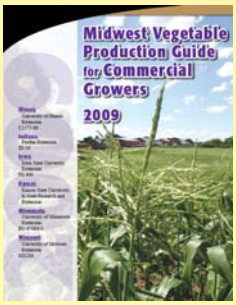
Soil Fertility & Plant Nutrition Topics-
GPVGC- veggie workshop

James Quinn- Horticulture Specialist
Central Region- based in Jefferson City

Who knows about or uses this book?

- An excellent resource
- Has focused on the needs of conventional growers
- Attempting to include organic information
- We anticipate a free copy 2010 will be available to all MVGA members
- MVGA is still waiting on 'formal award announcement'



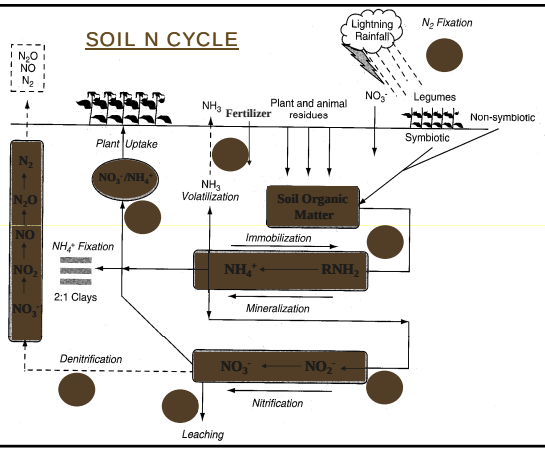
Fertilizer recommendations- Quick Review on the Basics *(QRB)*

- Are based on soil test levels
- Nitrogen recommendations are adjusted for-
  - Soil type
  - Cropping history
  - OM added
  - Crop culture system
- Organic Matter is critical
  - Influences N availability
  - Key in soil quality
  - Cropping system should maintain or slightly increase it

Examples

- Soils with more then 3% OM and following a legume crop, no sidedressed N may be needed
- Soils with less than 3 % OM (following a legume) ½ of the total N can be applied preplant, ½ sidedressed
- When following a non legume, there may be little residual N so additional N may be sidedressed

SOIL N CYCLE



QRB- Fertilizer recommendations - transplants

- Often respond to a small amount of water soluble fertilizer at transplanting
- 3 pounds/50 gallons common for special grades, like 14-28-14, 10-52-10, & 23-21-17.
- High P fertilizers like 10-34-0 can be used at 2 quarts per 50 gal
- Apply at 8 ounces per plant

QRB-pH for Veggie Production

	Range	Target
Fescue	4.7-6.8	5.5
Alfalfa	5.8-7.7	6.5
Tomatoes*	6.0-6.8	6.4
Sweet corn*	6.0-6.5	6.2
Leafy veggies	6.5-6.8	6.7
Muskmelon	6.3-6.8	6.5
Beets	6.5-7.0	6.8
Potatoes	5.0-5.2	*scab***

* & many others

**If the field has a history of scab, using scab-resistant varieties is recommended. Then, the soil pH can be 6.5 where phosphorus is most available.

'Sweet' soils increase major nutrient availability

Percent Nutrient Availability

pH (salt)	Nitrogen %	Phosphorus %	Potassium %
4.0	30	23	33
4.5	53	34	52
5.0	77	48	77
5.5	89	52	100
6.5	100	100	100

From Webster's Dict.- Sweet, free from acidity or sourness, as in soil

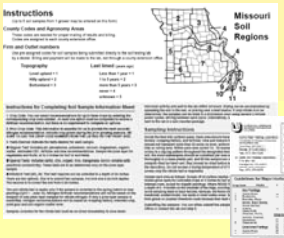
Added Expense of a Low pH

Cool Season Grass Hay Crop

pH (salt)	Fertilizer Wasted %	Required Fertilizer Bill
4.0	71	$185
4.5	54	$115
5.0	33	$80
5.5	20	$71
6.5	0	$51

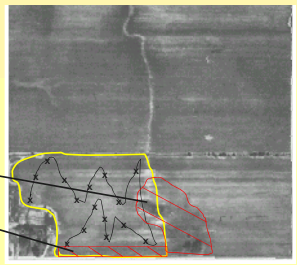
Based on applying 100 lbs N ($.25/lb), 90 lbs P ($.20/lb) and 60 lbs K ($.13/lb) for a total of $51 / Acre spent for fertilizer.

QRB- Don't Guess – Submit for a Soil Test!



