W 886

Corn Silage Mineral Nutrient Concentrations and Harvest Removal Rates

PRODUCER SUMMARY

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This publication presents applied research quantifying corn silage mineral concentrations across a range of commercial and manure nitrogen fertilization rates. Mineral nutrient sufficiency was assessed using ear leaf samples collected at silking (**Figure 1**). Mineral nutrient concentrations at harvest were measured to help producers better predict crop removal rates (**Figure 2**). Critical study findings are summarized below. Detailed data are presented on the following pages for potassium, phosphorus, sulfur and select micronutrients.

MINERAL SUFFICIENCY. **The mineral content of corn silage produced in Tennessee is typically sufficient** (**Figure 1**). Calcium, magnesium and iron deficiency in corn is rare and so will not be discussed herein. The concentration of other mineral nutrients of more concern tend to increase as nitrogen fertilization rates increase (**Figure 1; Figure 2**). For this reason, **producers should avoid overfertilizing corn silage with nitrogen** [1]. Plant uptake of mineral nutrients beyond sufficiency levels generally doesn't improve silage quality, but may eventually produce soil deficiencies that increase future production costs.

POTASSIUM. **Corn silage harvest typically removes about 220 lbs-K_2O per acre**. Over repeated cropping seasons, this high removal rate can lead to potassium deficiencies in soil. **It is important to prioritize manure application to corn silage because it is prohibitively expensive to replace the potassium removed during harvest using potash.** In this study, corn silage contained about 9.9 pounds of K_2O per ton of harvested silage at 65 percent moisture (**9.9 lbs-K_2O/ton-65%**). This updated estimate is higher than several older reference values (for example, the USDA **Crop Nutrient Tool** concentration estimate is 8.8 lbs-K_2O/ton-65%) [2]. **Producers should soil test silage fields every one to two years to make sure potassium remains sufficient** [1].

PHOSPHORUS. **Corn silage harvest typically removes about 100 lbs-P_2O_5 per acre**. An accurate estimate of crop phosphorous removal rates is often required to set efficient dairy manure land application rates [3]. This research indicates that, pre-harvest, corn silage can be assumed to contain about **4.2 lbs-P_2O_5/ton-65%**. This is higher than the current Tennessee reference value in the **Manure Management Planner** (MMP - 3.6 lbs-P_2O_5/ton) [4], a software tool used to prepare dairy farm nutrient/manure management plans. Producers can measure corn silage mineral nutrient removal rates by collecting and drying corn silage samples at harvest and sending them to a commercial laboratory for a forage analysis. Mineral removal rates are simply the measured mineral concentration multiplied by the actual yield.

MANURE MANAGEMENT. **Target manure to corn silage fields.** In addition to increasing soil organic matter and improving soil tilth and long-term fertility, manure can be used to efficiently replace soil minerals removed during harvest.

