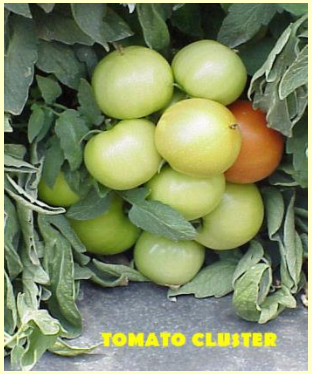
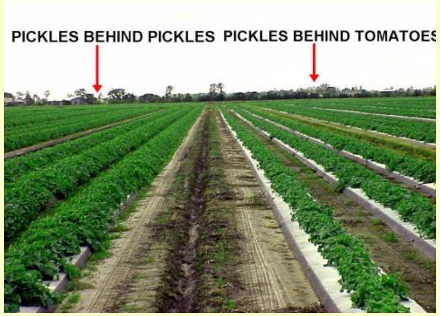
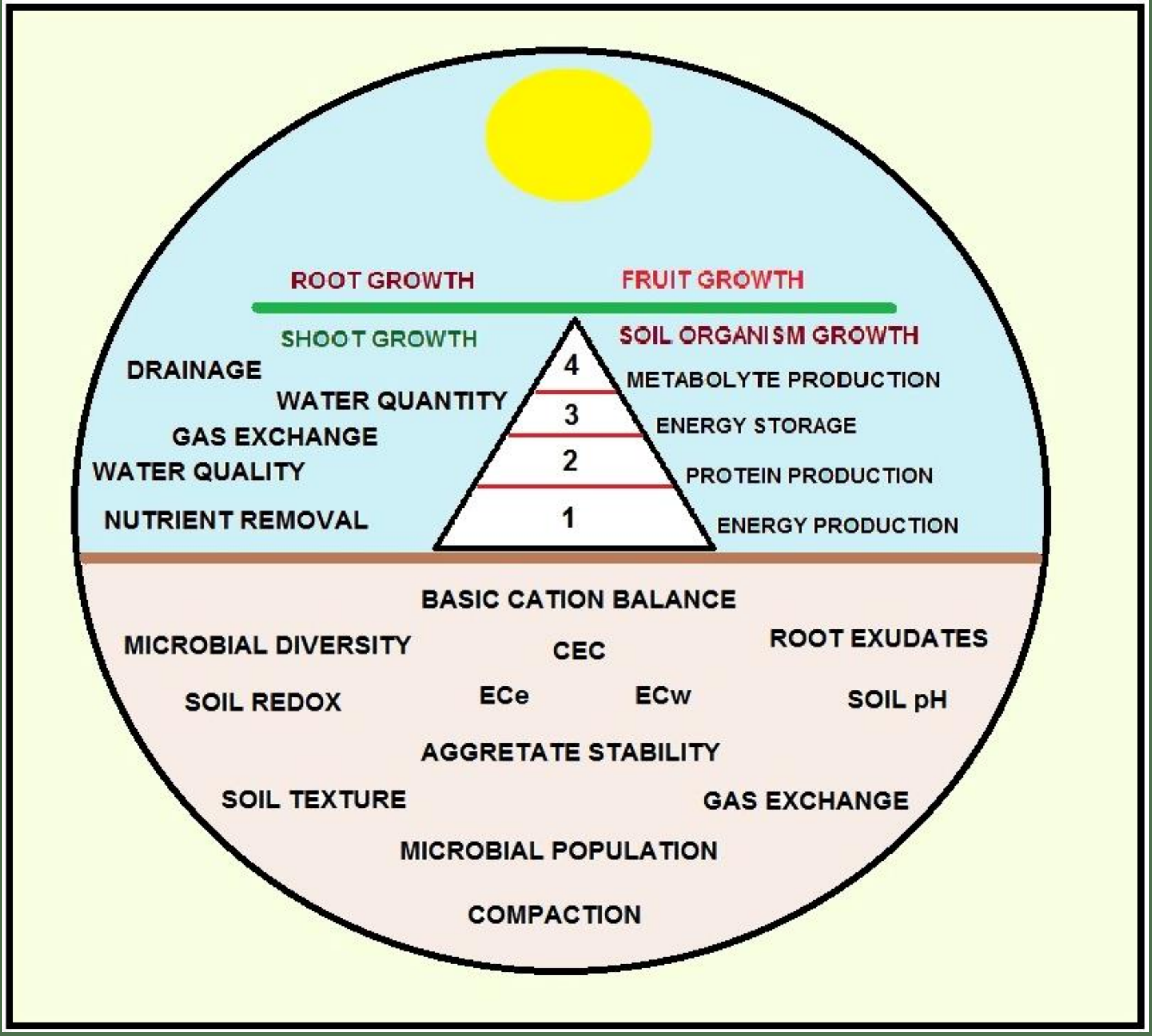
Creech Crop Services, LLC
Soil Biology






ROOT GROWTH
FRUIT GROWTH
SHOOT GROWTH
SOIL ORGANISM GROWTH
DRAINAGE
WATER QUANTITY
GAS EXCHANGE
WATER QUALITY
NUTRIENT REMOVAL
4
3
2
1
METABOLYTE PRODUCTION
ENERGY STORAGE
PROTEIN PRODUCTION
ENERGY PRODUCTION
BASIC CATION BALANCE
MICROBIAL DIVERSITY
CEC
ROOT EXUDATES
SOIL REDOX
ECe
ECw
SOIL pH
AGGREGATE STABILITY
SOIL TEXTURE
GAS EXCHANGE
MICROBIAL POPULATION
COMPACTION

SOIL FOOD WEB

- As total ecosystem productivity increases, biodiversity below ground, i.e., the structure and function of the soil food web, also increases.

