Nutrient considerations with corn silage and stover harvest

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Introduction

Harvested cornstalk residue (corn stover) after grain harvest has traditional use as bedding and co-feed for livestock. Interest is increasing with other uses, especially for energy production such as direct burning and cellulosic ethanol. The potential growth for cellulosic ethanol is large as two plants in Iowa are either proposed or in initial construction. If proven feasible and economical, cellulosic ethanol production and concurrent stover demand could increase substantially.

While silage harvest has been practiced for many years, and nutrient removal with silage is well known, corn stover harvest and related nutrient removal is different due to the timing of harvest and a separate grain harvest. Also, stover harvest being promoted by companies for ethanol production must have low soil contamination and total removal may not be desirable for soil sustainability reasons. Therefore, stover harvest will be less than total aboveground vegetation. Company suggested stover harvest rates appear to be approximately one-half of the stover, which is much less than removed when silage is harvested (with silage could be 90-95+ % of total aboveground material). Therefore, grain plus some stover harvest will remove lesser amounts of biomass carbon (C) and plant nutrients compared to silage harvest. The frequency of stover harvest in a specific rotation will determine long-term impact on nutrient removal and recycling to soil.

Corn silage nutrient removal

Corn silage harvest often removes the majority of aboveground plant biomass. This makes nutrient removal much higher than with grain only harvest. For high quality silage that stores properly, harvest typically is recommended when silage moisture is 60-70%. Waiting for the plant to reach physiological maturity (often evidenced by a black layer on the kernel tip or no milk remaining at the kernel base) is too late as the silage will be too dry. Therefore, silage harvest often takes place before plant maturity. This means total aboveground biomass (and grain yield) has not yet accumulated and total plant nutrient uptake and grain nutrient content are not final. Therefore, nutrient content in silage (aboveground plant parts including grain) will be less than at plant physiological maturity.

There are published average values for silage nutrient content; for example Iowa State University Extension publication PM 1688, General Guide for Crop Nutrient and Limestone Recommendations in Iowa, lists phosphorus (P) and potassium (K) content per ton of corn silage at 65% moisture as 3.5 lb P_2O_5 and 8.0 lb K_2O. On a dry matter (DM) basis these values are 10 lb P_2O_5 and 23 lb K_2O. With the silage harvested amount and these estimates, the removal of P and K can be easily determined. The increase in amount of P and K removed with corn silage compared to grain differs because the relative amounts of these nutrients are different in vegetative parts than in grain. For P there can be an approximately four times greater amount of P per ton of dry matter in grain than vegetative parts, but for K the opposite occurs, on average with almost three times greater amount of K per ton of dry matter in the vegetative parts.

Drought conditions (as this year) can complicate the estimate of nutrient removal with silage harvest due to potential change in nutrient concentrations and uptake in different plant parts, and associated effects of the timing of drought and time of silage harvest relative to plant growth stage. These effects are difficult to predict, therefore, analysis of silage samples can aid in determining nutrient concentrations. No matter the method used to estimate silage P and K concentration, the amount of silage harvested per acre has the greatest impact on nutrient removal. Therefore, it is important to have a good estimate of silage harvested and moisture content.

Over the years, P and K have been the nutrients of interest with silage harvest due to the large removal amounts, but not nitrogen (N) or other nutrients. This is changing as more focus is being placed on C and N due to effects on sustainability of the soil resource with silage and stover harvest, and for N also effects on water quality.

Corn stover nutrient content

Determining corn stover nutrient content is complicated because nutrients, especially K, can be leached out of plant tissue from maturity to grain harvest, and after grain harvest. This means that nutrient concentrations of stover can be quite different depending on the rainfall pattern from plant maturity to time of stover harvest.

Table 1 gives a complete nutrient analysis of corn at maturity for the grain, vegetative components, and cob. The grain dry matter is approximately one-half of the aboveground vegetative plus cob dry matter. Since the C concentration is similar for all plant components, the grain C is also approximately one-half of the vegetative plus cob components. The nutrient content of cobs is quite low, and for the data set in Table 1 were not measured except for C and N. The cob N is very low, there is more N and P in the grain than the vegetative component, and more K in the vegetative component than grain. This difference in relative P and K content of vegetative tissues compared to grain is why nutrient removal has to be calculated differently for grain, silage, or stover harvest. As is typically found, the concentration and amount of micronutrients is low in both the grain and vegetative component. There is some additional Ca and Mg removed with stover harvest, but that amount is easily corrected by normal liming, or is not an issue in soils with neutral pH or with free lime (calcareous).