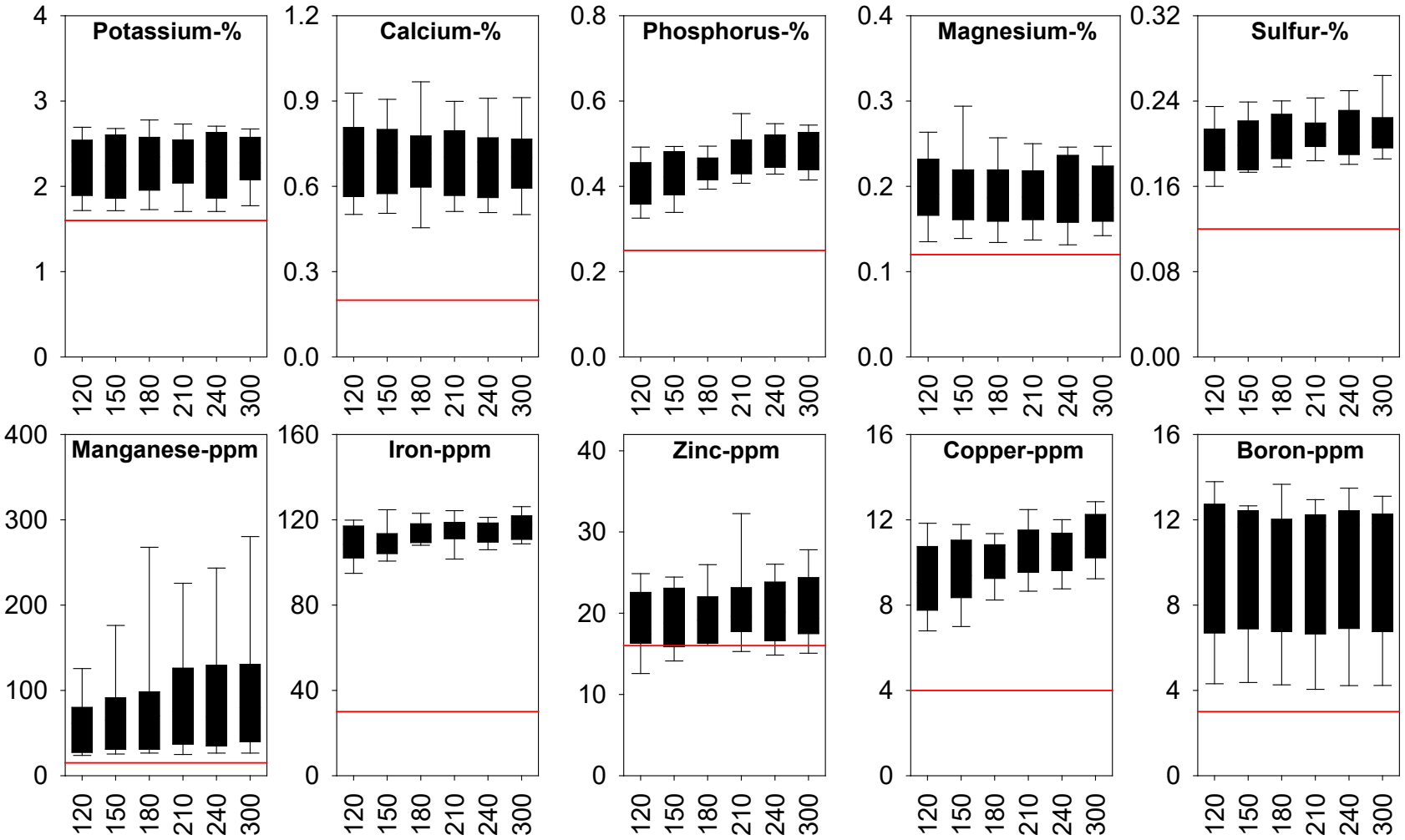

Figure 1. Corn ear leaf mineral concentrations at maturity (silking to milking growth stages). Higher concentration macrominerals (top row) are quantified as a percentage of dry matter (%). Trace minerals (bottom row) are quantified in parts-per-million (ppm) of dry matter. Boxes contain the middle 50 percent of the average concentration data across three years and four test locations at different commercial nitrogen application rates (120-300 lbs-N/ac); lines extend from the boxes to cover 80 percent of the study data. Red lines are a mineral sufficiency threshold below which plant deficiency and limited yield/quality may occur [5]. The study data indicate that sufficient mineral nutrients will typically be recovered from Tennessee soils.

