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FACT SHEET

Plant Tissue Test

Best Sampling Practices and Making Sense of Results

Greg LaBarge, Field Specialist, Agronomic Systems

Best Sampling Practices

Plant tissue testing is a valuable nutrient management tool. We often use it to identify if off-colored plants have a nutrient deficiency. Another place tissue testing fits into management is to evaluate our fertility program. This use can help identify any hidden deficiencies that could limit yield. Combining soil testing, which predicts the soil's available nutrients and fertilizer needs, with tissue testing, which measures plant uptake, is a robust data set to make nutrient decisions. Tissue testing also fills a gap in nutrient management, where soil testing is unreliable for determining sulfur and micronutrient needs. If you use plant tissue testing, use these best sampling practices.

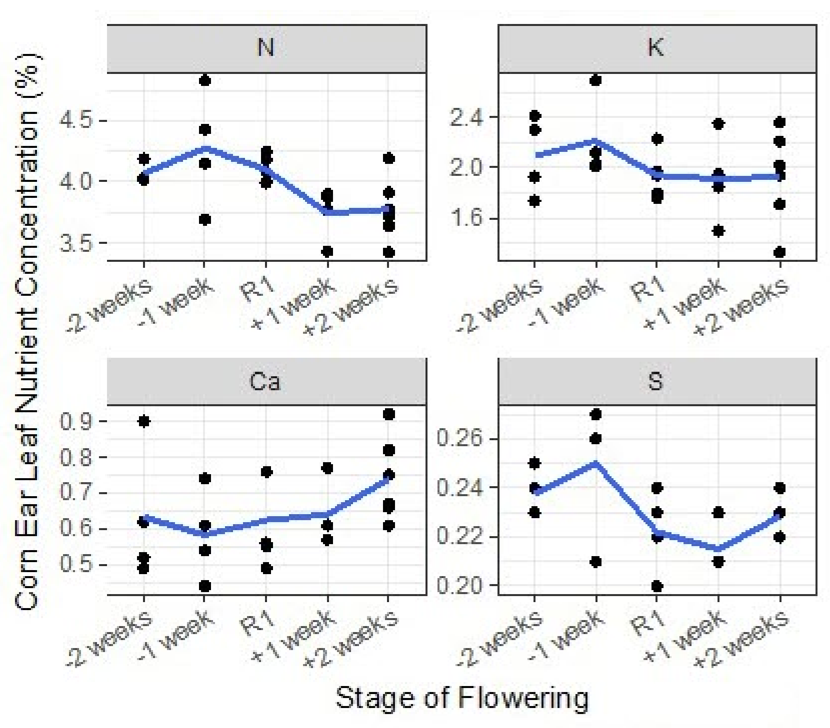

Figure 1. Variation in the nutrient content of corn ear leaf sampled before and after R1 growth stage. Adapted from CORN Newsletter Issue 20-2018.

Collect the appropriate growth stage and plant part to compare to established sufficiency standards. To know if your test result is "good" or "bad," you must compare your result to a standard that includes the yield response at the end of the season. Nutrient sufficiency ranges for most crops are available for samples collected at the mid-vegetative and early reproductive stages. Figure 1 demonstrates the importance of proper staging to time the sampling. Notice the variation in nutrient content when collecting leaves earlier or later than the target R1 corn stage. A sample collected at the wrong time can lead to the wrong conclusion when comparing results to established standard sufficiency ranges.

Nutrient sufficiency ranges in the *Tri-State Fertilizer Recommendations* Bulletin 974 are available for corn and soybeans in the V5 and R1 stages for corn and soybeans. For V5 samples, collect the entire above-ground (1 inch above soil surface) portion of the plant of 20-30 plants. For R1 samples, collect 15 to 20 ear leaves. For alfalfa, collect the top six inches before initial flowering.

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Select plants from representative areas of the field. Avoid plants affected by insects, disease, or adverse weather conditions such as too much or too little water.

When the goal is to diagnose a nutrient deficiency, collecting samples from the affected area and comparing them with a nearby good area is a helpful comparison. In problem areas, target moderately affected plants collected from the transitional area of bad to good rather than the center of severely impacted plants. The most severely affected plants will have several nutrients out of balance, making it challenging to isolate the problem nutrient.

When collecting plants with symptoms, take pictures of the individual leaves, plants, and field areas. These may be useful if you have similar symptoms in other fields in future years.