- Plant growth is dependent on microbial nutrient immobilization and soil food web interactions to mineralize nutrients.

- Ratios of fungal to bacterial biomass also predict this type of response. Highly productive agricultural soils tends to have ratios near one.

- Bacteria and fungi perform one of the major nutrient cycling processes, nutrient retention, in soil.

SOIL FOOD WEB

- **When the bacterial or fungal component of the soil declines, more nutrients are lost into the ground and surface water**

- **Plants are strongly influenced by the presence of bacteria in the rhizosphere, especially with respect to microbial immobilization of nutrient, and mineralization of nutrients from bacterial biomass by predators**

- **processes of immobilization and mineralization are tightly coupled to plant growth but following disturbance, this coupling may be lost or reduced**

SOIL FOOD WEB

- **Fungi break down the more difficult-to-decompose organic matter, and retain those nutrients in the soil as fungal biomass. Just like bacteria, fungal waste products become soil organic matter, and other organisms use these waste materials. Agricultural crops require fungal biomass for greatest productivity, but in order for best crop growth, there should be an equal biomass of bacteria as compared to fungi.**

- **Between 40 and 80% of the N in plants can come from the predator-prey interaction of protozoa with bacteria.**

SOIL FOOD WEB

- "bad" nematodes can be controlled biologically, as they are in natural systems, by fungi that trap nematodes, by having fungi that colonize root systems and prevent nematode attack of roots, or by predation of nematodes by arthropods. In cases of extreme outbreaks, however, the only answer may be the use chemicals to control these plant-feeding nematodes. However, once a chemical is used which kills the beneficial nematodes as well as the plant-feeding ones, the beneficial nematodes need to be replaced through inoculation. (fix collateral damage)

SOIL FOOD WEB

- Bacteria break down easy to-use organic material, and retain the nutrients, like N. P and S. in the soil. About 60% of the carbon in those organic materials are respired as carbon dioxide, but 40% of that carbon is retained as bacterial biomass. The waste products bacteria produce become soil organic matter. This "waste" material is more recalcitrant than the original plant material, but can be used by a large number of other soil organisms.

- The interactions between these organisms form a web of life, just like the web that biologists study above ground. What most people don't realize is that the above ground wouldn't exist without the below ground systems in place and functioning.

SOIL FOOD WEB

- Plants grown in soil where competing organisms have been knocked back with chemicals are more susceptible to disease-causing organisms.

- Bacterial dominance is maintained by mixing plant material into the soil. But the bacteria and fungi eat this material at an amazingly rapid pace and new inputs are required every year; Fungi can be maintained by letting litter accumulate on the soil's surface.

- Total bacterial numbers range between 1 million and 100 million per gram soil in agricultural soils, and between 10 million and 1,000 million in forest soils. Bacterial numbers can be above 100 million in decomposing logs, in anaerobic soils, in soil amended with sewage sludge or in soil with high amounts of composted material.

SOIL FOOD WEB

- At least 12% of the root system of grasses and other crops, (i.e., most crop plants), should be colonized by VAM in order to obtain the minimum required benefits from this symbiotic relationship. Colonization upwards of 40% is usually seen in healthy soils. VAM colonization can limit root-feeding nematode attack of root systems, if the nematode burden is not too high.

- In the most productive agricultural systems, however, the ratio of total fungal to total bacterial biomass equals one (F/B = 1) or the biomass of fungi and bacteria is even. When agricultural soils become fungal-dominated, productivity will be reduced, and in most cases, liming and mixing of the soil (plowing) is needed to return the system to a bacterial-dominated soil.

ORGANIC SOIL AMENDMENTS

Michael Boyle, et.al. (89)

Organic soil amendments increase soil aggregate stability.

These amendments also lead to better water infiltration rates.

The aggregate stability is a result of an increase in soil polysaccharides from increased numbers of organisms in the soil induced by the added carbon sources.

MacRay and Mehuys (85)

Grasses can pump as much as 50% of their photosynthate below ground into the soil.

Uninterrupted growth is needed to maximize this process.

Grass roots also produce mucigels that directly or indirectly supply polysaccharides for aggregate formation.

C.P. Singh, et.al. (87)

31.7% and 29.5% of added P in soils with added glucose or starch was converted into organic P within 10 and 20 days respectively. This P was readily mineralized again. Cellulose and crude fiber addition resulted in organic P within 40 and 50 days respectively. Most of the P (63%) in the cellulose and crude fiber added soil was immobilized by fulvic and humic P fractions and showed resistance to mineralization.

