END-OF-SEASON CORN STALK NITRATE-NITROGEN TEST FOR POST-HARVEST EVALUATION—A CASE STUDY

Abstract

Land application of dairy manure to cornfields is a common practice and a major method of manure disposal for dairy operations. Dairy manure provides numerous benefits for corn and other silage crops. However, excess applications of dairy manure can have negative impacts when nitrogen (N) is lost from the agricultural fields to the environment. Public concerns about pollution of groundwater, surface water, and drinking water have motivated dairy farmers and other stakeholders to explore strategies for fine-tuning dairy manure applications. The end-of-season corn stalk nitrate-N test (CSNT) is a proven and reliable post-harvest evaluation tool for both silage corn and grain corn production under both rain-fed and irrigated conditions. This case study illustrates how to use the CSNT as a post-harvest tool to evaluate N availability and discuss how CSNT results can be used to fine-tune N management in future growing seasons.

Introduction

One of the major feed sources for livestock in confined dairy operations in the Pacific Northwest (PNW) is corn silage produced on land associated with the operations. Land application of manure to the cornfields is a common practice and a major method of manure disposal for the dairy operations (Figure 1).

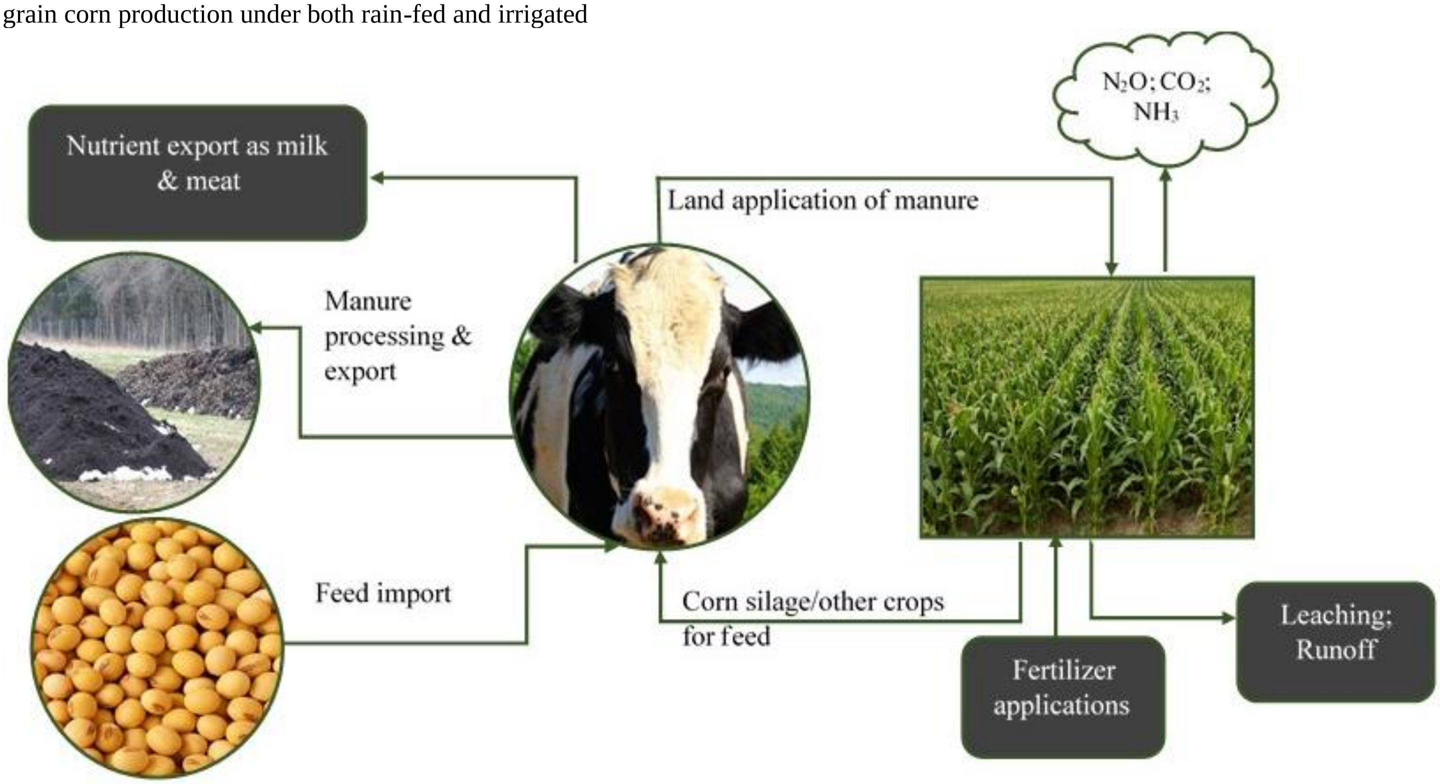

Figure 1. Typical nutrient flows in a confined dairy operation.

Land application of dairy manure provides numerous benefits for corn and other silage crops. Manure provides a large amount of nitrogen (N), phosphorus, potassium, and many other essential nutrients for crop growth. In addition, manure provides organic matter that increases the soil's organic matter (SOM) reservoir (Figure 2). Improving SOM content leads to improvements in soil health, such as greater nutrient availability, increased soil water-holding capacity, and better soil structure and stability. Under optimum conditions, SOM can be mineralized by soil organisms that convert organic forms of N into inorganic forms of N, which are then readily available for plant uptake.