QRB- Obtaining a quality soil sample

- 15 - 20 cores at random points along a zig-zag pattern in the field
- One sample for every 20 acres
- Sample top 6 inches
- Avoid sampling near feeding areas and shade trees in pasture
- Avoid sampling near road



QRB-Timing of Soil Sampling

- Avoid sampling soon after P fertilization, liming or manure application.
  - Best to wait 3 months
- Sample every 3 to 5 years.
  - Better to do a quality job (more cores per sample) less frequently
- Sample the same time every year.

QRB-Soil sampling devices

T-probe tube. Cost: ~$30-50

Step probe (fixed) Cost ~$65

Screw auger s/ T-bar. Cost: ~$120 - $170

Back-saver probe. Cost: ~ $350

Drill w/auger. Cost: $200 - $300

QRB- Don't Guess – Read your Soil Test!

- MU has a guide- Interpreting Missouri Soil Test Reports
- Organic matter, pH, and major nutrients are key
- 3 to 4 cropping options are usually allowed
- Major nutrients and lime recommendations
- The special notes section is especially important for vegetable crops on N recommendations

QRB- Using the Midwest veggie production guide- preplant

Two examples

Tomatoes	Green beans
• P- 0 to 250 lbs/acre	• P- 0 to 75 lbs/acre
• K- 50-300 lbs/acre	• K- 0-100 lbs/acre
• N- 30 if OM less then 3% & following a legume	• N- 30 if OM less then 3% & following a legume
• N- 60 if OM less then 3% & **not** following a legume	• N- 40-60 if OM less then 3% & **not** following a legume

QRB- Using the Midwest veggie production guide- preplant

Two examples- based on a soil test*

Tomatoes	Green beans
• P- 25 lbs/acre	• P- 0 lbs/acre
• K- 140 lbs/acre	• K- 60 lbs/acre
• N- 30 lbs/acre	• N- 20 lbs/acre
• (50 pounds N later)	• (probably assumes beans are inoculated)
• & 1440 lbs/acre of lime (ENM)	• & 1800 lbs/acre of lime (ENM)

*** Midwest Laboratories- Morgan County soil test report**

Soil science theories on crop production

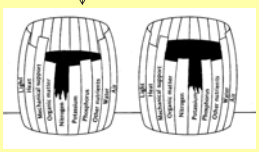
Sufficiency level approach
- Certain levels of nutrients are 'optimum'
- Below some defined level, crops will respond to that nutrients addition

Low
- Yield loss likely

Medium
- Yield loss possible
- Improved disease resistance

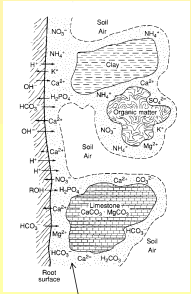
High
- Benefits from fertilization unlikely

Basic cation saturation ratio
- Ideal ratio of Ca, Mg, K
- Is not concerned with recommendations for N, P & S and micronutrients



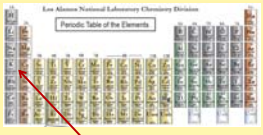
Basic cation saturation ratio- background information

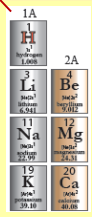
- Soil solution is the thin film of water around roots and particles
- A cation is an ion with a positive charge
- Cations are also held onto particle 'exchange sites', which are negatively charged
- This negative charge can be measured and is called 'cation exchange capacity'
- Clay soils are high (about 18 or higher) sandy soils are low, 5 to 8
- Higher CEC holds more nutrients



Basic cation saturation ratio- ideas and origin

- Based on research in the '1940's
- Research was in New Jersey which has sandier soils
- Focuses on the optimum ratio of the cations Ca, Mg & K
- Suggested optimum ratio has changed over time
- Originally was (about) 6:1:½ (Ca:Mg:K)
- Suggested ratio was modified over the years, to a wider range-
  - 6 : 1: 1/5th
  - 4 : 1: 1/4th





Basic cation saturation ratio- testing the theory

- Initial work by Bear may be due to change in pH, not cation ratio
- Recent research studies-
  - Mclean ('81) in N. Ohio
  - Simpson ('79) in Wisconsin
  - Rehm & Sorensen ('85) in Nebraska

Some concerns developed

- Even if the ratio of cations is optimum, a deficiency can exist, especially in sandy soils
- For fine textures soils, 'less than ideal ratios' did not reduce crop yields
- Striving for an ideal ratio, could result in over applying nutrients