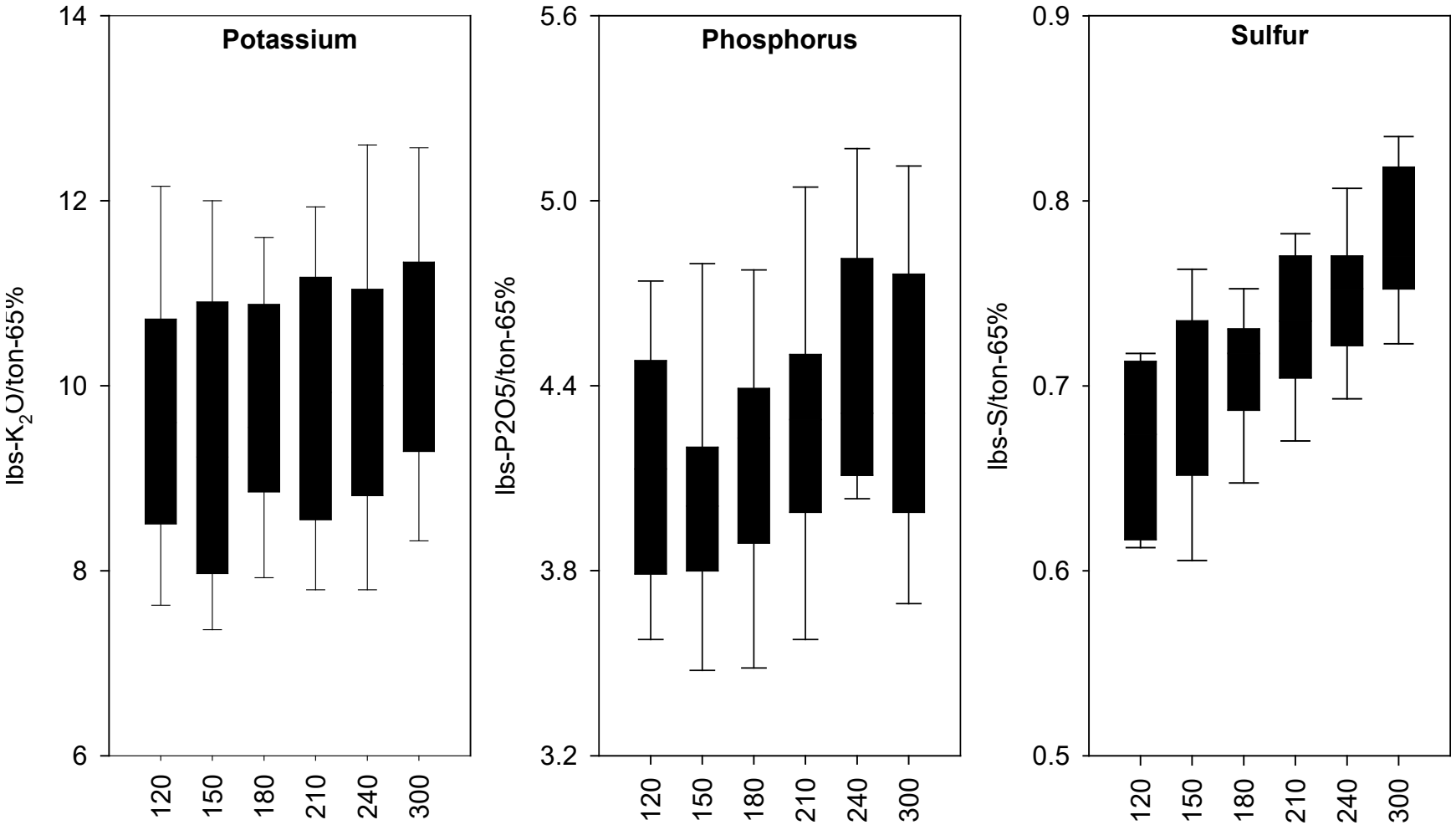

Figure 2. Select corn silage macromineral nutrient concentrations at harvest. Boxes contain the middle 50 percent of the average concentration data across three years and four test locations at different nitrogen application rates (120-300 lbs-N/ac); lines extend from the boxes to cover 80 percent of the study data. Producers can use the concentration range of these mineral nutrients to estimate the range of harvest removal rates at the preferred nitrogen application rate (Concentration × Expected Yield). Note that corn silage sulfur concentrations increase significantly as the nitrogen fertilization rate increases.

POTASSIUM

Concentration. Corn silage potassium concentrations range from ≈ 6-14 lbs-K_2O/ton-65 percent moisture and vary between fields and crop years (**Figure 3**). Potassium concentrations tend to increase as nitrogen fertilization rates increase, but the increase in this study was not statistically significant (**Table 1**). A recommended pre-harvest concentration estimate is:

≈ 9.9 lbs-K_2O/ton-65%

This estimate of corn silage potassium content is higher than the value currently used in the Manure Management Planner (**MMP** = 8.3 lbs K_2O/ton) [4] and reported by **USDA** (7.2 lbs K_2O/ton-65%) [2], but similar to the concentration reported by the National Research Council (**NRC**: 10.1 lbs K_20/ton-65%) [6] (**Figure 3**). A comparison of corn silage fertilized with and without solid manure during 2019 indicates that corn silage fertilized with manure may have higher potassium concentrations (**Figure 3**).

Crop Removal. Target manure to corn silage fields because silage potassium removal rates are very high (**Table 1**):

≈ 207-232 lbs-K_2O/ac

Table 1. An analysis of average corn silage potassium concentrations and crop harvest removal rates at different commercial fertilizer nitrogen application rates (data are from plots where manure was not used as a fertilizer).