Collecting soil samples when you are collecting tissue samples can be helpful. Pulling a tissue test sample and a soil probe at the plant just sampled provides valuable information, especially when diagnosing plants with symptoms. A soil sample may not be required when collecting tissue tests in established soil sample zones.

One year of tissue testing is insufficient to evaluate your nutrient management program. Consider collecting 4-5 years of plant tissue analysis. Weather conditions, planting dates, and other crop production factors vary yearly and may impact your results.

If you have not included tissue testing in your nutrient management program, this year is a good time to start. Collecting samples in high and low-productivity areas or fields within your operation would be the place to begin.

Making Sense of Results

The lab results you receive typically report nutrients in two different ways. The macronutrients of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) are found in higher quantities in the plant and reported as a percentage of the total biomass. Micronutrients of Manganese (Mn), iron (Fe), boron (B), copper (Cu), zinc (Zn), and molybdenum (Mo) are reported as the plant concentration using the units parts per million (ppm). As we have preached in the interpretation of soil test results, it is important to note these units and see that they match the sufficiency tables you use for comparison.

One common soil-plant growth interaction seen in tissue testing occurs with P & K. There is a significant and positively correlated linkage between soil tests P and plant P, and soil tests K and plant K, irrespective of other soil factors. The simple lesson is that you generally find low soil test values when plant tissue P & K are insufficient.

Table 1 shows tissue test results from corn ear leaves collected at the R1 stage at the Western Ag Research Station long-term P and K rotation trials. This site has been managed with various P and K fertilizer rates since 2006. The low Soil Test Potassium (STK) site has a soil test potassium of 76 ppm Mehlich 3, while the adequate STK value was 132 ppm. The sufficiency soil test potassium range for corn and soybeans is 120 to 170 ppm.

The plant tissue sufficiency range shown in Table 1 were developed through numerous yield response trials. Where plant tissue values fall within the sufficiency range, yields are not limited by that nutrient.

Table 1 shows the Ohio established sufficiency ranges for corn ear leaf collected at the R1 growth stage. When you compare the tissue test results from both sites with the standard sufficiency ranges, all nutrients except K and Mg for the Low STK site (highlighted with the black outline) fall within the sufficiency range.

The low K and high Mg numbers in these results are related. The plant takes up potassium as K^{+} and Mg^{2+} ions. These two ions are similar in size and compete for uptake at the plant root surface. If K and Mg supplies in the soil are out of balance, one nutrient will outcompete the other. In this case, the STK is low, and Mg accumulates in the plant. Unfortunately, Mg is not a substitute for K in the plant. Thus, yields suffer.

The problem identified with this tissue test is that K is deficient. The accumulation of Mg is a by-product, but it supports the conclusion that K is deficient. Correct STK and plant tissue Mg come into balance. One situation to look for in tissue tests is one nutrient below and one above the sufficiency.

Table 1. Tissue test results from corn grown on two soils at Western Ag Research Station. One site had Soil Test Potassium (STK) levels below, and the other was above the critical soil test value.

Nutrient	Sufficiency Range *	Low STK	Adequate STK
Nitrogen (%)	2.90-3.50	3.44	3.35
Phosphorus (%)	0.30-0.50	0.48	0.46
Potassium (%)	1.91-2.50	0.63	2.02
Calcium (%)	0.21-1.00	0.94	0.67
Magnesium (%)	0.16-0.60	1.21	0.34
Sulfur (%)	0.16-5.0	0.23	0.22

*The sufficiency range shown for each nutrient is from the Ohio Agronomy Guide.

Luxury uptake is another scenario you may see in tissue test results. Luxury uptake is where you see one nutrient higher than the sufficiency range. I have seen this occasionally with the nutrients N and K. This situation results from a more than adequate nutrient soil supply and takes up the nutrients above plant needs. The nutrient accumulates in the tissue.

Excess plant tissue nutrients can have consequences. Forages, hay, or silage may be nutritionally out of balance for livestock. Excessive micronutrients can indicate plant toxicities that affect yield. Do not only look for low but also high tissue test results.

I have put together tissue test sufficiency tables from Ohio and a few surrounding. Numbers for several crops beyond corn and soybean included. You will also find data for additional growth stages that you will find helpful when interpreting tissue test results.

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Ohio State University Extension Publication Tables

Table 3.12 from the soon to be published *Ohio Agronomy Guide, 16th Edition* is shared below. The table was also published in the 15th edition as Table 3.13. Table 31 from the *Tri-State Fertilizer Recommendations* provides micronutrient guidelines for additional growth stages of corn and soybean from studies conducted in 2015 - 2016.