Soluble carbon amendments stimulated P mineralization resulting in more bio-availability. Very critical to add a P source when adding a soluble carbon source to prevent immobilization, especially during early plant growth when the material is placed into the root zone. In heavy cellulose or fiber soils most of the P may be tied up for long periods of time in the fulvic and humic fraction.

P.M. Rutherford, et.al. (91)

Microbial biomass is a source and sink for nitrogen and it is a transformation agent for soil nitrogen. Microbes have a high growth rate and can transform significant quantities of nitrogen into non-microbial organic nitrogen when sufficient carbon (sugar) is available. Recovery of nitrogen from the microbial biomass is 1 - 3% after one season, but the recovery from non-microbial organic nitrogen ranges from 14 - 21% per season.

One way to conserve fertilizer nitrogen in the plant-soil system is to immobilize it at the time of application by adding a readily available carbon source and to rely on the microorganisms to mineralize it concurrently with crop nitrogen demand during the season.

Glucose is an ideal source. Glucose addition increased the absolute size of the microbial nitrogen and non-microbial organic nitrogen pools in the 0 - 10 cm soil depth. Rates are important because too much carbon addition or poor timing can negatively affect crop production.

Allison (68)

The rhizosphere provides for aggregate formation and stabilization.

UNSTABLE AGGREGATES	STABLE AGGREGATES
RESTRICTED WATER MOVEMENT	ADEQUATE WATER MOVEMENT
RESTRICTED GAS (O_2) EXCHANGE	ENHANCED GAS (O_2) EXCHANGE
RESTRICTED ROOT GROWTH	GOOD ROOT GROWTH
REDUCED NUTRIENT AVAILABILITY	BETTER NUTRIENT AVAILABILITY
REDUCED BIOLOGICAL ACTIVITY	NORMAL BIOLOGICAL ACTIVITY

Paul W. Syltie, (85)

Minerals of P, Ca, Mg and other plant nutrients can be made available by both root exudates and products of microbial activity. Bacteriostatic factors in soils that restrict root growth are overcome by root exudates. These inhibitory substances may be overcome by addition of glucose and other root exudates, vitamins and other nutrients. These compounds are typically exudated from roots: Vitamins, Sugars, Tannins, Alkaloids, Phosphatides, Indole, Salicylic acid, Purines, Pyrimidines, Nucleic acids, Tartaric acid, Oxalic acid, Malic acid, Citric acid, and Scopoletin.

It is clear that the soil-plant system is a complex, highly ordered symbiotic "factory" by which plants help select and direct microbe species to mediate the release of soil nutrients. This is done primarily through root exudates upon which the microbes feed. These organisms in the rhizosphere produce compounds that are beneficial to the plant.

M. Kralova, et.al. (79)

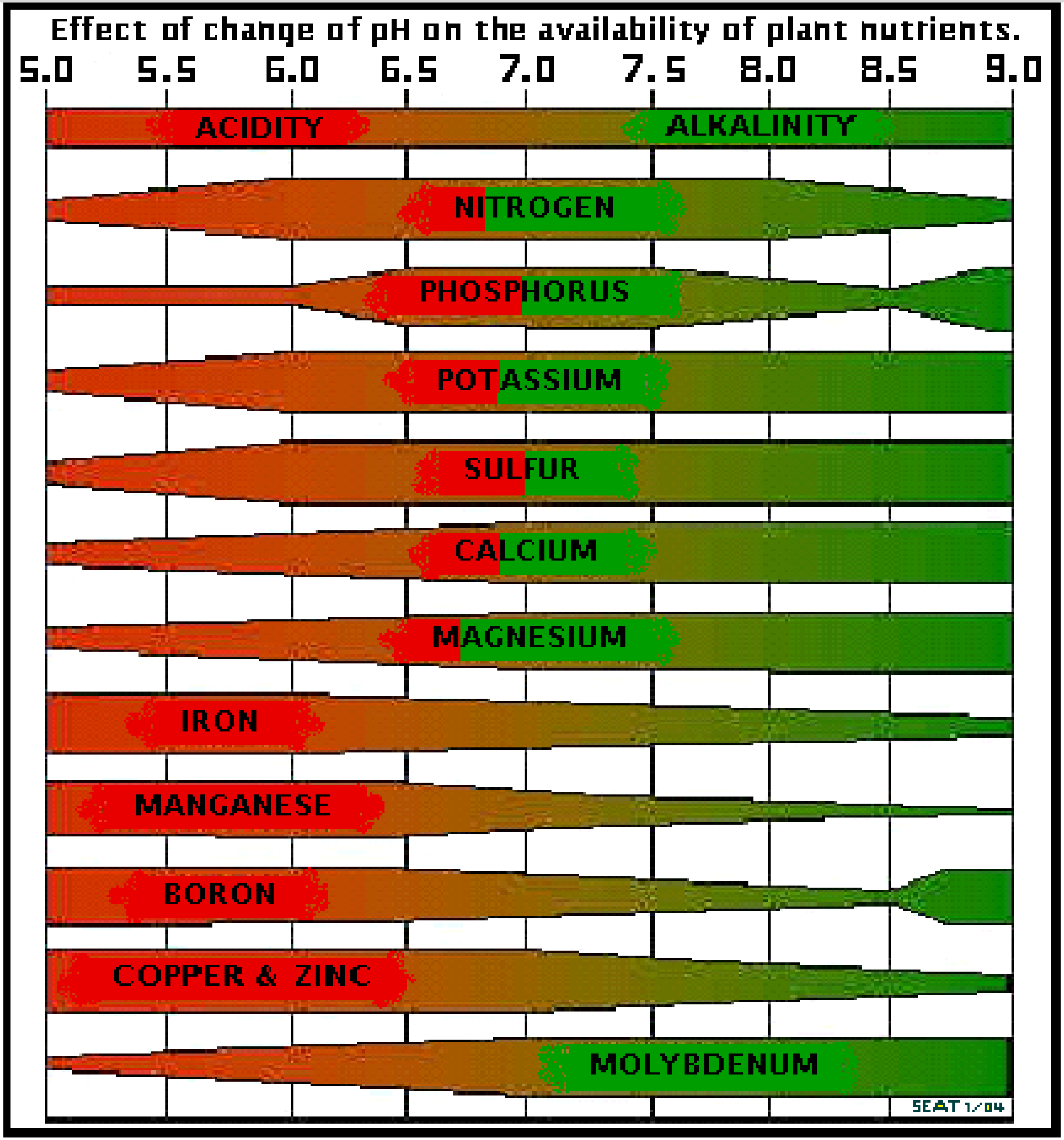
Soluble carbohydrates need to be incorporated in conjunction with fertilizer use, not after the fact. Assimilation of nitrates to organic nitrogen compounds occurs due to the heterotrophic aerobes in the soil.

