

# *Understanding and Interpreting Soil and Plant Tissue Lab Reports*

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# What do we expect in a report?

## What we need in a report

- Clear identification of the samples tested
- Clear identification of what the tests performed were
- Good results
- Reliable results
- Understandable units

## What we might want in a report

- Interpretation of the results
- Information on what testing procedure was used

## What might we want but may not think to ask

- The method detection limit
- The error in the results

# Clearly identified samples, tests and understandable units

ppm (parts-per million) in this case is mg/kg

Labs tend to label tests by client expectations or needs. This is electrical conductivity. (SI units for EC are dS/m)

SAMPLE NUMBER	Nitrogen NO <sub>3</sub> -N ppm	Sulfur SO <sub>4</sub> -S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Excess Lime Rating	Soluble Salts mmhos/cm	Chlorid Cl ppm
130-1	5L	5L	0.3VL	3M	53VH	0.2VL	0.1VL	L	0.3L	
130-2	3VL	41VH	0.1VL	1VL	14M	0.2VL	0.1VL	L	0.6L	
12-1	2VL	5L	0.1VL	2L	50VH	0.1VL	0.3VL	L	0.2VL	
12-2	2VL	4L	0.1VL	1VL	53VH	0.1VL	0.2VL	L	0.1VL	

Spelling out the name of the analyte and including the abbreviation is helpful but can also be misleading

RY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), AND VERY HIGH (VH).

ROGEN RELEASE

TS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM

TS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P<sub>2</sub>O<sub>5</sub>



# Soil Units

## Fertility Tests

Exchangeable cations,  
nitrogen, carbon,  
nitrate, ammonium,  
micronutrients,  
sulfate



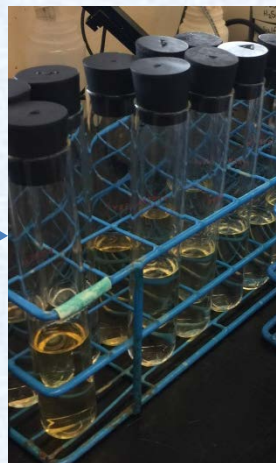
**Results on a  
per mass of solid**  
meq/100 g  
mg/kg (ppm)  
percent

Saturation Percentage



## Salinity Tests

pH, EC, salts,  
bicarbonate,  
carbonate,  
sulfate, chloride



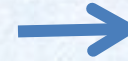
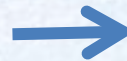
**Results on a  
per volume of liquid**  
meq/L  
mg/L (ppm)  
dS/m or mmhos/cm  
pH units

meq = mM x number of charges  
For example 1 mM  $\text{SO}_4^{2-}$  is 2 meq  $\text{SO}_4$

# Plant Tissue

## Common Tests

Nitrogen, carbon, minerals, nitrate-N, ammonium-N, sulfate-S, chloride



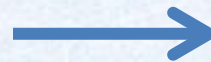
**Results on a  
per mass of solid**  
mg/kg (ppm)  
Percent

Percent x 10,000 = ppm

# Water and Wastewater

## Common Tests

pH, EC, bicarbonate, carbonate, salts, minerals, nitrate, ammonium, sulfate, chloride, total nitrogen, total carbon, DOC, total solids



**Results on a  
per volume of liquid**  
mg/L (ppm)  
percent  
meq/L  
dS/cm or mmhos/cm  
pH units

# Unit Conversion

## Water

mg/L → meq/L  
divide by:

Potassium	K <sup>+</sup>	39.1
Calcium	Ca <sup>2+</sup>	20
Magnesium	Mg <sup>2+</sup>	12.2
Sodium	Na <sup>+</sup>	23
Chloride	Cl <sup>-</sup>	35.5
Sulfate-S	SO <sub>4</sub> <sup>-S</sup>	16
Sulfate	SO <sub>4</sub> <sup>2-</sup>	48
Nitrate-N	NO <sub>3</sub> <sup>-N</sup>	14
Nitrate	NO <sub>3</sub> <sup>-</sup>	62
Bicarbonate	HCO <sub>3</sub> <sup>-</sup>	61
Carbonate	CO <sub>3</sub> <sup>2-</sup>	30
Ammonium-N	NH <sub>4</sub> <sup>-N</sup>	14
Ammonium	NH <sub>4</sub> <sup>+</sup>	18