Table 3.12. Marginal and sufficient nutrient concentrations for various crops

Nutrient Element	Corn Ear Leaf Sampled at Initial Silk During Initial Flowering		Soybean Upper Fully Developed Leaf Sampled During Initial Flowering		Alfalfa Top 6 Inch Sampled During Initial Flowering		Small Grains Upper Leaves Sampled During Initial Flowering Midseason	
	Marginal	Sufficient	Marginal	Sufficient	Marginal	Sufficient	Marginal	Sufficient
	Percent							
Nitrogen (N)	2.44–2.89	2.90–3.50	3.99–4.24	4.25–5.50	2.99–3.75	3.76–5.50	2.75–3.24	2.59–4.00
Phosphorus (P)	0.17–0.29	0.30–0.50	0.15–0.29	0.30–0.50	0.20–0.25	0.26–0.70	0.18–0.24	0.21–0.50
Potassium (K)	1.24–1.90	1.91–2.50	1.24–2.00	2.01–2.50	1.74–2.00	2.01–3.50	1.50–1.99	1.51–3.00
Calcium (Ca)	0.09-0.20	0.21–1.00	0.19–0.35	0.36–2.00	0.50–1.75	1.76–3.00	0.18–0.24	0.21–1.0
Magnesium (Mg)	0.09–0.15	0.16–0.60	0.09–0.25	0.26–1.00	0.19–0.30	0.31–1.00	0.11–0.14	0.15–0.60
Sulfur (S)	0.09–0.15	0.16–5.0	0.15–0.20	0.21–0.40	0.20–0.30	0.31–0.50	0.15–0.2	0.21–0.40
	ppm							
Manganese (Mn)	14–19	20–150	14–20	21–100	19–30	31–100	15–19	16–200
Iron (Fe)	9–20	21–250	29–50	51–350	19–30	31–250	7–10	11–300
Boron (B)	1–3	4–25	9–20	21–55	19–30	31–80	2–5	6–40
Copper (Cu)	2–5	6–20	4–9	10–30	2–10	11–30	3–5	6–50
Zinc (Zn)	10–19	20–70	10–20	21–50	10–20	21–70	9–20	21–70
Molybdenum (Mo)	—	—	0.4–0.9	1.0–5.0	0.4–0.9	1.0–5.0	—	—

Source: *Ohio Agronomy Guide 16th Edition*, Ohio State University Extension.

Table 31. Corn and Soybean Tissue Ranges at Three Development Stages Across Three Sites Over Two Years

These crops were not responsive to micronutrient (B, Cu, Fe, Mn and Zn), so these ranges can be considered adequate for micronutrient needs.

Crop	Plant part (Stage)	Boron	Copper	Iron	Manganese	Zinc
		-------------------- part per million (ppm) --------------------				
Corn	Whole young plant (V5)	16–32	3–17	109–800	15–111	20–63
	Ear leaf at silking (R1)	10–44	6–19	87–448	16–86	14–45
	Harvested grain (R6)	3–10	1–4	9–49	3–8	10–36
Soybean	Whole young plant (V5)	37–74	3–37	238–2800	24–170	17–80
	Upper trifoliate at flowering (R1-R2)	45–100	6–18	83–384	22–124	18–76
	Harvested grain (R8)	25–52	11–24	49–107	18–42	26–50

Source: Culman, 2015 & 2016. Soil Amendment and Foliar Application Trials, extension.agron.iastate.edu/compendium/index.aspx

Source: *Tri-State Fertilizer Recommendations-Bulletin 974*, (2020), Ohio State University Extension.

A few recent articles summarizing multi-year micronutrient and sulfur responses studies in Ohio plus additional sulfur background are provided below.

Micronutrients

Corn, Soybean, and Alfalfa Yield Responses to Micronutrient Fertilization in Ohio
ohioline.osu.edu/factsheet/agf-519

Sulfur

Do we need sulfur in Ohio?
ocj.com/2023/01/do-we-need-sulfur-in-ohio/
Are Sulfur Deficiencies Becoming More Common in Ohio?
corn-newsletter/2020-03/are-sulfur-deficiencies-becoming-more-common-ohio
Ohio grain crop response to sulfur fertilization
acsess.onlinelibrary.wiley.com/doi/full/10.1002/agj2.21328

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PennState University Extension Publication Tables

Table 1 from the PennState *Mid-Season Crop Tissue Testing*.