Basic cation saturation ratio- where are we now

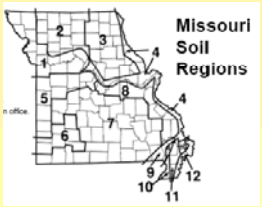
- Optimum soil cation ratio has been incorporated into some fertilization recommendations- 'In various ways'
- Labs should advise to raise soil nutrients above a deficiency level
- A sufficient supply of cations in the root zone is the most important consideration

Some concerns developed

- Even if the ratio of cations is optimum, a deficiency can exist, especially in sandy soils
- For fine textures soils, 'less than ideal ratios' did not reduce crop yields
- Striving for an ideal ratio, could result in over applying nutrients

Does your choice of a soil lab matter?

- Took samples from 4 locations- Audrain, Callaway, Cole, & Morgan counties
- Three locations are planned for veggies in 2008
- From soil regions 3, 4, 8 & 7
- Submitted each for crop recommendations of tomatoes, sweet corn and watermelons
- Samples were dried and ground at MU, then divided and analyzed by MU Soil Lab (Columbia) and Midwest Laboratories (Omaha, NB)



Two of the fields-

can you guess where the either one is?

Basic cation saturation ratio- let's look at an example

	Audrain		Callaway		Cole		Morgan	
Parameter	MU	MidW	MU	MidW	MU	MidW	MU	MidW
pH *	7.5	7.1	8.0	7.8	5.8	5.8	5.6	5.5
OM	1.9	3.3	1.2	2.4	2.6	2.8	2.3	3.1
P	90	88	222	126	5	18	91	92
K	332	354	358	430	330	302	258	172
Ca	6236	4748	7570	4918	2192	2026	2596	2620
Mg	355	374	303	332	657	648	597	665

Approximate Cation ratios using MidWest Labs

- **Audrain-** **13: 1: 1**
- **Callaway-** **15: 1 : 4/3**
- **Cole-** **3: 1 : ½**
- **Morgan-** **4: 1 : ¼**

Case study- comparison, tomatoes

	Audrain		Callaway		Cole		Morgan	
Nutrient	MU	MidW	MU	MidW	MU	MidW	MU	MidW
Lime	0	0	0	0	1085	1080	1615	1440
N	110	80	120	100	105	80	105	80
P	150	25	0	0	225	180	150	25
K	45	105	20	70	45	125	115	140
S	0	0	1300	0	0	0	0	0

Basic cation saturation ratio- let's look at an example

Before fertilizer addition

- Audrain- 13: 1: 1
- Callaway- 15: 1 : $^{4}/_{3}$
- Cole- 3: 1 : ½
- Morgan- 4: 1 : ¼

After fertilizer addition*

- 13: 1: $^{5}/_{4}$
- 15: 1 : $^{3}/_{2}$
- 3 ½ : 1 : $^{2}/_{3}$
- 4 $^{2}/_{3}$: 1 : ½

Remember the optimum ratio was 6:1:½

***Typical Ag Lime is about 30% actual calcium (e.g. 1 ton lime = 600 pounds of applied calcium)**
•½ ton lime for Cole
•¾ ton lime for Morgan

Case study- comparison, watermelons

	Audrain		Callaway		Cole		Morgan	
Nutrient	MU	MidW	MU	MidW	MU	MidW	MU	MidW
Lime	0	0	0	0	1085	720	1615	1080
N	80	110	90	120	75	110	75	110
P	115	25	0	0	220	140	110	25
K	0	100	0	70	0	120	65	130
S	0	0	1300	0	0	0	0	0

• MU's yield basis for watermelons is low (8 ton/ac)
•Difference in N recommendation is primarily due to OM test difference
• Midwest uses corn as the basis for its recommendations; MU uses research on vegetable crops from Michigan and Minnesota
•Midwest uses a higher P# before recommending additions
•Midwest uses a lower K# when recommending additions
•MU's pH test was higher enough for Callaway to recommend S

Case study- comparison, sweet corn

	Audrain		Callaway		Cole		Morgan	
Nutrient	MU	MidW	MU	MidW	MU	MidW	MU	MidW
Lime	0	0	0	0	1085	1080	1615	1440
N	120	95	130	135	115	120	115	100
P	75	0	0	0	180	105	75	0
K	0	75	0	50	0	90	20	100
S	0	0	1300	5	0	5	0	0