However, excess applications of dairy manure can have negative impacts when N is lost from the agricultural fields to the environment (Erickson 1995; Sharpley et al. 2003). Public concerns about ground- and surface water pollution, human health risk from nitrate polluted drinking water, and eutrophication of surface water bodies have motivated dairy farmers and other stakeholders to explore strategies for minimizing the negative effects while retaining the benefits of dairy manure applications. In addition, organic amendments, such as animal manure, when applied to crop fields, potentially elevates the release of greenhouse gases, such as nitrous oxide and carbon dioxide (Wagner-Riddle et al. 1997; Zhai et al. 2011), suggesting that manure application rates need to be closely monitored to help mitigate agricultural contributions to climate change.

Post-harvest evaluation can estimate N sufficiency levels during the corn growing season and provide a valuable tool for fine-tuning future N management strategies. The end-of-season corn stalk nitrate-N test (CSNT) is a proven and reliable post-harvest evaluation tool for both silage and grain corn production under both rain-fed and irrigated conditions (Binford et al. 1990, 1992; Blackmer and Mallarino 2000; Ketterings et al. 2013).

Objectives

The objectives of this article are to (1) illustrate how to use the CSNT as a post-harvest tool to evaluate N availability and sufficiency during the growing season and (2) discuss how CSNT results can be used to fine-tune N management in future growing seasons.

Materials and Methods

Study Site Selection

During the 2016 growing season, we obtained permission from Yakima County, Washington (WA) dairy farmers to conduct the study on 15 irrigated cornfields. Corn was planted between May 1st and May 20th, 2016. Preplant soil samples were collected from each field for soil N analysis. For each field, we recorded information about manure application history, current season fertilizer N rate and application method, and current season manure application type, rate, timing, and method.

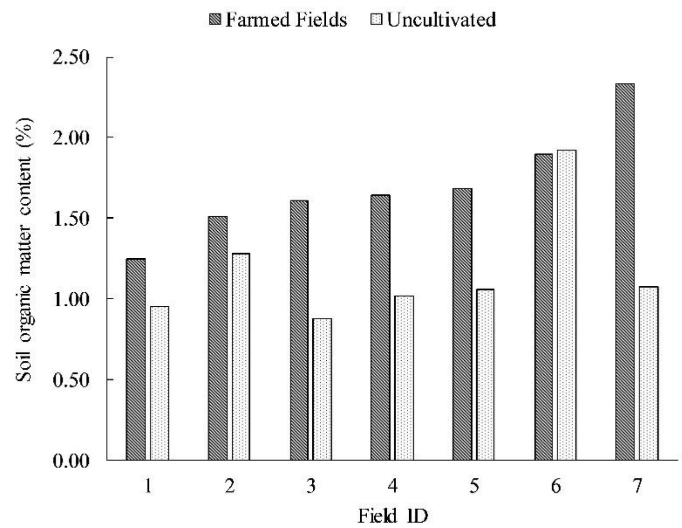

Figure 2. Farmed fields with a long-term manure application history had higher soil organic matter content in the surface 0–1 ft depth compared with nearby uncultivated sites.