Table 1. Nutrient sufficiency ranges in selected agronomic crops for specific plant parts and growth stages. Reprinted from Penn State Extension Agronomy Guide, Table 1.2-7.

Crop:	Corn	Corn	Alfalfa	Small grains	Soybeans
Plant part:	Whole plant	Ear leaf	Leaves, top 33% of plant	Uppermost leaves	Uppermost full leaves
Growth stage:	~12 inches tall	Silking	Bud to 10% bloom	Before heading	Prior to or early flowering
Sufficiency range percent (%)	*Sufficiency range percent (%)*	*Sufficiency range percent (%)*	*Sufficiency range percent (%)*	*Sufficiency range percent (%)*	*Sufficiency range percent (%)*
Nitrogen	3.50–5.00 %	2.75–3.50 %	3.75–5.50 %	2.50–3.50 %	4.25–5.50 %
Phosphorus	0.30–0.50 %	0.25–0.50 %	0.25–0.70 %	0.20–0.40 %	0.25–0.50 %
Potassium	2.50–4.00 %	1.70–2.50 %	2.00–3.50 %	1.50–3.00 %	1.70–2.50 %
Calcium	0.30–0.70 %	0.20–1.00 %	1.75–3.00 %	0.20–1.00 %	0.35–2.00 %
Magnesium	0.15–0.45 %	0.20–0.60 %	0.30–1.00 %	0.15–0.60 %	0.25–1.00 %
Sulfur	0.21–0.76 %	0.20–0.50 %	0.25–0.50 %	0.15–0.50 %	0.20–0.40 %
Sufficiency range (ppm)	*Sufficiency range (ppm)*	*Sufficiency range (ppm)*	*Sufficiency range (ppm)*	*Sufficiency range (ppm)*	*Sufficiency range (ppm)*
Manganese	20–300 ppm	20–150 ppm	30–100 ppm	25–150 ppm	21–150 ppm
Iron	50–250 ppm	20–250 ppm	30–250 ppm	20–250 ppm	50–350 ppm
Boron	5–25 ppm	4–25 ppm	30–250 ppm	6–25 ppm	20–50 ppm
Copper	5–20 ppm	6–20 ppm	10–30 ppm	6–25 ppm	10–30 ppm
Zinc	20–60 ppm	20–70 ppm	20–70 ppm	20–70 ppm	20–50 ppm

Source: *Mid-Season Crop Tissue Testing* (2022), PennState University Extension. extension.psu.edu/mid-season-crop-tissue-testing

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University of Kentucky Extension Publication Tables

Table 1 and Table 2 from the University of Kentucky *Sampling Plant Tissue for Nutrient Analysis*.

Table 1. Macronutrient sufficiency range for crops grown in Kentucky.