•Some difference in lime recommended
•Midwest recommended micronutrients (not shown)-
- **Mn for Audrain & Callaway**
- **Zn for Cole and Morgan**
- **Boron for all**

•?- Mn & iron compete in high pH soils
•?- Additional Zn required in low pH
•Midwest recommended a small addition of S for corn

Estimating yield- page 17

Table 11. Yields of Vegetable Crops

	Expected Yields in Tons per Acre		
Crop	Average	Good	Excellent
Asparagus	1	1-2	3
Bean, Snap	2	4	5
Cabbage	13	15	20
Corn, Sweet	3	8	10
Cucumber (slicing)	4	12	15
Cucumber (pickling, hand harvest)	7	10	13
Muskmelon	8	12	16
Onion	15	20	25
Pepper, Green	5	10	17
Potato (fall)	10	15	20
Pumpkin	10	15	40
Spinach	6	8	10
Summer Squash	10	15	20
Sweet Potato	7	12	15
Tomato (fresh market)	6	13	15
Tomato (processing)	25	30	35
Watermelon	15	20	25

Some soil test labs require a yield estimate. MU's does not.

Smaller field plantings, with a mixture of crops

- May be easier to apply the P & K and initial N to whole field
- Then sidedress or fertigate additional N
- Large amounts of P & K should not be applied via drip irrigation
- All of the required P and most of the K should be applied preplant
- Some extra P & K won't 'hurt' anything

Crop	Initial N	P_2O_5	K_2O
Tomatoes	26	150	115
Melons	37	110	65
Sweet Corn	46	75	20
High Average	40	125	100

Too many fertilizers, too little time (costs you $$)

- 'Dry' fertilizers- N, P, K use as preplant
- If the fertilizer is banded on the raised bed, the rate is calculated based on the width and length of each bed and not the entire field or plot planted
- 'Dry' N (e.g. urea, calcium nitrate)- for sidedressing
- Fertilizers for injection (drip system)- lots of choices, but higher $/higher purity; convert to $$ per pound of N-P-K for cost analysis
- Manure- has time restrictions before harvest, ideal in fall
- Composted manure- good if planting soon

Using Poultry Litter What is it worth?

Manure Test: typical*

Total N	60 lbs/ton
P_2O_5	75 lbs/ton
K_2O	45 lbs/ton

* Typical values for other sources of manure are available

Nutrient availability

• Nitrogen	60-70% available
• P_2O_5	100% available
• K_2O	100% available

What's it worth?

• Available N	40 lbs./ton (60 x 0.65)
• P_2O_5	75 lbs./ton
• K_2O	45 lbs./ton
• N 40¢/lb	$16
• P_2O_5 24¢/lb	$18
• K_2O 24¢/lb	$11
• Poultry litter	$45 per ton*

Assuming your crop needs all three

Fertigation

- Fertigation can be used to fill sidedress N requirements
- Midwest veggie guide has specific comments on cucurbits
- Watering and fertilizing tomatoes in a high tunnel has some easy to follow recommendations

Typical plant nutrient deficiency symptoms

- Soil pH
- Can be aggravated by-
  - Cool weather
  - Wet conditions
  - Disease (root rot)
  - Hot weather
- Crop sensitivity to develop symptoms varies
- May even vary by the variety
- More likely to 'display' at certain growth stages
- Do you know what the deficiency symptoms look like?

Lettuce, and specifically varieties forming heads is more likely to get tip burn, caused by low calcium, and more likely to occur in hot humid weather, during head formation

Nitrogen Deficiencies

- Appear in the old foliage since N is mobile in the plant
- Symptoms include an overall chlorosis of the older leaves
- Stunting or slowing of the growth, which is not easy to notice if you are not tracking the height or have others to compare to

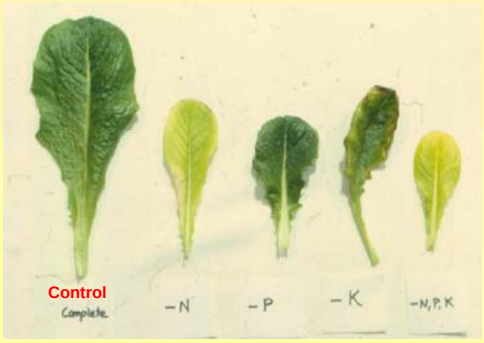
Phosphorus Deficiencies

- Phosphorus is very mobile in the plant so deficiency symptoms normally show up on the older leaves
- Often purple leaves
- Monopotassium phosphate (KH2PO4) 11-52-0