## Soil

mg/kg → meq/100g  
divide by:

391
200
122
230
355

ppm is parts-per-million  
ppm = mg/kg (solids)  
ppm = mg/L for (liquids)

percent x 10,000 = ppm

Convert Saturated Paste Extract result to ppm (mg/kg)  
soil basis using saturation percentage (SP%):

$$\text{Cl (ppm or mg/kg)} = [\text{Cl (mg/L or ppm)}] / [\text{SP(\%)/100}]$$

Nitrate-N x 4.42 = Nitrate

Ammonium-N x 1.22 = Ammonium

Sulfate-S x 3.00 = Sulfate

Electrical Conductivity (EC)

1 mS/cm = 1 mmhos/cm = 1 dS/m

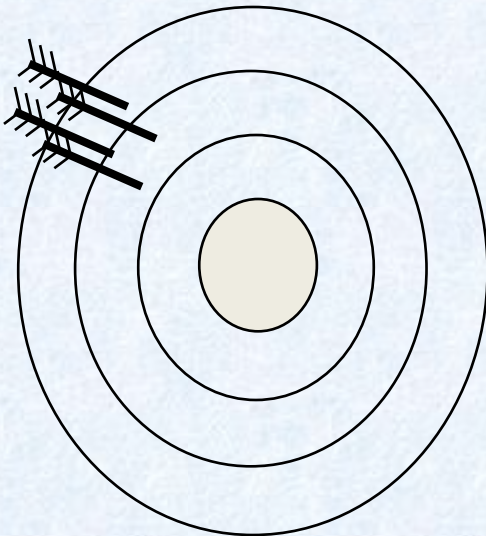
1 μS/cm = 1 μmhos/cm

1 mS/m = 10 μmhos/cm

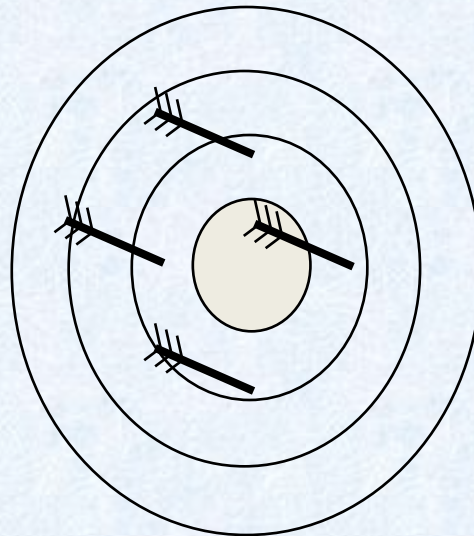


# Good and Reliable Results

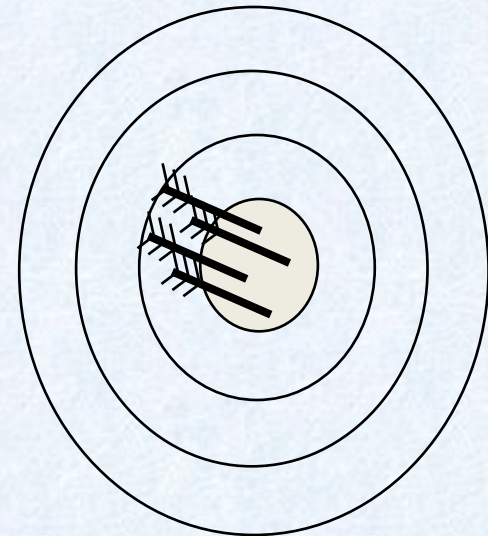
- **Good results** (Accurate Results)
  - **Reliable results** (Precise Results)
- **Accuracy** is the closeness of the measured value to the “true value”.
- **Precision** is the agreement between replicate measurements (2 or more) that are made by the same procedure.
- **Bias** is a consistent trend towards a particular result.



