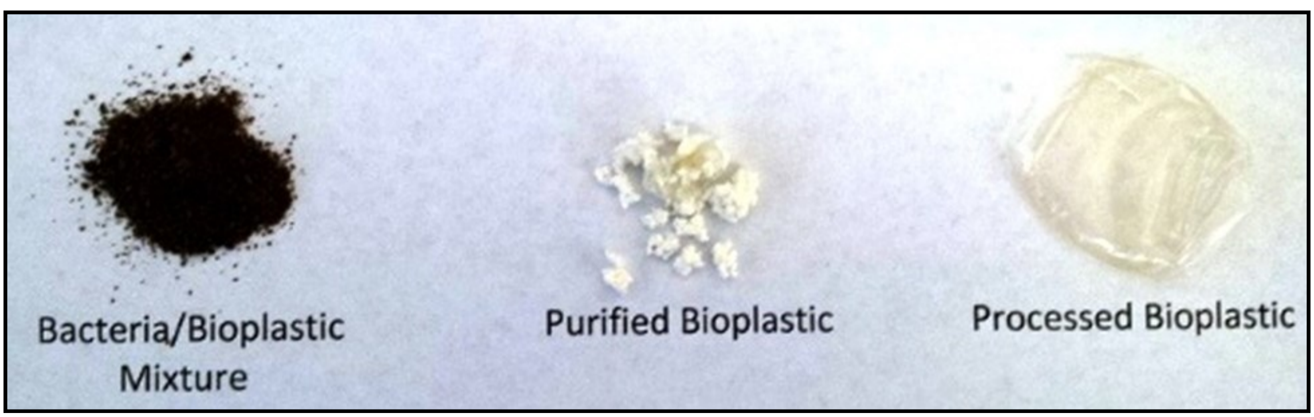

Figure 1. Bioplastic produced from manure through fermentation.

Achieving Nutrient and Carbon Removal through an Integrated Dairy Manure Treatment Process, cont. from pg 4

Figure 2. Bioplastic Scale Model System (Nick Guho, PhD student (right) and Erik R. Coats (left).

Figure 3. Algal production raceways (Feris Lab, Boise State University).

MANAGING NITROGEN IN ORGANIC TOMATO PRODUCTION

By Sebastian Castro and Tim Hartz – University of California–Davis

The organic processing tomato is an important crop in California, with 9,000 acres of organic tomato production in California reported in 2009 (reference?). In partnership with a major tomato processor we conducted a survey of commercial organic tomato fields in 2012-13. Our objectives were to develop information on current nitrogen management practices, and to determine whether early-season soil and/or plant N monitoring could identify fields at risk of nitrogen deficiency early enough for sidedress N application to be effective.

A total of 37 commercial fields in California's Sacramento Valley were sampled every other week from approximately 3-4 weeks after transplanting (first flower stage) until about 11 weeks after transplanting (first red fruit stage, approximately 6 weeks pre-harvest). Mineral N (NO_3-N + NH_4-N) in the top two feet of soil was determined at the first sampling date, with top foot soil NO_3-N sampling repeated through 11 weeks after transplanting. Leaf total N and petiole NO_3-N analysis was also done. The cooperating growers were surveyed regarding their N management practices (use of cover crops, and manure, compost and organic fertilizer application).

The predominant N input in these fields was fall application of manure or manure compost (Table 1). Fall application allows more time for N mineralization to make organic N forms plant-available, provides the required pre-harvested period for non-composted manure, and avoids application and incorporation problems associated with wet spring conditions. Fear of wet spring weather is one reason for the near absence of cover crops in this production system. Spring application of high-N organic fertilizers (feather meal, guano, etc.), whether pre- or post-transplant, was common, but rates were limited to 40 lb N/acre or less, due to the high cost of these materials. Growers differed significantly in the type, amount and timing of N inputs.

Table 1. Type and timing of organic nitrogen applications to organic processing tomato fields.

N management practice	Number of fields
Overwinter cover crop	1
Fall manure or manure compost application	29
Spring pre-transplant fertilizer application	14
Post-transplant fertilizer application	9

In 22 of the 37 fields monitored, whole plant sampling (vine plus fruit) was conducted at approximately 11 weeks after transplanting, and whole plant nitrogen concentration was determined. Based on prior research into the critical N concentration for processing tomato (the whole plant N concentration required to reach maximum growth potential, Hartz and Bottoms, 2009), these fields were classified as either N deficient or N sufficient. In these 22 fields, soil mineral N at 3-4 weeks after transplanting ranged widely, from 6 to 32 ppm in the top 2 feet (Fig. 1); at typical soil bulk density this indicated that soil mineral N varied between approximately 50 to 250 lb/acre. The vast majority of this N was in NO_3-N form. In all fields, soil NO_3-N fell throughout the season as plant N uptake (which can reach 4-5 lb N/acre/day and 250 lb N/acre seasonally in a high-yield tomato crop) outpaced the N mineralization capacity of these soils. By 11 weeks after transplanting, soil NO_3-N was commonly below 10 ppm, and below 5 ppm in some fields.