90% of added glucose is gone after 90 days. The maximum reduction of nitrite nitrogen takes place approximately four days after the addition of the glucose.

A higher level of organic nitrogen compounds is found in the presence of the glucose amendment.

Mucigel

A slimy substance that covers the rootcap of the roots of plants. It is a highly hydrated polysaccharide, most likely a pectin, which is secreted from the outermost (epidermal) cells of the rootcap. Mucigel is formed in the Golgi bodies of such cells, and is secreted through the process of exocytosis. The layer of microorganism-rich soil surrounding the mucigel is called the rhizosphere.


Effect of change of pH on the availability of plant nutrients.
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
ACIDITY
ALKALINITY
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER & ZINC
MOLYBDENUM
SEAT 1/04

SOIL ACIDITY

- **Soil acidity is determined by the amount of acid forming Cations Al^{+3} and H^{+1} and Basic Cations Ca^{+2}, Mg^{+2} & K^{+} in the soil.**

- **Form acids; H_2CO_3 & HNO_3**

- **Release H^{+} ions into soil solution**

- **$Al^{+3} + H_2O \rightarrow Al(OH)^{+2} + H^{+1}$**

CEC AND SOIL pH

In most soils as the pH becomes more basic the CEC generally climbs. This is not the case in 2:1 clays and some organic colloids and in some 1:1 clays.

CEC is usually determined at pH 7.0 and higher. The CEC reflects most pH dependent charges and the permanent charge at neutral pH.

pH of Rain

The pH of rain varies, especially due to its origin. On America's East Coast, rain that is derived from the Atlantic Ocean typically has a pH of 5.0-5.6; rain that comes across the continental from the west has a pH of 3.8-4.8; and local thunderstorms can have a pH as low as 2.0.

Rain becomes acidic primarily due to the presence of two strong acids, sulfuric acid (H_2SO_4) and nitric acid (HNO_3). Sulfuric acid is derived from natural sources such as volcanoes, and wetlands (sulfate reducing bacteria); and anthropogenic sources such as the combustion of fossil fuels, and mining where H_2S is present. Nitric acid is produced by natural sources such as lightning, soil bacteria, and natural fires; while also produced anthropogenically by the combustion of fossil fuels and from power plants.

CEC & Nutrient Availability

Several factors operate to expedite or retard the release of a nutrient into the soil solution.

- **% saturation on exchange site of target nutrient**
- **Other adsorbed cations on the soil exchange sites**
- **Biological diversity and activity in the root zone**
- **Colloid Material ***

****(type, size and abundance of soil material)***

RELATIVE AFFINITY FOR SOIL EXCHANGE SITES

$Al^{+3} = H^{+1} > Ca^{+2} > Mg^{+2} > K^{+1} = NH4^{+1} > Na^{+1}$

→

(BASE FORMING TENDENCY)

REACTION OF SULFURIC ACID WITH CALCIUM CARBONATE

$$H_2SO_4 + CaCO_3 \rightarrow CO_2 + H_2O + CaSO_4$$

REACTION OF GYPSUM TO FORM LEACHABLE SODIUM

$$2NaHCO_3 + CaSO_4 \rightarrow CaCO_3 + Na_2SO_4 + CO_2$$

BICARBONATE

$$Na_2CO_3 + CaSO_4 \leftarrow\rightarrow CaCO_3 + Na_2SO_4$$

CARBONATE

(Na_2SO_4 is the leachable form of sodium)