Approximately one week prior to harvest in late August to early September 2016, when corn growth was at the quarter to half milk line stage, we took corn stalk samples, following the standard CSNT sampling protocol (Tao et al. 2019). Briefly, in each of the 15 fields, we randomly collected 15 corn stalk samples by cutting an 8-inch section between 6 and 14 inches above the ground surface (Figure 3). After removing the leaves and sheaths, we immediately sent the samples to a commercial laboratory for testing nitrate (NO_3^-) concentration.

Results and Discussion

Relationships between End-of-Season Corn Stalk NO_3^--N Concentration and Manure Application

The CSNT test results for the 15 cornfields varied from 215 to 10,550 ppm. Because the cornfields were sprinkler irrigated, we used the CSNT "deficient" category value of < 708 ppm established by Isla et al. (2015). We found that three of four fields without manure applications for the 2016 crop season had “deficient” N levels, while only one of 11 fields with manure applications for the 2016 season was “deficient.” The majority (9) of the 15 fields tested far above optimal N levels (> 1,700 ppm in sprinkler irrigation systems), indicating excess N availability during the growing season (Figure 4).

Figure 3. Demonstration of taking corn stalk samples for the CSNT test (photo by Haiying Tao)

The 10 of 11 fields with manure applications during the 2016 crop season had significantly higher CSNT values compared with the four fields without manure applications (p = 0.05; Figure 4). This finding suggests that excessive amount of N was available in these fields and there was a potential of N loss to the environment or buildup of nitrate in the soils below the root zones. Reducing manure application rates in these fields can reduce the risk of N loss while maintaining sufficient N availability for optimum corn yield.

We could not perform statistical analysis on the significance of CSNT response to manure applied at different forms, rates, and timing due to the small number of fields in each category. Five different forms of manure were applied on the 11 manured fields, including separated liquid, solid, slurry, compost, and bedding materials. The fields were applied with manure at different rates and timing. For example, separated liquid was applied at 50,000 gal/acre on five fields and at 150,000 gal/acre on one field with irrigation, compost was applied at 13–16 ton/acre on three fields, slurry was applied on four fields at 10,000–15,000 gal/acre, and various amounts of bedding materials were applied on a few fields. Most fields received a

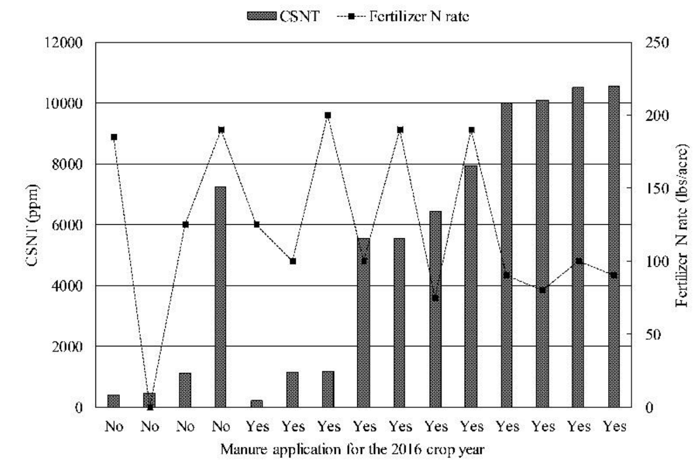

Figure 4. End-of-season corn stalk nitrate-N test (CSNT) concentrations (ppm) from 15 cornfields, as affected by manure and fertilizer applications.

one-time application, and some fields received manure applications in both fall and spring. Future research on how field management practices and manure and fertilizer application rates, forms, timing, and placement affect CSNT should focus on surveying large numbers of fields using the approach described in this article and analysis method described in Tao et al. (2018).