**Precise, not Accurate**



**Accurate, not Precise**



**Precise and Accurate**



# Good and Reliable Results

It is the lab's job to demonstrate **on every set of samples** tested that the test was both accurate and precise.

Precision and accuracy data are typically not reported (and not always measured). It is a good idea to add your own duplicates and samples with known concentration to the samples you submit.

Samples with known concentration can be purchased at <http://www.naptprogram.org>

DANR SECTION:		CTY: KERN			
COPY TO:					
COMMODITY:		Pistachio Water			
Sample Type: WATER		Date Sampled: 9/6/07 + 10/3; Grower/Location:			
SAMPLE #	DESC	pH [SOP 805]	EC [SOP 815] dS/m	SAR [SOP 840]	Ca (Soluble) [SOP 835] meq/L
1		7.8	0.55	2.9	0.88
1 dup		8.0	0.54	2.9	0.86
2		7.6	3.07	3.8	12.02
3		8.0	3.15	4.4	11.85
4		7.5	8.01	6.3	37.73
5		8.1	0.67	3.0	1.60
6		7.7	4.61	4.8	20.03
7		7.5	8.06	6.3	37.49
8		8.3	2.34	16.7	1.63
9		7.8	17.76	36.8	21.41
10		8.5	7.37	102.1	0.82
10 dup		8.5	7.29	103.5	0.80
Analysis Date:		12/20/2007	12/20/2007	12/26/2007	12/17/2007
Method Detection Limit:		0.1	0.01	0.1	0.01
Blank Concentration:		-	-	-	0.00
Standard Ref as Tested:		6.48	0.28	1.9	0.44
Standard Ref Acceptable:		6.45±0.06	0.28±0.02	2.0±0.2	0.44±0.04
Standard Reference:		UCD 004	UCD 006A	UCD 006A	UCD 006A

NOTE: The SOP # (Standard Operating Procedure number)

Duplicate analysis results to assess **precision** of method

Reference material (known concentration) test results given to assess **accuracy**.

# Interpretation of the Results

- Many labs report an optimum range, or interpret results as high or low
- It is important to ask where this range came from.
- Many of these ranges come from UC research using UC methods
- Not all labs follow UC methods, or they use modified UC methods, so the UC recommendations may not be appropriate.
- UC recommendations may also not be appropriate for you to interpret the results.

Test Description	Result	Optimum Range
<b>Primary Nutrients</b>		
Nitrate-Nitrogen	4.9 PPM	See Note 1
Phosphorous	6 PPM	12 - 60
Potassium (Exch)	120 PPM	81 - 500
Potassium (Sol)	ND meq/L	0.25 - 1.0
<b>Secondary Nutrients</b>		
Calcium (Exch)	4800 PPM	---
Calcium (Sol)	19.2 meq/L	2.0 - 50
Magnesium (Exch)	100 PPM	---
Magnesium (Sol)	1.2 meq/L	1.5 - 60
Sodium (Exch)	500 PPM	---
Sodium (Sol)	50.6 PPM	See SAR
Sulfate	9.9 PPM	0.6 - 20
<b>Micro Nutrients</b>		
Zinc	0.5 PPM	0.7 - 50
Manganese	5.2 PPM	1.4 - 50
Iron	5.0 PPM	8.0 - 100
Copper	0.2 PPM	0.2 - 40
Boron	1.2 PPM	0.3 - 1.5
Chloride	53.5 PPM	0.1 - 4.0
CEC	27.1 meq/100g	Variable
<b>% Base Saturation</b>		
CEC - Calcium	87.8 %	60 - 80
CEC - Magnesium	3.0 %	10 - 20
CEC - Potassium	1.1 %	2 - 5
CEC - Sodium	8.0 %	0 - 5
CEC - Hydrogen	0.0 %	0 - 3
pH	7.5 ---	6.8 - 8.2

# Information on what method was used

- Why do you need to know the method?
  - To understand the interpretation
  - To reference in a paper
  - To verify that the appropriate method was used
  - When trying to compare test results from another lab
- Most labs do not report the method used.
- This information may be located on their website or available by request.