Nitrogen (lbs/ac)	Yield tons/ac @ 65% moisture	Concentration[1] lbs-K_2O/ton-65%			Crop Removal Rate[2] lbs-K_2O/ac		
		Average	Low	High	Average	Low	High
120	22.1	9.7	9.2	10.1	213 A B	195	232
150	22.9	9.4	8.8	9.7	207 B	189	224
180	23.3	9.8	9.0	9.9	213 A B	195	231
210	24.4	9.9	9.3	10.3	229 A B	211	247
240	25.1	10.0	9.3	10.2	232 A	214	250
300	25.3	10.3	9.7	10.7	249 A	230	267

NSD

1. Average results were not significantly different (NSD); low and high estimates of the average concentration are given.

2. Average results that do not share a common letter are significantly different; low and high estimates of the average crop removal rate are given at the specified yields.

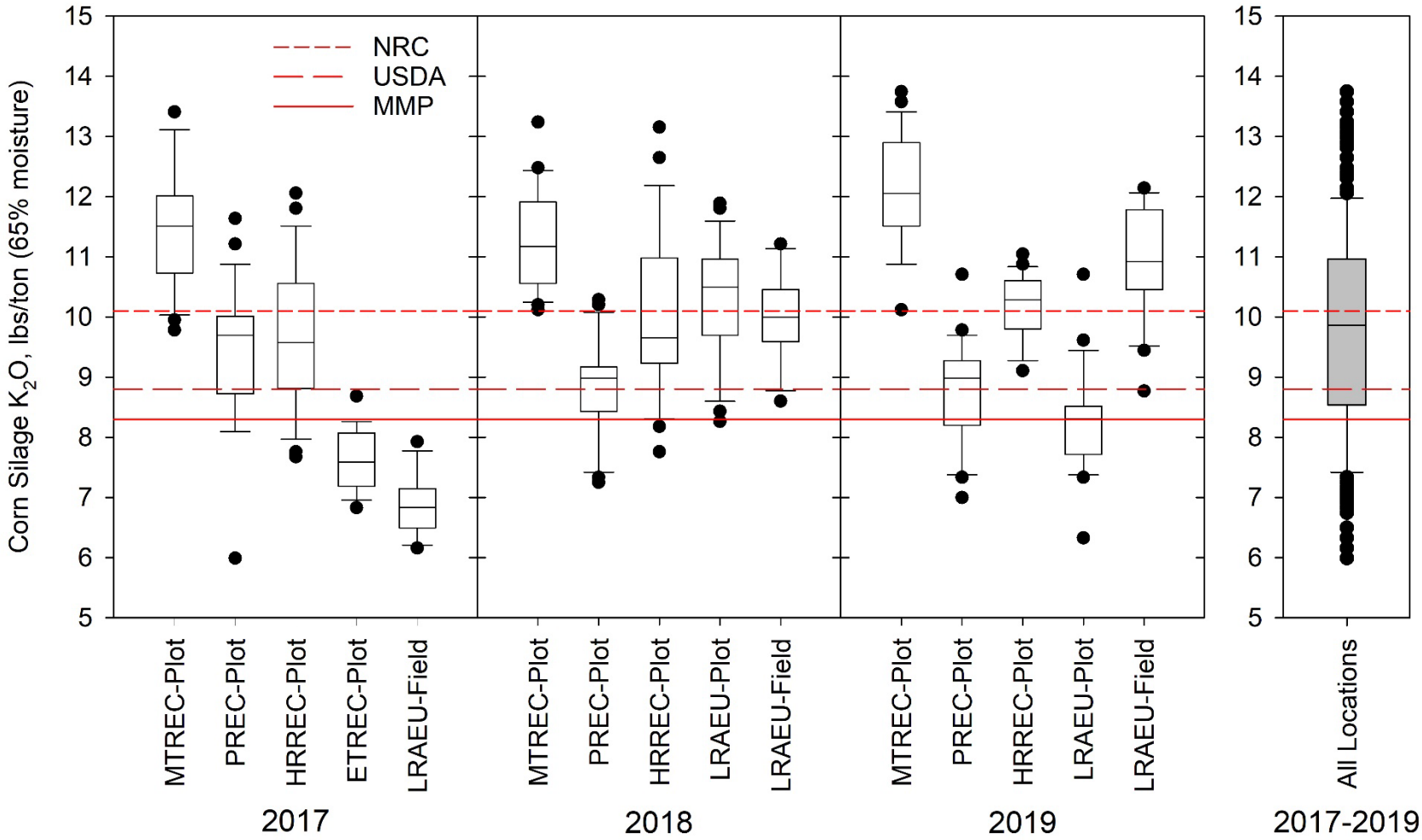

Figure 3. Corn silage K_2O content measured during plot and field scale trials at these UT AgResearch and Education Centers: Middle Tennessee (MTREC), Plateau (PREC), Highland Rim (HRREC), East Tennessee (ETREC), and Little River Animal and Environmental Unit (LRAEU, where manure was used as a fertilizer for the 2018-2019 field plots). Boxes contain 50 percent of the average concentration data at the four test locations for three years at different nitrogen application rates (120-300 lbs-N/ac); lines extend to cover 80 percent of the study data. Reference estimates of the corn silage K_2O content from the **Manure Management Planner** software (MMP) [4], the **Crop Nutrient Tool** (USDA) [2], and the **National Research Council** (NRC) [6] are provided.

PHOSPHOROUS

Concentration. Corn silage phosphorus concentrations range from ≈3-6 lbs-P_2O_5/ton-65 percent moisture and vary between fields and crop years (**Figure 4**). Phosphorus concentrations tend to increase as the nitrogen fertilization rates increase (**Table 2**). A recommended pre-harvest estimate of corn silage phosphorus concentration is:

$$\approx 4.2 \text{ lbs } P_2O_5\text{/ton-65\%}$$

This estimate of corn silage phosphorus content is higher than the value currently used in the **MMP** (3.6 lbs P_2O_5/ton) [4]. **MMP** is a software package frequently used to prepare dairy farm nutrient/manure management plans. Manure application rates in **MMP** are often set to replace predictions of crop phosphorus removal (estimated P_2O_5 concentration multiplied by expected yield).Dairy producers should be aware that underestimating silage phosphorus concentrations, and in turn phosphorus removal rates, can result in less efficient utilization of manure nutrients.

Crop Removal Rate. When you harvest corn silage, expect the crop phosphorus removal rate to be (**Table 2**):

$$\approx 90\text{-}105 \text{ lbs } P_2O_5\text{/ac}$$

Table 2. An analysis of average corn silage phosphorus concentrations and crop harvest removal rates at different commercial fertilizer nitrogen application rates (data are from plots where manure was not used as a fertilizer).

Nitrogen (lbs/ac)	Yield tons/ac @ 65% moisture	Concentration[1] lbs-P_2O_5/ton-65%			Crop Removal Rate[2] lbs-P_2O_5/ac		
		Average	Low	High	Average	Low	High
120	22.1	4.1	3.9	4.4	91 A B	84	99
150	22.9	4.0	3.8	4.3	90 B	82	97
180	23.3	4.2	3.9	4.4	93 A B	86	101
210	24.4	4.3	4.0	4.5	99 A B	92	107
240	25.1	4.5	4.2	4.7	105 A	97	112
300	25.3	4.4	4.1	4.6	107 A	99	115

NSD

1. Average results were not significantly different (NSD); low and high estimates of the average concentration are given.
2. Average results that do not share a common letter are significantly different; low and high estimates of the average crop removal rate are given at the specified yields.