Relationships between End-of-Season Corn Stalk NO_3^--N Concentration and N Applications and N-Related Soil Factors

One preplant soil N test was performed on the soil samples taken from each field. Results showed that soil extractable inorganic N (nitrate-N and ammonium-N) varied from 10 to 135 lb N/acre in the zero- to one-foot depth and 23 to 321 lb N/acre in the zero- to three-foot depth. However, the preplant soil test N was not a factor that significantly affected CSNT (p = 0.1). The Illinois Soil Nitrogen Test (ISNT), which estimates the amount of readily mineralizable organic N in the soil (Khan et al. 2001), can be a potentially useful test for these long-term manured fields. We believe that the ISNT might be a better test to adequately estimate N availability for corn in long-term manured and irrigated fields. However, more studies need to be conducted to evaluate the usefulness of ISNT for irrigated, long-term manured fields in WA.

The farmers used a N-based mass balance approach to determine manure and fertilizer N application rates. One of the important components of the mass balance approach is estimation of soil N mineralization rate. Farmers used the typical book value of 20 lb N/acre available from soil N mineralization for every 1% SOM. However, N mineralization rates could be substantially higher in long-term manured fields (Wu et al. 2017) with additional manure applications (Nett et al. 2010) and under irrigated conditions that can achieve optimum soil moisture and temperature for microbial activity (Campbell et al. 1998). Research on how to accurately estimate soil N mineralization rates in long-term manured fields under irrigated conditions is necessary to estimate the right N rates for corn-based cropping systems.

Although fertilizer N rate varied from zero to 200 lb/acre, rate did not significantly contribute to the variability of CSNT results ($p = 0.1$). This finding suggests that reducing fertilizer applications in these fields may not cause N deficiency or yield losses.

Although each of the 15 fields had a long-term manure history, CSNT varied from 400 to 7,250 ppm in the four fields without manure applications during the 2016 crop season. This finding might be due to large within-field spatial variability or different histories of manure application rates and timing. Farmers can use the remote sensing imagery-guided corn stalk sampling method described in Tao et al. (2019) to ensure the samples are taken in the representative areas in a field.

Fine-Tuning N Rate

We recommend that farmers regularly conduct end-of-season CSNT to evaluate N sufficiency levels in their cornfields and further fine-tune their N management strategies in subsequent growing seasons. Farmers should begin their fine-tuning by reducing or even eliminating fertilizer N applications in the cornfields where CSNT results were in the excessive category. If subsequent CSNTs consistently report excessive CSNT values after eliminating fertilizer N, farmers should then reduce manure application rates. We suggest cutting fertilizer N first because land application is a major method of using dairy manure due to the high cost of exporting manure off the farm. If farmers find themselves with excess manure after appropriately adjusting their N management strategies, they must find acceptable, low-cost, or marketable alternatives for disposal. Potential alternatives include exporting manure as compost, manure pots, or manure pellets.

A recent publication suggested using a remote sensing imagery-guided corn stalk sampling technique for CSNT as an efficient method to evaluate within-field spatial variability in N sufficiency levels (Tao et al. 2018). This method uses aerial or satellite imagery to measure the corn canopy's vegetative index, such as the NDVI (normalized difference vegetation index) or NDRE (normalized difference red edge index), and a digital soil map to predetermine sampling locations. When within-field CSNT variability is combined with other spatial data, including weather, irrigation, soil properties, management practices and fertilizer rate, form, and timing, farmers will understand how various parameters affect N sufficiency levels. In turn, this comprehensive information will help farmers fine-tune their future N management strategies for corn production with increasing accuracy and confidence.

Conclusions

Although the fields were managed using a mass balance approach to determine N application rates, 60% of the 15 irrigated cornfields studied had excess N availability, based on the CSNT. Farmers should consider reducing or eliminating fertilizer N applications in fields with excess N and continue to monitor CSNT and yield. If CSNT values remain high and yield is unaffected by reduced fertilizer N, farmers may then consider reducing manure-based N application rates. Additional research is needed to estimate N mineralization rates in long-term manured fields under irrigated conditions so that farmers can better estimate N rates for corn production.

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