DANR SECTION:		CTY: KERN			
COPY TO:					
COMMODITY:		Pistachio Water			
Sample Type: WATER		Date Sampled: 9/6/07 + 10/3; C			
		pH	EC	SAR	Ca
		[SOP 805]	[SOP 815]	[SOP 840]	[S
SAMPLE #	DESC		dS/m		
1		7.8	0.55	2.9	
1 dup		8.0	0.54	2.9	
2		7.6	3.07	3.8	
3		8.0	3.15	4.4	
4		7.5	8.01	6.3	
5					
6					
7					
8					
9					
10		8.5	7.37	102.1	
10 dup		8.5	7.29	103.5	
Analysis Date:		12/20/2007	12/20/2007	12/26/2007	12
Method Detection Limit:		0.1	0.01	0.1	
Blank Concentration:		-	-	-	
Standard Ref as Tested:		6.48	0.28	1.9	
Standard Ref Acceptable:		6.45±0.06	0.28±0.02	2.0±0.2	0.
Standard Reference:		UCD 004	UCD 006A	UCD 006A	UC
NOTE: The SOP # (Standard Operating Proced					
The SOP heading in this Excel file is link					
NOTE: No result within this report is accurate to					



# Things to Look For

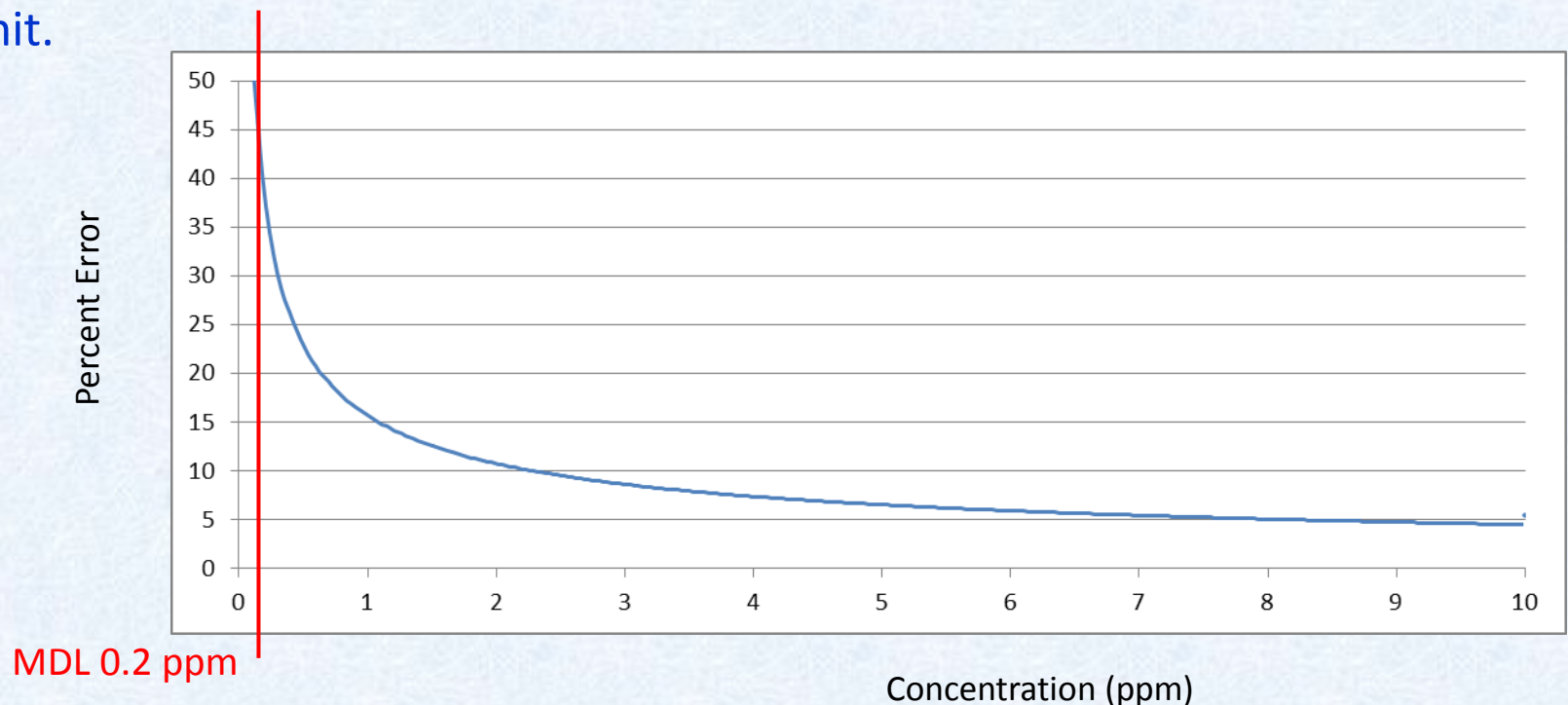
## Methods Used

- Labs may use different methods, so comparison between labs is typically not possible.
- Example: Olsen-P (alkaline soils) or Bray-P (acidic soils)?
- Phosphorous or phosphate-P?
- How was pH run – on saturated paste, 1:1 water:soil (with or without 0.01 M CaCl<sub>2</sub>? This can make ± 0.5 pH units difference.
- Hopefully the lab's website has this information.

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<b>Primary Nutrients</b>		
Nitrate-Nitrogen	4.9 PPM	See Note 1
Phosphorous	6 PPM	12 - 60
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Potassium (Sol)	ND meq/L	0.25 - 1.0
<b>Secondary Nutrients</b>		
Calcium (Exch)	4800 PPM	---
Calcium (Sol)	19.2 meq/L	2.0 - 50
Magnesium (Exch)	100 PPM	---
Magnesium (Sol)	1.2 meq/L	1.5 - 60
Sodium (Exch)	500 PPM	---
Sodium (Sol)	50.6 PPM	See SAR
Sulfate	9.9 PPM	0.6 - 20
<b>Micro Nutrients</b>		
Zinc	0.5 PPM	0.7 - 50
Manganese	5.2 PPM	1.4 - 50
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CEC - Hydrogen	0.0 %	0 - 3
pH	7.5 ---	6.8 - 8.2

