Amounts of Nutrients Removed in Corn Grain at Harvest in Delaware

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Abstract
The Delaware Nutrient Management Act requires that nutrient management plans be written for most land in Delaware that receives nutrients. This law states that phosphorus (P) cannot be applied at rates greater than three-year crop removal rates. Calculations of crop nutrient removals require knowledge of the concentration of P in the harvested crop and crop yield. Research in the surrounding region has shown wide variation in P concentrations of corn (*Zea mays* L.) grain, which is a major crop in Delaware. The objective of this project was to determine average nutrient concentrations and ranges in these concentrations in corn grown in Delaware and Maryland. Based on 668 corn grain samples, grain nutrient concentrations and removals varied considerably among different fields, and these variations were almost as great within individual fields. This variability suggests little value in analyzing the harvested portion of corn from individual fields but instead using average removal concentrations for writing nutrient management plans. The results also suggest that average P removal concentrations utilized by universities and government agencies around the United States for calculating crop nutrient removals may be too high, with the exception being the Natural Resources and Conservation Service (NRCS) crop nutrient removal database. In other words, most nutrient management plans are probably overestimating P removal concentrations and subsequent P removals for corn grain. The results from this project indicated that the mean nutrient removal concentrations for nitrogen (N), P, and potassium (K) were 0.88, 0.19, and 0.22 kg nutrient per hectoliter of grain, respectively.

Key Words
Corn, phosphorus removal, grain P, nutrient removal

Introduction

The Chesapeake Bay and Delaware's Inland Bays have serious water quality problems. The application of nutrients at rates greater than those needed for optimal crop production is considered a contributing cause to these water quality problems. To address these problems, the Delaware Nutrient Management Law was passed in 1999. A significant requirement of this law is that no more than a three-year crop removal rate of P can be applied to soils that are considered "high" in P, with "high" currently defined as soil test P concentrations above 150 mg P/kg (Mehlich III extractant). This requirement assumes that reliable information exists on the amount of nutrient that is removed by commonly grown crops in Delaware.

There are several published reports that document the amount of nutrient removed by crops (Christenson *et al*. 1992; Eghball *et al.* 2003; Mitchell 1999; Sims and Campagnini 2002; Steinhibler *et al.* 2004; Zublena 1997). However, a recent study (Heckman *et al.* 2003) from the Mid-Atlantic region of the United States, which included 23 site-years across five states (DE, NJ, PA, MA, & MD), reported a wider range in the P concentration of corn grain than expected. The standard value assumed for P removal concentration in corn grain in several states is 0.225 kg of P per hectoliter (hL) of grain. The study of Heckman *et al.* (2003) found the average P removal concentration of corn grain to be 0.24 kg P/hL, however, this value ranged from 0.13 to 0.33 kg P/hL. This range raises concerns because if it is assumed that an irrigated field was planted to corn each year for three years and that the corn crop averaged 12.5 Mg/ha each year, then the estimated three-year grain removal of P would be somewhere between 70 and 175 kg P/ha. This represents a range of over 100 kg P/ha, which would be the equivalent of about 6 Mg/ha of poultry litter in terms of P content. This is a very wide range in the amount of nutrient potentially removed by the crop and could represent gross under- or over-estimates in nutrient removal if "standard" nutrient removal concentrations are utilized.

It is important to determine if this variability in corn grain P concentration is as great in Delaware as was found with corn in the Heckman *et al.* (2003) study. If this type of variability is common, it may be important to recommend nutrient testing of the harvested crop so that proper nutrient removals could be determined for each field in a nutrient management plan. The objective of this project was to determine the nutrient concentrations and nutrient removal rates for corn grain grown in the Chesapeake Bay and Delaware Inland Bays region and to determine the variability in these concentrations and removals.

Methods

This project began in 2003 and has continued through the 2009 growing season. Corn grain samples have been collected from several different projects and from random fields throughout Delaware. One set of corn samples involved collecting grain from hybrid strip trials that were yield-performance trails on several farms throughout Delaware and the Eastern Shore of Maryland. Another set of corn samples were from two projects that involved different fertilizer and manure treatments. With these two studies, only plots that had adequate levels of soil fertility were included. One project was located at the University of Delaware's Research and Education Center near Georgetown, DE, while the other project was located at Chesapeake Farms near Rock Hall, MD. Two separate fields (one in Kent County, DE and one in Sussex County, DE) were sampled by taking corn grain samples in a grid pattern across the field to evaluate within-field variability. Additional corn grain samples were taken from random fields throughout the states of Delaware and Maryland during grain harvest. All corn grain samples were taken by removing a subsample from either the combine or the weigh wagon following the yield measurement. The grain samples were dried in an oven at 60 degrees C. All samples were ground to pass a 1.0 mm sieve and analyzed for nutrient concentrations by Brookside Laboratories in New Knoxville, Ohio. The samples were digested in nitric acid using a CEM MARS5 microwave digestion system (CEM Corporation, Matthews, NC), and analyzed for essential plant nutrients (P, K, Ca, Mg, Mn, Cu, Zn, Fe, B, S and Al) using a TJA Enviro II inductively-couple plasma atomic emission spectrometer (Thermo Electron Corporation, Franklin, MA). Total N in the plant samples was determined by combustion using a LECO CNS-2000 elemental analyzer (LECO Corp. St. Joseph, MI). Corn grain yields were all adjusted to 155 g/kg moisture content. The results from these studies have been summarized in units of mass concentration (g/kg), volume concentration (kg/hL) that will be discussed as removal concentrations (kg/hL), and nutrient removals per area (volume yield X volume concentration, in kg nutrient/ha).