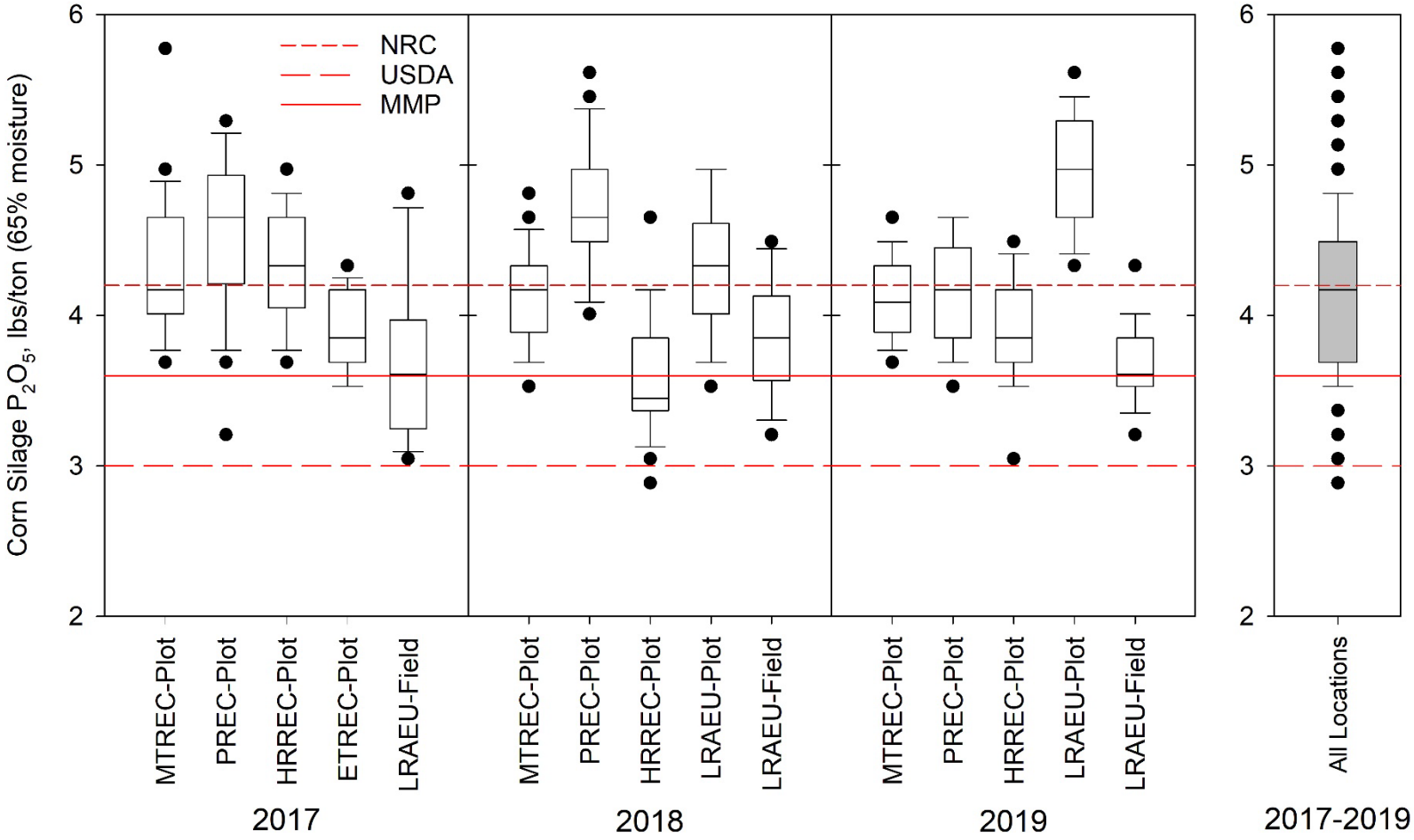

Figure 4. Corn silage P_2O_5 content measured during plot and field scale trials at these UT AgResearch and Education Centers: Middle Tennessee (MTREC), Plateau (PREC), Highland Rim (HRREC), East Tennessee (ETREC), and Little River Animal and Environmental Unit (LRAEU, where manure was used as a fertilizer for the 2018-2019 field plots). Boxes contain 50 percent of the average concentration data at the four test locations for three years at different nitrogen application rates (120-300 lbs-N/ac); lines extend to cover 80 percent of the study data. Reference estimates of the corn silage P_2O_5 content from the **Manure Management Planner** software (MMP) [4], the **Crop Nutrient Tool** (USDA) [5], and the **National Research Council** (NRC) [6] are provided.

SULFUR

Concentration. Average corn silage sulfur concentrations range from ≈0.6-0.8 lbs-S/ton-65 percent moisture and increase as nitrogen application rates increase (**Table 3; Figure 2**). Because corn sulfur deficiencies are becoming more common in Tennessee [7], producers should avoid overapplying nitrogen fertilizer to corn silage. Targeting dairy manure to silage fields will help maintain sufficient sulfur in the soil [8]. A recommended pre-harvest estimate of corn silage sulfur concentration is:

≈ 0.72 lbs-S/ton-65%

Crop Removal. Expect corn silage sulfur removal rates to be (**Table 3**):

≈ 15-18 lbs S/ac

Table 3. A statistical analysis of average corn silage sulfur concentrations and crop harvest removal rates at different commercial fertilizer nitrogen application rates (data are from plots where manure was not used as a fertilizer).