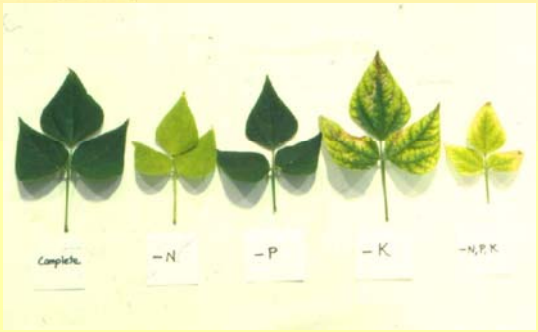
Potassium Deficiencies

- Because K is very mobile in the plant symptoms show up first on the older leaves
- Leaves may be chlorotic which may lead to necrotic spots
- In monocots the spots may be on the margins first
- Potassium sulfate K2 SO4
- Potassium chloride (only used to correct K deficiencies)

Macronutrients N, P, K Deficiencies- Leaf Lettuce



Macronutrient Deficiencies Beans



Calcium Deficiencies

- Deficiencies of calcium reflect this in that calcium deficient plants are weak stemmed
- Calcium deficiencies are a problem with crops like poinsettia which can show bract burn due to calcium deficiency
- Calcium is applied as Ca(NO3)2
- Can be applied as calcium chloride if deficient but be careful if you used Na in your system

Blossom End Rot of Tomato Calcium Deficiency

Right-Hydroponic tomatoes grown in the greenhouse, Left-Blossom end rot of tomato fruits induced by calcium (Ca^{++}) deficiency

Blossom End Rot (BER)

- Early in season
- Fluctuations in watering
- Lush, succulent growth
- Underdeveloped root system
- *Most early maturing varieties are more prone to developing it*

Avoid sidedressing with *ammonium* forms of N fertilizer. (common one is *urea*).

Preferred:

- Calcium nitrate
- Liquid N
- Organic sources

Magnesium Deficiencies

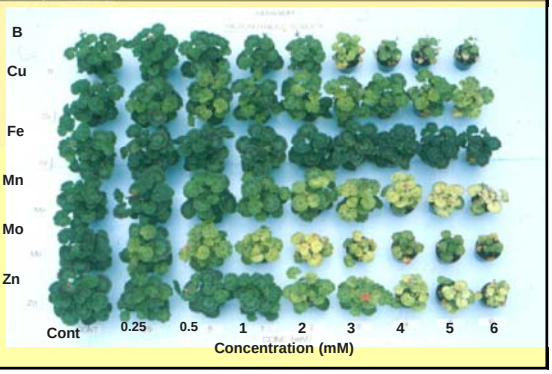
- Interveinal chlorosis on lower leaves
- Generally at the tips and moving inward
- Generally applied as MgSO4

Interveinal Chlorosis on Mature Leaves

Iron (Fe) Deficiency Symptoms

1-Piggyback Plant, 2- Petunia, 3-Silver Maple, 4-Rose (A-normal, B-Fe-deficient)

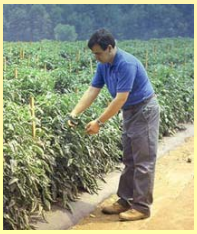
Micronutrient Toxicity on Seed Geranium



Boron toxicity example

- Boron became a micronutrient of interest in 2004 with bootheel melon growers
- One grower tried a new fertilizer blend with boron
- It was a liquid, and he miscalculated on the rate
- But the toxicity results were 'spotty', and some rows were less affected

Using Plant Tissue Sampling



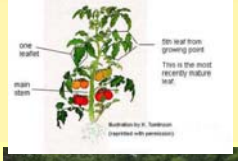
Leaf Samples identify in-season nutrition problems in time to take corrective action.

How Often? At least monthly.

Can be used to troubleshoot problems on unhealthy plants.

Test results list the macronutrients as a percent, while micronutrients are listed as parts per million (ppm).

Using Plant Tissue Sampling- *continued*



Plant Part:
Most recently matured leaf.

Using Plant Tissue Sampling- *continued*

- Optimal nutrient ranges may not be an exact science!
- Sufficient nutrients levels go down as the plant ages.