OXIDATION OF SULFUR IN SOIL

$$H_2S + 2O_2 \rightarrow H_2SO_4 \rightarrow 2H+ + SO_4^{-2}$$

Hydrogen Sulfide

$$2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4 \rightarrow 4H+ + 2SO_4^{-2}$$

Elemental Sulfur

MICROBIAL AND OTHER SOIL CHEMICAL REACTIONS OXIDIZE SULFUR

(S BECOMES MORE POSITIVELY CHARGED)

CALCIUM UPTAKE AND MOVEMENT

Calcium uptake and availability poses several obstacles: uptake and contact with the root tip, transportation within the plant and reaction with/antagonism with other materials (ions) like: NH_4^+, etc.

Calcium only (predominantly) moves via Xylem and will follow the water flow (usually this flow is towards an area of greater water potential/usage (new growth)).

Calcium once deposited in the cell vacuole or cell membrane becomes very immobile and will not easily move from storage or complexed points to new growth areas where it is needed.

Calcium availability is related to water movement, particle size (free calcium or organically bound calcium) and growing point need/requirements.

ENVIRONMENTAL CONTROL OF GENETIC EXPRESSION
PHENOTYPE

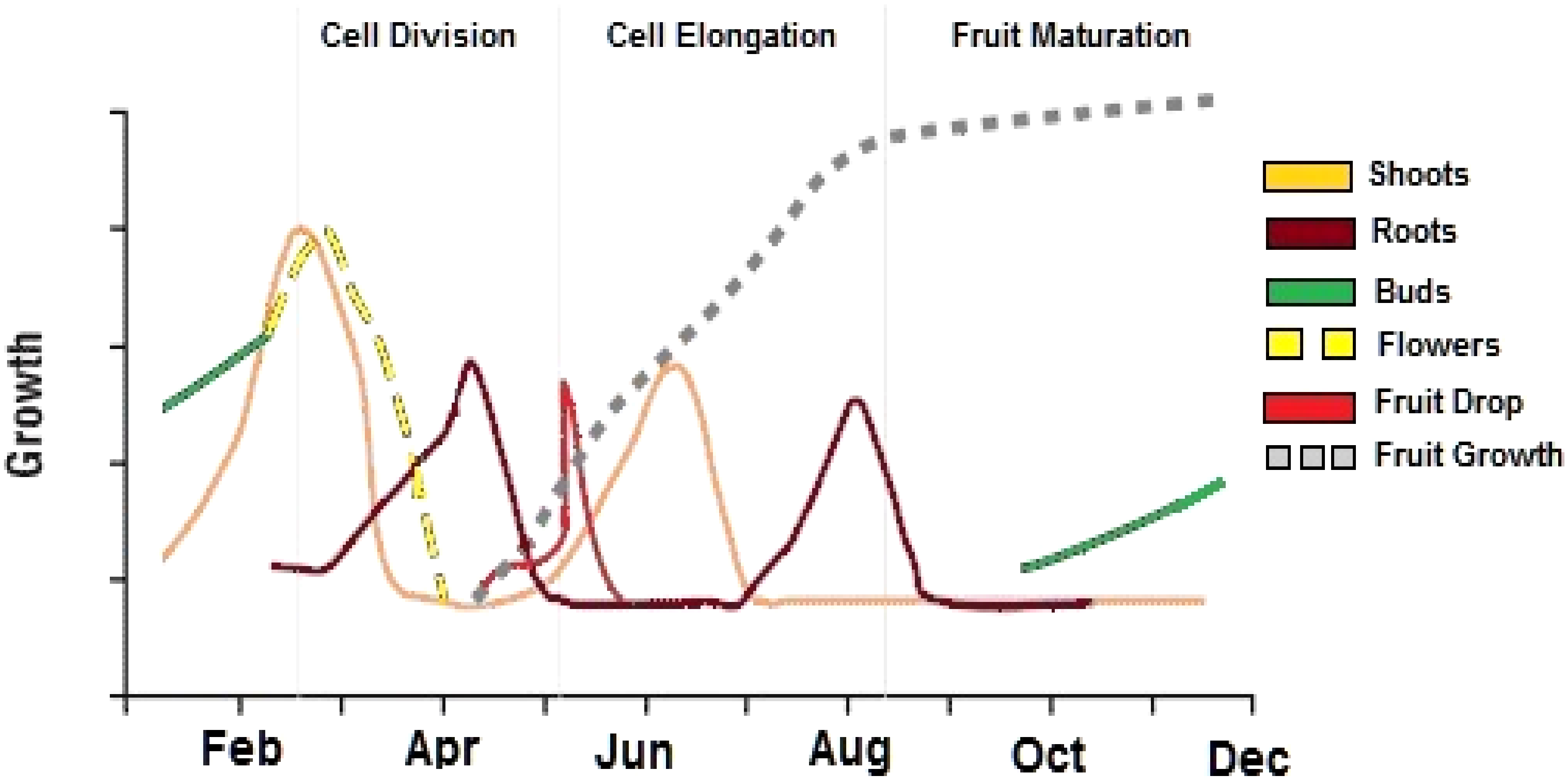
Genotype - Genetic potential is referred to as Genotype. What you are is in your genetic makeup.