Table 1. Corn nutrient composition at plant maturity by plant part.

Nutrient	Grain	Veg.	Cob	Grain	Veg.	Cob
	------------- lb/acre -------------			------------- lb/ton (DM) -------------		
C	3717	3283	469	795	840	787
N	110	48	6	24	12	10
P_2O_5	55	11	--	12	3	--
K_2O	37	85	--	8	22	--
Ca	8	37	--	2	9	--
Mg	9	25	--	2	6	--
S	8	5	--	2	1	--
Zn	0.14	0.12	--	0.030	0.031	--
Mn	0.03	0.27	--	0.006	0.069	--
Cu	0.02	0.06	--	0.004	0.015	--
B	0.04	0.06	--	0.009	0.015	--
Fe	0.22	1.10	--	0.047	0.281	--
Dry Matter	9355	7816	1192	--	--	--

From 14 site years at plant maturity, mean 198 bu/acre yield. J. Sawyer and D. Barker, 2006-2007.

A better estimate of potential corn stover nutrient concentration is from data collected at grain harvest (Table 2). The concentrations in Table 2 are for stover that includes the cob, and stover was collected where there would be little or no soil contamination. The P concentration is similar to the data in Table 1 (collected from whole standing plants at maturity), but the K concentration is lower. This would be due to leaching from the vegetation, mostly leaves, after maturity and until grain harvest. Of note is the large range in nutrient concentrations across the study sites (Table 2). This range is greater than found for grain nutrient concentrations, and makes estimation of actual stover nutrient removal from specific fields difficult. However, the actual amount of stover baled would have a great impact on removal. One could sample stover bales and have samples analyzed if a more precise estimate of concentration is needed. However, sampling stover bales can be difficult. That method may also reflect soil contained in the baled stover, and concentrations including soil would overestimate the actual nutrient amount from just the stover material, but not total nutrient removal from the field. Also, nutrients in baled stover originating from soil could have less agronomic value compared to that in the stover due to different crop availability when originating from soil versus stover (the soil component would be a total amount, not a reflection of just plant available nutrient).

Table 2. Corn stover nutrient concentration at the time of grain harvest.

Nutrient	Average	Range
	------------- lb/ton (DM) -------------	
P_2O_5	3	10
K_2O	19	44
Ca	8	8
Mg	4	7
S	1	1
Zn	0.033	0.052
Mn	0.096	0.167
Cu	0.013	0.024
B	0.010	0.011
Fe	0.148	0.171

From 29 site years, 2008-2011. Little or no soil contamination. R.R. Oltmans and A.P. Mallarino, 2011.

Figure 1 shows the decrease in corn stover P and K concentration across time after corn maturity (from information presented at the 2011 ICM conference). The largest decrease occurred from black layer to grain harvest. After that, there was a slow but steady decline for K (with rainfall) in the fall and spring, but P concentration was the same in the fall and then decreased slightly across the wintertime. As mentioned earlier, this change in nutrient concentration with time after grain harvest makes estimates of P and K removal more complicated. However, a reasonable estimate based on the recent research in Iowa would be 3 lb P_2O_5/ton and 19 lb K_2O/ton (dry matter based).