Figure 1 clearly shows that fields that began with soil mineral N below 10 ppm were at risk of developing N deficiency; in fields 2, 3 and 5 the growers applied high-N organic fertilizers after the

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Managing Nitrogen in Organic Tomato Production, cont. from pg 6

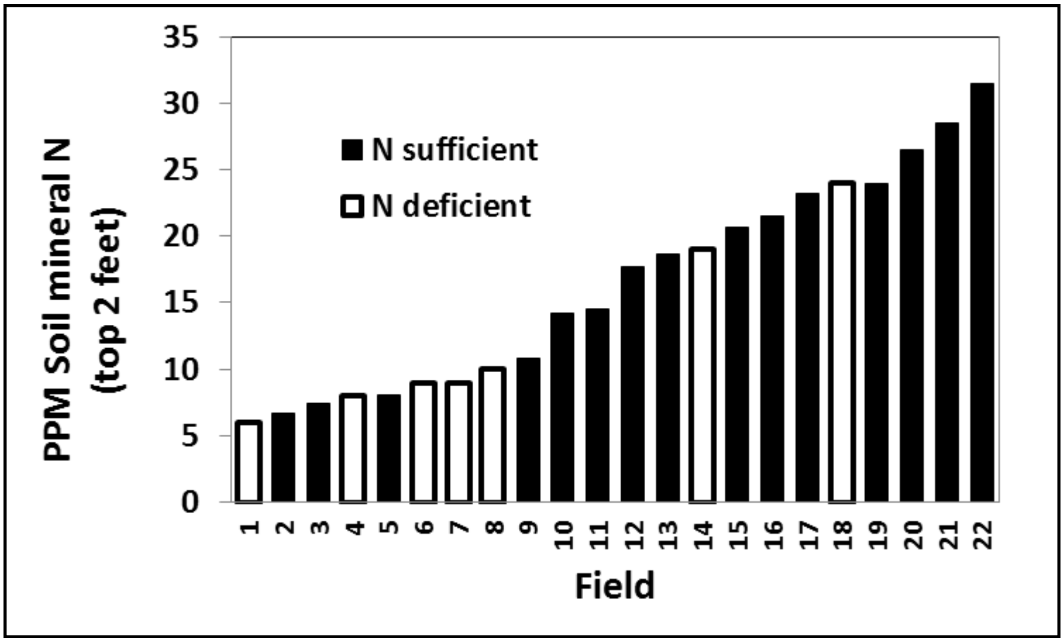

Figure 1. Relationship between crop N status at 11 weeks after transplanting (as determined by whole plant N determination) and early-season soil mineral N concentration (top two feet, sampled 3-4 weeks after transplanting).

initial soil sampling, apparently satisfying the crop N demand. Nitrogen deficient fields averaged only 28 tons of fruit per acre, compared to 41 tons/acre in N-sufficient fields. The apparent N deficiency encountered in fields 14 and 18, both of which began the season with high soil mineral N, may have reflected poor irrigation management more than initial soil N availability.

Early-season soil testing appears to be a valuable tool for organic tomato growers to determine which of their fields are at high risk of developing N deficiency, helping them target in-season application of expensive organic N fertilizers. Early season (3-5 weeks after transplanting) leaf total N and petiole NO_3-N monitoring also showed promise as tools to predict N fertilizer need. In the case of processing tomato, sidedressing is possible as late as 6-7 weeks after transplanting in furrow-irrigated fields; N fertigation could be done even later in drip-irrigated fields. High-N organic fertilizers can mineralize > 60% of N content in 4 weeks at summer soil temperatures (Hartz and Johnstone, 2006; Hartz et al., 2010); with processing tomato taking up substantial N through at least 12 weeks after transplanting (Hartz and Bottoms, 2009), organic N application could be effective at least through 8 weeks after transplanting.

We realize that processing tomato is a specialty crop not widely grown outside of California. However, the basic principle identified in this study should be applicable to the production of other high-N demand crops. Even in organically managed soils, in-season soil N mineralization is unlikely to keep pace with crop N uptake, so fields that do not begin the season with a substantial bank of mineral N are at risk of developing N deficiency. Soil N action thresholds need to be worked out for other crops and production areas.

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