Phenotype - Environmental influence on the organism (and ultimately its genetic potential) imparts an expression potential referred to as phenotype. A Phenology chart shows seasonal expression of genetic potential.

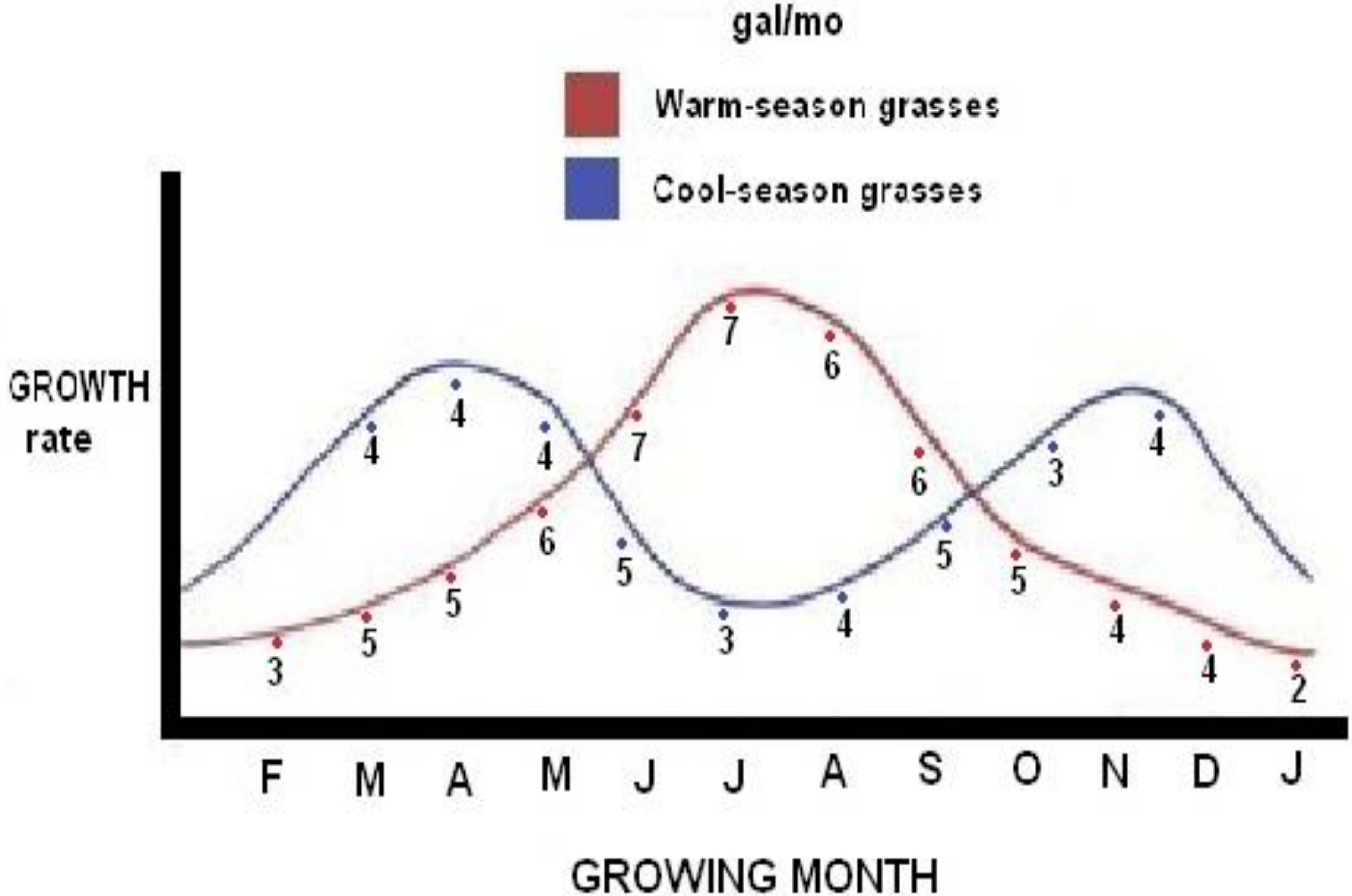
> **Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate, as well as habitat factors (such as elevation).**

Supplying the right microbe, nutrient amount and form and combination of materials at the right time is the golden opportunity that every farmer/grower seeks to achieve success with their program.

Citrus Phenology Growth Chart



ACS - TYPICAL INJECTION SCHEDULE



ACS GENERAL USE RATES

FOR APPLICATION VIA IRRIGATION SYSETM OR SPRAY RIG

The attached Phenology chart for turf grass (showing both warm season and cool season ACS usage rates for feeding during the year) is provided to give general application rate and timing guidelines.