Crop	Growth Stage	Plant Part	Percent					
			N	**P**	**K**	**Ca**	**Mg**	**S**
Corn	Seedling (<4 inches)	Whole plant	4.0-5.0	0.4-0.6	3.0-4.0	0.30-0.8	0.2-0.6	0.18-0.50
	Vegetative	Uppermost mature leaf	3.0-4.0	0.3-0.5	2.0-3.0	0.25-0.8	0.15-0.6	0.15-0.4
	Tasseling	Ear leaf	2.8-4.0	0.25-0.5	1.8-3.0	0.25-0.8	0.15-0.6	0.15-0.6
Soybean	Early growth	Uppermost mature trifoliate	3.5-5.5	0.3-0.6	1.7-2.5	1.1-2.2	0.03-0.6	0.30-0.80
	Flowering	Uppermost mature trifoliate	3.25-5.0	0.3-0.6	1.5-2.25	0.8-1.4	0.25-0.7	0.25-0.60
Small Grain*	Seedling (before jointing)	Whole plant	4.0-5.0	0.2-0.5	2.5-5.0	0.2-1.0	0.14-1.0	0.15-0.65
	Flowering	Flag leaf	4.0-5.0	0.2-0.5	2.0-4.0	0.2-1.0	0.14-1.0	0.15-0.65
Grain Sorghum	Seedling (<12 inches)	Whole plant	3.9-5.0	0.2-0.5	2.0-4.0	0.3-0.6	0.25-0.6	0.24-0.5
	Vegetative	Uppermost mature leaf	3.0-4.0	0.2-0.4	2.0-4.0	0.3-0.6	0.2-0.5	ND
	Flowering	Flag leaf	2.5-4.0	0.2-0.35	1.4-4.0	0.3-0.6	0.2-0.5	ND
Burley Tobacco	Seedling	Whole plant	4.0-6.0	0.2-0.5	3.0-4.0	0.6-1.5	0.2-0.6	0.15-0.6
	Early growth	Uppermost mature leaf	4.0-5.0	0.2-0.5	2.5-3.5	0.75-1.5	0.2-0.6	0.15-0.6
	Flowering	Uppermost mature leaf	3.5-4.5	0.2-0.5	2.5-3.5	0.75-1.5	0.2-0.6	0.15-0.6
Alfalfa	At 1/10 bloom	Top 4-6 inches (leaves and stems)	3.0-5.0	0.25-0.70	2.0-3.5	0.8-3.0	0.25-1.0	0.25-0.50
Clover, Red	Prior to bloom	Top 4-6 inches (leaves and stems)	3.0-4.5	0.2-0.6	2.2-3.0	2.0-2.6	0.21-0.6	0.26-0.30
Clover, White	Prior to bloom	Top 4-6 inches (leaves only)	4.5-5.0	0.36-0.45	2.0-2.5	0.5-1.0	0.2-0.3	0.25-0.50
Orchard Grass	5 weeks after cutting or spring green-up	Whole plant	2.5-3.5	0.25-0.35	2.5-3.5	0.3-0.5	0.15-0.3	0.2-0.3
Tall Fescue	Actively growing	Whole plant	2.8-3.8	0.26-0.4	2.5-3.5	ND**	ND	ND

* Small grain includes wheat, oats, barley, and rye.
** A sufficiency range for these elements has not been determined.

Table 2. Micronutrient sufficiency range for crops grown in Kentucky.

Crop	Growth Stage	Plant Part	Parts per Million (ppm)					
			Fe	**Mn**	**Zn**	**Cu**	**B**	**Mo**
Corn	Seedling (<4 inches)	Whole plant	40-250	25-160	20-60	6-20	5-25	0.1-2.0
	Vegetative	Uppermost mature leaf	30-250	20-150	20-70	5-25	5-25	0.1-2.0
	Tasseling	Ear leaf	30-250	15-150	20-70	5-25	5-25	0.1-2.0
Soybean	Early growth	Uppermost mature trifoliate	ND**	ND	ND	ND	ND	ND
	Flowering	Uppermost mature trifoliate	25-300	17-100	21-80	4-30	20-60	0.1-2.0
Small Grain*	Seedling (before jointing)	Whole plant	30-200	20-150	18-70	4.5-15	1.5-4	0.1-2
	Flowering	Flag leaf	30-200	20-150	18-70	4.5-15	1.5-4.0	0.1-2.0
Grain Sorghum	Seedling (<12 inches)	Whole plant	75-400	13.200	12-150	4-20	3-30	ND
	Vegetative	Uppermost mature leaf	75-200	8-100	12-100	2-15	1-10	ND
	Flowering	Flag leaf	65-100	8-100	12-100	2-7	1-10	ND
Burley Tobacco	Seedling	Whole plant	50-300	20-250	20-60	5-10	18-75	0.2-1.0
	Early growth	Uppermost mature leaf	50-300	20-250	20-60	5-10	18-75	0.2-1.0
	Flowering	Uppermost mature leaf	50-300	20-250	20-60	5-10	18-75	0.2-1.0
Alfalfa	At 1/10 bloom	Top 4-6 inches	30-250	25-100	20-70	4-30	20-80	0.2-4.0
Clover, Red	Prior to bloom	Top 4-6 inches (leaves and stems)	30-250	30-120	18-80	8-15	30-80	0.5-1.0
Clover, White	Prior to bloom	Top 4-6 inches (leaves only)	25-100	25-100	15-25	5-8	25-50	0.15-0.25
Orchard Grass	5 weeks after cutting or spring green-up	Whole plant	50-250	50-200	20-50	3-10	5-20	ND
Tall Fescue	Actively growing	Whole plant	ND	ND	ND	ND	ND	ND

* Small grain includes wheat, oats, barley, and rye.
** A sufficiency range for these elements has not been determined.

Source: *Sampling Plant Tissue for Nutrient Analysis*, University of Kentucky Extension. uky.edu/agcomm/pubs/agr/agr92/agr92.pdf