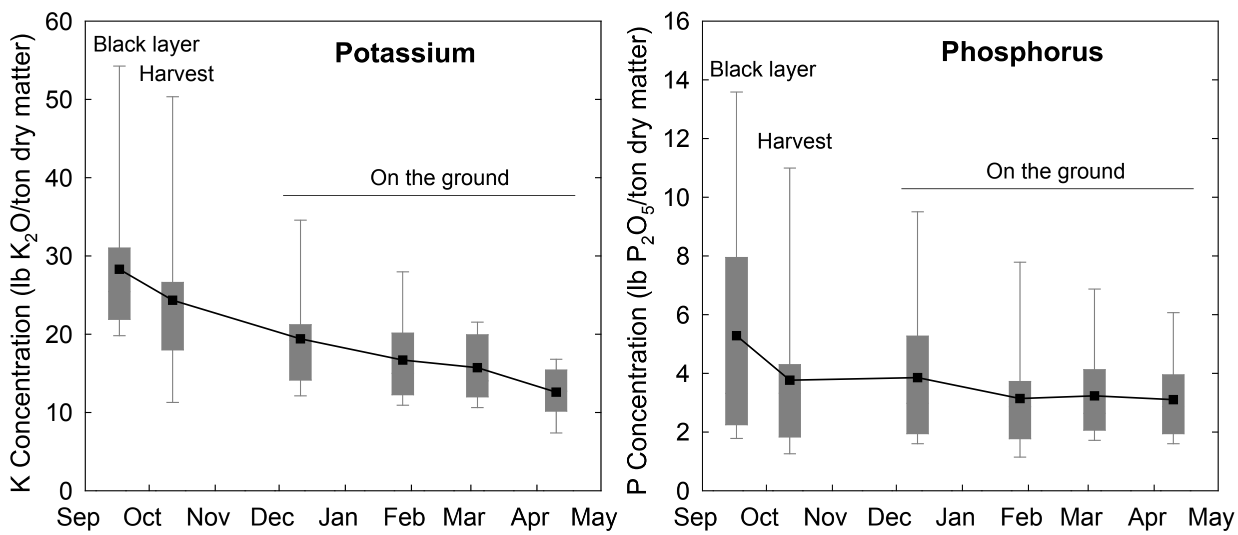

Figure 1. Phosphorus and K concentration in corn stover across time after plant maturity, R.R. Oltmans and A.P. Mallarino, 2011. At each sample time, average (black squares), 50% central distribution (grey boxes), and range (vertical lines) across nine trials and eight plots per trial.

Estimating corn stover production

Although the nutrient concentration in corn stover affects the amount of nutrient removed with stover harvest, but often the amount of biomass harvest has a greater impact. Therefore, a good estimate of the amount of stover harvested is important. The grain harvest index (proportion of total aboveground dry matter as grain) is approximately 50%. Therefore, about one-half of aboveground biomass is in grain and half in vegetative plus cob components. Corn grain, at a 56 lb/bu and 15.5% moisture equivalent, has 47.32 lb dry matter per bu. Therefore, one can quickly estimate the amount of corn stover dry matter by multiplying grain yield times 47.32. This conversion (harvest index) will vary due to season and hybrids, but should give a reasonable estimate of stover production. The amount actually removed for a specific harvest (especially dry matter basis) will be harder to determine as the weight per acre harvested has to be determined at or after baling, along with the stover moisture content which can vary considerably depending on many factors such as moisture at grain harvest, dry down after harvest, and rainfall.

Economic value of nutrients in corn stover

Table 3 gives the value of nutrients (macro and secondary nutrients) in corn grain and stover with plants sampled at maturity. The calculations assume prevailing Midwest prices for commonly used fertilizers. The normal method is to account for P and K in harvested grain when figuring crop removal. Applying the same process to stover, the cost for P is much less in stover, but the cost for K is much greater. The values given in Table 3 reflect total stover harvest. Actual harvest, for example 2 ton/acre, would reduce the cost proportionally.

Table 3. Nutrient value equivalent to fertilizer in corn grain and stover when sampled at plant physiological maturity.

					Fertilizer/Lime		
Nutrient	**Grain**	**Stover**	**Grain**	**Stover**	**Price**	**Nutrient**	**Product**
	- - lb/acre - -		- - $/acre - -		$/ton	$/lb	
N	110	54	52.80	25.92	768	0.48	Ammonia
P_2O_5	55	14	28.05	7.14	645	0.51	DAP
K_2O	37	99	18.50	49.50	615	0.50	Potash
Ca	8	41	0.24	1.23	20	0.03	Lime
Mg	9	27	0.27	0.81	20	0.03	Lime
S	8	5	3.36	2.10	750	0.42	Elemental
Total			103.22	86.70			

Corn grain at 198 bu/acre and corn stover at 4.5 ton DM/acre. J. Sawyer and D. Barker, 2006-2007.