Results

The P concentration of 668 corn samples ranged from 1.9 to 5.2 with a mean of 3.1 g/kg (Table 1). These P concentrations correspond to P removal concentrations ranging from 0.12 to 0.31 kg of P per hectoliter with a mean of 0.19. This mean is lower than most reported values with the exception of NRCS, whose reported value is 0.19 kg P per hectoliter (USDA-NRCS 2007). The mean N removal concentration was 0.88 kg N per hectoliter, which is lower than all other reported values. The mean K removal concentration was 0.22 kg K per hectoliter, which is also lower than most other reported values with the exception of the NRCS value of 0.21. In a Canadian study, Parsons *et al*. (2007) found an average P concentration of 3.0 g/kg and an average K concentration of 5.8 g/kg in corn grain, which is considerably higher than the concentration of 3.6 g K/kg found in this study. Heckman *et al*. (2003) found an average P concentration of 3.3 g/kg. Statistical summaries of other nutrient concentrations, nutrient removal concentrations, and nutrient removals are also shown in Table 1. For all nutrients, the primary factor that influenced nutrient removals in corn was grain yield.

The concentration of P in 15 samples of corn that were taken in a grid pattern from one field in Sussex County, DE ranged from 2.2 to 3.5 with a mean of 3.0 g/kg; while another field of corn in Kent County where 20 grid samples were taken ranged from 2.2 to 3.7 with a mean of 3.1 g/kg. Interestingly, the P concentration from 60 samples within a 2-acre area of a field ranged from 2.6 to 5.2 with a mean of 3.5 g/kg. These 60 samples represented six replications of ten fertilizer treatments and these treatments had no significant effect on grain P concentration. These data suggest that variations in grain P concentrations within individual fields are nearly as great as variations across fields and years.

Conclusions

The goal of this project was to determine nutrient removal concentrations and the mass of nutrients removed by corn grain in Delaware and Maryland fields and to compare these amounts to values derived from standard "book values" that are used for writing nutrient management plans. An evaluation was also conducted of the variability in these nutrient removal concentrations among fields and within fields. The findings suggest that nutrient removal amounts vary considerable for corn, but this variability seems to be nearly as great within individual fields of the same hybrid as it is across different fields and hybrids. Because of this variability, it seems that there would be little value in analyzing the harvested portion of crops from individual fields; instead average values should likely be used when writing nutrient management plans. An important finding is that the average P removal concentrations utilized by universities and governmental agencies around the United States for calculating corn P removals has been too high, with the exception

being the NRCS nutrient removal database. In other words, most nutrient management plans are probably overestimating P removal rates for corn. Nutrient concentration and grain yield are the two factors that control nutrient removal, and this study found that grain yield is the most important factor controlling removals of most nutrients in corn grain. The results from this project indicated that the mean nutrient removal concentrations of N, P, and K were 0.88, 0.19, and 0.22 kg nutrient per hectoliter of grain, respectively.

Table 1. Range in yield and nutrient concentrations for 668 corn grain samples.

Parameter	Units	Min	Max	Mean	Median	Std Dev
Yield	Mg/ha	3.2	17.9	10.9	11.4	2.7
N*	g/kg	10.40	18.50	14.49	14.30	1.49
P	g/kg	1.90	5.16	3.05	3.04	0.43
K	g/kg	2.20	5.20	3.62	3.70	0.44
Mg	g/kg	0.70	1.60	1.04	1.01	0.16
S	g/kg	0.60	1.32	0.99	1.00	0.14
B	mg/kg	0.30	25.60	3.21	2.40	2.58
Mn	mg/kg	3.30	46.80	8.68	5.40	8.18
Cu	mg/kg	0.45	4.80	1.32	1.20	0.74
Zn	mg/kg	12.5	77.4	19.6	19.0	4.2
N	kg/hL	0.633	1.127	0.883	0.871	0.091
P	kg/hL	0.116	0.314	0.186	0.185	0.026
K	kg/hL	0.135	0.318	0.221	0.226	0.027
Mg	kg/hL	0.043	0.097	0.063	0.062	0.009
S	kg/hL	0.037	0.080	0.061	0.061	0.009
N Removal	kg/ha	66.1	246.2	141.2	138.9	28.9
P Removal	kg/ha	9.2	48.7	27.9	28.4	7.4
K Removal	kg/ha	8.4	57.6	33.7	35.2	9.8
Mg Removal	kg/ha	2.5	17.8	9.6	9.8	3.0
S Removal	kg/ha	2.7	16.0	9.1	9.3	2.7
B Removal	kg/ha	0.0024	0.2675	0.0291	0.0220	0.0243
Mn Removal	kg/ha	0.0174	0.4769	0.0751	0.0543	0.0724
Cu Removal	kg/ha	0.0026	0.0479	0.0121	0.0098	0.0081
Zn Removal	kg/ha	0.0553	0.6152	0.1798	0.1759	0.0580

*Based on 548 grain samples.

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