N lbs/ac	**Yield** tons/ac	**Concentration**[1] lbs-S/ton-65%			**Crop Removal Rate**[2] lbs-S/ac		
		Average	Low	High	Average	Low	High
120	22.1	0.67 D	0.65	0.68	14.7 C	13.5	15.8
150	22.9	0.70 D E	0.68	0.71	15.5 B C	14.4	16.6
180	23.3	0.71 C D	0.70	0.73	16.1 B C	15.0	17.2
210	24.4	0.74 B C	0.72	0.75	17.2 A B	16.1	18.3
240	25.1	0.75 A B	0.74	0.77	17.8 A B	16.7	18.9
300	25.3	0.78 A	0.76	0.79	18.9 A	17.7	20.1

1. Average results that do not share a common letter are significantly different; low and high estimates of the average concentration are given.
2. Average results that do not share a common letter are significantly different; low and high estimates of the average crop removal rate are given at the specified yields.

MICRONUTRIENTS

Manganese. Corn silage harvests remove about 0.2-0.3 lbs-Mn per acre from field soils. Manganese concentrations tend to increase as nitrogen fertilization rates increase (**Table 4**). The ear leaves collected in this study always contained sufficient manganese (**Figure 1**) [5]. A comparison of corn silage fertilized with and without solid manure during 2019 resulted in a significantly higher corn silage manganese concentration for the manured plots (**Table 5**). These data indicate that micronutrients in manure are likely available and can be used to efficiently replace the mineral nutrients removed during corn silage harvest.

Zinc. Corn silage harvests remove about 0.1-0.2 lbs-Zn per acre from field soils. Nitrogen fertilization rates tend to increase corn silage zinc concentrations (**Table 4**). Notably, the ear leaves collected in this study contained zinc concentrations that occasionally fell below a threshold for sufficiency [5] (**Figure 1**). Zinc deficiencies can be caused by prolonged cool, wet and cloudy conditions, as well as high soil phosphorus concentrations not associated with manure application [9]. The good news is that a comparison of corn silage fertilized with and without solid manure during 2019 resulted in a higher zinc concentration for the manured plots (**Table 5**). These data again confirm that micronutrients in manure are likely available and can be used to efficiently replace mineral nutrients removed during harvest.

Copper. Corn silage harvests remove small amounts of copper, and the corn ear leaf samples taken during this study always contained sufficient copper [5] (**Figure 1**). However, corn silage copper concentrations sharply increase as the nitrogen fertilization rate increases (**Table 4**). The added copper does not significantly improve silage quality, but does indicate that producers should avoid overfertilizing corn with nitrogen. In this study, corn silage copper concentrations were highly variable, but the corn silage fertilized with solid manure during 2019 did have a higher copper concentration than silage fertilized at planting with only commercial fertilizers. These data again indicate that micronutrients in manure are plant available.

Boron. The corn ear leaf samples collected in this study always contained sufficient boron (**Figure 1**). In Tennessee, boron is generally recommended only for cotton and tobacco production and would rarely be expected to be deficient, particularly in manured fields [10].

Table 4. Average corn silage micronutrient concentrations (parts per million of dry matter) at different nitrogen application rates (N-rate) when manure was not used as a fertilizer. N-rate averages that do not share a common letter are significantly different; NSD = No Significant Difference between the averages at different nitrogen application rates. Low and high estimates of the average concentration are provided.

N-Rate	Manganese			Zinc			Copper		
lbs/ac	Mean	Low	High	Mean	Low	High	Mean	Low	High
120	30	21	39	20	17	22	4.0 C	3.5	4.5
150	32	21	43	20	17	22	4.3 B C	3.9	4.8
180	37	21	52	20	19	22	4.6 A B C	4.1	5.0
210	35	22	49	21	18	24	4.9 A B	4.4	5.5
240	35	23	48	21	19	23	5.0 A B	4.6	5.4
300	40	23	57	22	19	25	5.4 A	5.0	5.7

NSD (Manganese) and NSD (Zinc)

Table 5. A statistical analysis of 2019 field scale corn silage micronutrient concentration data. Two treatments were utilized, one of which received manure only as a replacement for commercial nitrogen fertilizer at planting. Average concentrations designated "A" are significantly higher than concentrations designated "B"; NSD = No Significant Difference. Low and high estimates of the average concentration are provided.

Solid Manure	Manganese			Zinc			Copper		
	Average	Low	High	Average	Low	High	Average	Low	High
Yes	33 A	30	36	20 A	18	21	7.9	7.3	8.6
No	29 B	26	32	18 B	16	19	7.6	8.3	18.8

NSD (Copper)

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