# Method Detection Limit

- Method detection limit (MDL)
  - Also called limit of quantitation (LOQ), method detection limit
  - This is the lowest concentration that can be measured accurately and with precision.
- Significant figures
  - Significant figures are a statement of method detection limit/ limit of quantitation.
- Method error can increase dramatically as you approach the quantitation limit.



# Method Detection Limit

## Significant Figures and Detection Limit

- Significant figures are a statement of method detection limit/ limit of quantitation (not specified here)
- Numbers smaller than the method detection limit or are smaller than the last significant figure are essentially random.
- These values have 1 significant figure - beware using them in papers.
- This exchangeable cation method appears to have a limit of quantitation of 100 ppm.

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<b>Primary Nutrients</b>		
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Phosphorous	6 PPM	12 - 60
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Magnesium (Exch)	100 PPM	---
Magnesium (Sol)	1.2 meq/L	1.5 - 60
Sodium (Exch)	500 PPM	---
Sodium (Sol)	50.6 PPM	See SAR
Sulfate	9.9 PPM	0.6 - 20
<b>Micro Nutrients</b>		
Zinc	0.5 PPM	0.7 - 50
Manganese	5.2 PPM	1.4 - 50
Iron	5.0 PPM	8.0 - 100
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CEC - Sodium	8.0 %	0 - 5
CEC - Hydrogen	0.0 %	0 - 3
pH	7.5 ---	6.8 - 8.2



# Things to Look For

## Check results

- Verify results are reasonable based on sample location and history
- Verify results are reasonable based on chemistry, for example:
  - Carbonate not present at low pH
  - Sum of exchangeable cations = CEC  
Sum: 27.3 meq/100 g, CEC: 27.1 meq/100 g  
*(Replacement method or sum of cations used?)*
  - Water and saturated paste:  
Sum cations = sum anions  $\approx$  EC x 10
  - Total N > ammonium + nitrate
  - Total C > Organic C