When ACS is applied to stress/weak areas (through irrigation), our rates can elevate to twice the monthly total for specific reasons:

Stressed Turf (not flooded)

Play pressure (resulting in damage)

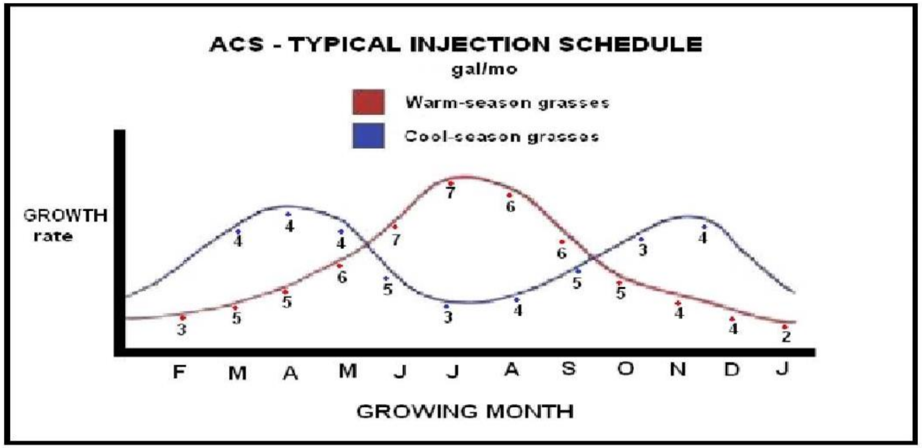
Compaction usage (in conjunction with aerification)

Renovation strategies

High traffic areas.

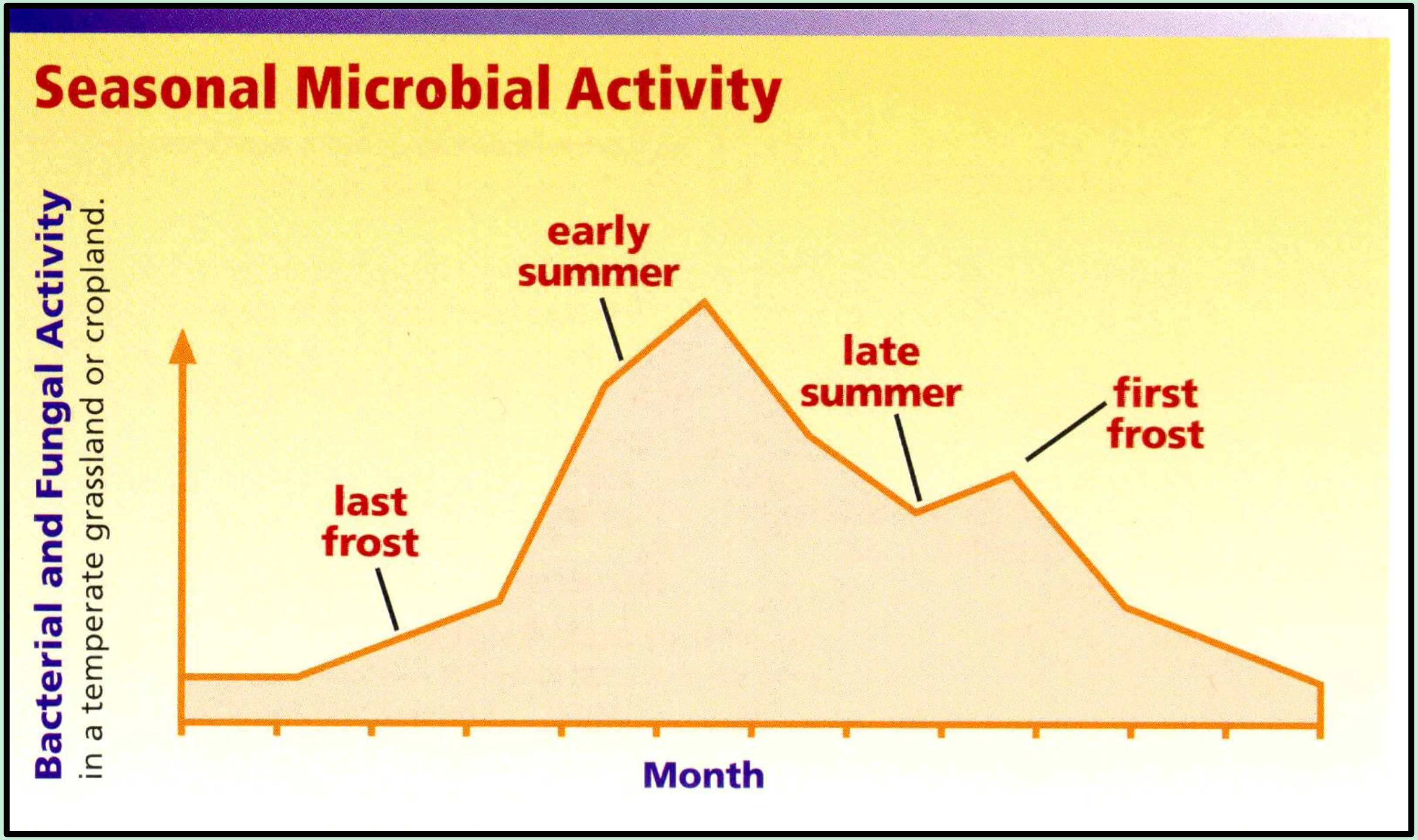
The Rate per season on the Phenology chart can be doubled for short periods of time. The maximum rate/acre of soil for one application is 20 gal.