Table 4 gives the nutrient value per ton stover (dry matter basis) at grain harvest. Those values can be used directly to calculate actual cost of removing nutrients in stover (with a conversion to stover moisture when baled). For example, if stover was harvested at 2 ton dry matter per acre, the cost for P would be $3.06/acre and K would be $19.00/acre. Typically, other nutrients are not accounted for with grain harvest when figuring nutrient replacement cost, and the same often is done for stover harvest. However, increased removal of other nutrients, most notably S, could increase potential for nutrient deficiency of subsequent crops.

Table 4. Nutrient value equivalent to fertilizer in corn stover when sampled at the time of grain harvest.

	Corn Stover		Fertilizer/Lime		
Nutrient	**Per Ton DM**		**Price**	**Nutrient**	**Product**
	lb/acre	$/acre	$/ton	$/lb	
P_2O_5	3	1.53	645	0.51	DAP
K_2O	19	9.50	615	0.50	Potash
Ca	8	0.24	20	0.03	Lime
Mg	4	0.12	20	0.03	Lime
S	1	0.42	750	0.42	Elemental
Total		11.81			

Little or no soil contamination. R.R. Oltmans and A.P. Mallarino, 2011.

Nitrogen fertilization after corn stover harvest

Results of an on-going corn stover harvest project in continuous corn were presented at the 2011 ICM conference. Although N removal from the field is not normally considered with grain harvest, it is sometimes of interest with stover harvest due to potential impacts of less residue return. In this research, the effect of stover harvest was a reduction in the N rate needed for maximum economic yield. The economic optimum N rate (EONR) was 20 lb N/acre less with approximately half stover removal and 40 lb N/acre less with full removal. At first this seems backward as N is removed with stover harvest and a greater N application need would be expected. However, with stover removal there is also less addition of C to soil for microbial processing; therefore it appears the change in biomass return (with high C:N ratio) to the soil has a greater influence on N fertilization requirement than less return of N. That study has been in place for only three years, and additional years will help determine if the effect of stover harvest on soil N, microbial mineralization, and EONR remains the same across time.

Table 5. Effect of tillage and corn stover removal on economic optimum N rate (EONR) corn grain yield at the EONR (YEONR) in continuous corn.

	Chisel Plow		No-Till	
Residue Removal	**EONR**	**YEONR**	**EONR**	**YEONR**
	lb N/acre	bu/acre	lb N/acre	bu/acre
None	228	179	227	162
Partial (50%)	203	177	212	173
Full (100%)	185	181	189	170

J. Sawyer, J. Pantoja, D. Barker, M. Al-Kaisi, and A.P. Mallarino, 2009-2011.

Summary

Corn stover harvest removes additional nutrients compared to grain only harvest. The proportion of nutrients in grain and stover varies by the nutrient. Compared to grain, on a dry matter concentration basis, corn stover has one-half the N, one-fourth the P, and three times more K. This means that different concentrations must be used for estimating harvest removal with grain and stover. For corn stover, suggested concentrations (per dry ton) are 3 lb P_2O_5/ton and 19 lb K_2O/ton. These values are lower than listed in Iowa State University publication PM 1688, General Guide for Crop Nutrient and Limestone Recommendations in Iowa. A main reason is that the values in that publication are for corn stover at plant maturity. Nutrients are lost from plant vegetation between maturity and grain harvest, therefore the P and K concentrations suggested above are lower than at maturity. Nutrient concentrations also vary considerably for corn stover, therefore, you should recognize that calculated removal amounts and associated costs are only estimates. Long-term management, including soil testing for P and K, will determine if stover harvest and nutrient removal are being correctly accounted for. Management of N with stover harvest is not straightforward as there is not a direct relationship between removal and need for additional N application in subsequent corn crops. In recent research a small reduction in needed N fertilization rate for continuous corn was found as a result of less corn biomass return to the soil with partial stover harvest. It is difficult to retain N in soils and simply adding more N to replace that removed in harvested stover will not add directly to soil organic-N, and could increase nitrate losses to drainage water.