Test Description	Result	Optimum Range
<b>Primary Nutrients</b>		
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Calcium (Sol)	19.2 meq/L	2.0 - 50
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Magnesium (Sol)	1.2 meq/L	1.5 - 60
Sodium (Exch)	500 PPM	---
Sodium (Sol)	50.6 PPM	See SAR
Sulfate	9.9 PPM	0.6 - 20
<b>Micro Nutrients</b>		
Zinc	0.5 PPM	0.7 - 50
Manganese	5.2 PPM	1.4 - 50
Iron	5.0 PPM	8.0 - 100
Copper	0.2 PPM	0.2 - 40
Boron	1.2 PPM	0.3 - 1.5
Chloride	53.5 PPM	0.1 - 4.0
CEC	27.1 meq/100g	Variable
<b>% Base Saturation</b>		
CEC - Calcium	87.8 %	60 - 80
CEC - Magnesium	3.0 %	10 - 20
CEC - Potassium	1.1 %	2 - 5
CEC - Sodium	8.0 %	0 - 5
CEC - Hydrogen	0.0 %	0 - 3
pH	7.5 ---	6.8 - 8.2

# Things to Look For

Sample Number	Olsen-P (ppm)
1	20.3
2	18.7
3	4.36
4	4.32
5	150.4
6	13.5
7	19.3
8	19.3
9	6.52
10	5.21
1 dup	2.03
10 dup	6.64
SRM	39.9
Blank	0.1
MDL	0.5

## Check results

Verify results are reasonable based possible lab errors

- Check quality control (accuracy and precision)
- Look for lab errors such as:
  - Switched samples
  - Double weighed samples
  - Sample result identical
  - Dilution errors (all values seem off by a constant factor)

SRM: Soil certified to contain Olsen-P at  $20.2 \pm 1$  ppm

Dup: Sample duplicate

MDL: Method detection limit

# Things to Look For

## Check results

Verify results are reasonable based possible lab errors

- Check quality control (accuracy and precision)
- Look for lab errors such as:
  - Switched samples
  - Double weighed samples
  - Sample result identical
  - Dilution errors (all values seem off by a constant factor)

*Duplicates don't match  
Possible dilution error  
or math error since it is  
exactly 10 x difference.*

*Very similar  
adjacent values –  
same sample  
weighed twice by  
mistake? Also,  
reported digits to 2  
decimals are invalid*

*Outlier. Possible contamination during weighing or extraction, or  
math error. Also, too many significant figures*

*Same value consecutively – possible data entry error*

*Duplicates show poor precision. This may be the inherent method error,  
or lab error, samples not well mixed or switched sample 10 with sample 9*

*SRM result out of certified range indicates (very)  
poor accuracy. Double result indicates systematic  
math or dilution error.*

Sample Number	Olsen-P (ppm)
1	20.3
2	18.7
3	4.36
4	4.32
5	150.4
6	13.5
7	19.3
8	19.3
9	6.52
10	5.21
1 dup	2.03
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SRM	39.9
Blank	0.1
MDL	0.5

SRM: Soil certified to contain Olsen-P at  $20.2 \pm 1$  ppm

Dup: sample duplicate



Sample Number	Olsen-P (ppm)
1	20.3
2	18.7
3	4.36
4	4.32
5	150.4
6	13.5
7	19.3
8	19.3
9	6.52
10	5.21

**Notice how incomplete the evaluation of the report is without quality control and MDL data. Critical failures in accuracy and precision are not observed.**

**You need the QC data.**

*Outlier. Possible contamination during weighing or extraction, or math error.*

*Same value consecutively – possible data entry error*

# Summary

- Lab reports differ by format and purpose
- Different labs' reports and test results may not be comparable
  - Units
  - Reference Ranges and Interpretation
  - Methods used
  - Quality control
  - Method detection limits
- Understand the methods and quality control used
- Check the data

## Final comments

Agricultural labs are not accredited like environmental labs. I recommend using a lab that participates in a proficiency program (NAPT or ALP) for research samples.

Check lab results periodically by submitting duplicate samples and samples with known values. These can be purchased from the NAPT or ALP proficiency programs.

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