Sufficient Ranges Seedling Stage

Crop	Element	Stage	Sufficient Range
Tomato	N	Early	3.5 - 5%
	P		0.3 – 0.65%
	K		3 – 4.5%
	Ca		1 – 2%
	Mg		0.3 – 0.75%
	S		0.2 – 0.8%
	Fe		45 – 300 ppm
	Mn		30 – 300 ppm
	Zn		18 – 75 ppm
	Cu		5 – 30 ppm
	B		30 – 75 ppm
	Mo		0.1 – 2 ppm

NC State Adapted for Plasticulture

Sufficient Ranges Bloom Stage

Crop	Element	Stage	Sufficient Range
Tomato	N	Bloom	2.5 – 4%
	P		0.2 – 0.4%
	K		2.5 - 4%
	Ca		1 – 2%
	Mg		0.25 – 0.5%
	S		0.3 – 0.8%
	Fe		40 - 100 ppm
	Mn		30 – 100 ppm
	Zn		20 - 40 ppm
	Cu		5 – 10 ppm
	B		30 – 75 ppm
	Mo		0.1 – 2 ppm

NC State Adapted for Plasticulture

Sufficient Ranges Fruit Stage

Crop	Element	Stage	Sufficient Range
Tomato	N	Fruit	2 – 3.5%
	P		0.2 – 0.4%
	K		2 – 3.5%
	Ca		1 – 2%
	Mg		0.25 – 0.5%
	S		0.3 – 0.6%
	Fe		40 - 100 ppm
	Mn		30 – 100 ppm
	Zn		20 - 40 ppm
	Cu		5 – 10 ppm
	B		30 – 75 ppm
	Mo		0.1 – 2 ppm

NC State Adapted for Plasticulture

Difficult situations Mother Nature throws at you

- Raised beds aide drainage and protect the soil
- But a hard packing rain can press down soil, even under plastic mulch
- What does one do?
  - More frequent irrigation
  - But with less water

Difficult situations Mother Nature throws at you

Nitrogen & saturated soils

- Nitrification is aerobic, ammonium→ nitrate-N stops
- Leaching of nitrate-N occurs on coarse textured (sandy) soils
- Denitrification nitrate-N to gaseous N occurs on medium to fine textured soils, needs:
  - Lack of oxygen
  - Nitrate-N
  - Warm soil temperatures with organic matter or organic residue

How do you decide if more N is needed? How do you apply it? Without watering more? Especially if the beds are mulched with plastic? Warm, sunny weather with no rain is what is needed!

Yellow shoulder disorder

Causes of it

- 10-20% Genetics
- 30% Location
- 5-10% Weather
- 40-50% ***Unknown***

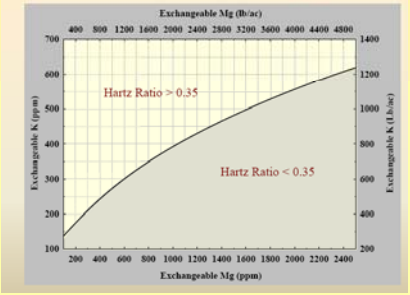
- Soils with organic matter less than 1.5% are more subject
- Soils low in K increase the disorder (raise to 400 or more)
- Foliar applied K does not help
- Other factors-
  - Ca to Mg ratio
  - K to Mg ratio (above 0.35)
  - Cation Exchange Capacity
- A web site can be used to evaluate a given soil-

http://www.oardc.ohio-state.edu/tomato/ysd

Yellow shoulder disorder

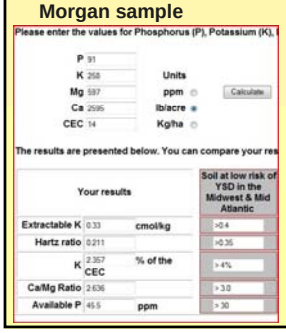
How to estimate the Hartz ratio?

www.oardc.ohio-state.edu/tomato click on "managing color disorder"

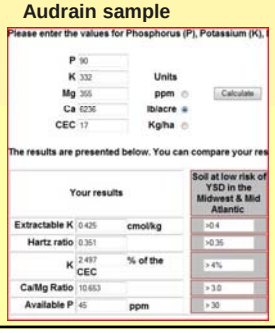


Yellow shoulder disorder

Morgan sample



Audrain sample



Conclusions

- Test your soil (sample correctly!)
- Add lime to get a pH of 6.5 (on average)
- Use recommended preplant fertilizers, avoid trying to 'make-up' later via fertigation
- Use the same test lab & be aware of the basis of their interpretations
- Consider plant tissue testing
- Nutrient deficiencies can be complex
- Get to know 'your' soil