When applying ACS, the total water ride should be great enough to move the ACS Sugars into the root zone. Topical application via a spray rig should be followed by watering the material into the root zone. A general rate for frequent application is 2 – 3 gal/ac/app. This can be applied via a spray rig with ~ 70 – 100 gal water ride per acre.



ACS application will provide the best results if it is incorporated in conjunction with a balanced fertility program. An ideal companion would be to apply ACS when a complete fertilizer is applied (dry) or along with a liquid fertilizer injection. The seasonal rates above should provide a good template to follow.

Microbial Activity



Sulfur Effect on Soil pH (lb.-S/acre)

CCS	Lower pH		Soil CEC Category (grouping)						
NO	Original pH	Target pH	1	5	10	15	20	25	35
1	5.0	4.5	88	175	353	530	685	800	1120
2	5.5	4.5	175	350	700	1060	1325	1600	2234
3	6.0	4.5	265	530	1035	1640	1925	2310	3228
4	6.0	5.0	110	220	335	460	550	650	885
5	6.0	5.5	109	218	272	327	382	436	576
6	6.5	4.5	330	660	1340	2020	2525	3030	4251
7	6.5	5.0	274	548	943	1337	1644	1951	2701
8	6.5	5.5	218	436	545	654	763	872	1161
9	7.0	4.5	420	840	1685	2550	3180	3830	5368
10	7.0	5.0	374	747	1267	1798	2188	2688	3547
11	7.0	5.5	327	654	818	981	1145	1308	1728
12	7.0	6.0	189	377	472	598	685	804	1061
13	7.0	6.5	50	100	125	150	225	300	375
14	7.5	4.5	501	1002	2004	3006	3758	4509	6317
15	7.5	5.0	468	937	1647	2167	2642	3127	4309
16	7.5	5.5	436	872	1090	1308	1526	1744	2301
17	7.5	6.0	343	686	870	1064	1213	1372	1826
18	7.5	6.5	250	500	650	800	900	1000	1349
19	7.5	7.0	183	490	486	607	688	729	967
20	8.0	5.0	845	1689	2024	2357	2641	2924	3849
21	8.0	5.5	763	1526	1789	2071	2344	2616	3414
22	8.0	6.0	692	1383	1575	1786	2047	2308	2980
23	8.0	6.5	600	1200	1350	1500	1750	2000	2545
24	8.0	7.0	518	1037	1126	1216	1463	1692	2111
25	8.0	7.5	437	874	901	926	1168	1384	1676
26	8.5	5.5	1090	2180	2507	2834	3161	3488	4526
27	8.5	6.0	1045	2090	2379	2667	2958	3244	4189
28	8.5	6.5	1000	2000	2250	2500	2750	3000	3871
29	8.5	7.0	952	1905	2143	2358	2570	2778	3584
30	8.5	7.5	907	1814	2040	2127	2402	2672	3318

This spreadsheet was prepared by CCS for general sulfur recommendations to lower soil pH.

Some gaps exist in the Target pH vs. Soil pH, therefore, when you don't get an answer, migrate the Target pH down to get the the next level. The chart to the left can be used to get into the range for the pH Targets and Sulfur needed. The spreadsheet will be improved over time. Comments are needed to improve the information. Lowering soil pH is a very hard task, especially when carbonates are precipitated in the soil. High bicarbonates and/or carbonates in irrigation water can over time cause soil precipitated calcium carbonate levels to rise resulting in very high soil pH. Under a very high soil pH (1 full log above the crops ideal pH) crop production will be hindered.

Formula calculations are in hidden cells to the right of column P.

Original pH	7.4	Soil Sulfur addition range based on Soil pH and Target pH							
Target pH	6.2	The soil pH is measured as water pH. The Target pH should be referenced by crop and soil.	The CEC comes from the input workbook data.						
CEC Group	5		Soil CEC Grouping						
Sulfur Needed in lbs/ac	686	If no number is in the Sulfur Needed Block, There is an issue with pH range for either the Original or Target pH. (See the Chart above for range values.)	<1 to 3	3 to 7	7 to 13	13 to 17	17 - 23	23 - 30	30 - 35
			1	5	10	15	20	25	35

The table used in this spreadsheet was used to project ranges of Elemental Sulfur to be used for soil pH reduction. High Clay soils and or Organic soils may require much more to effect a pH drop. The soil texture and bulk density will also affect the rate that water moves through the soil. Water movement is needed for sulfur to oxidize into sulfuric acid. Enter the Original soil pH from your soil test and then enter a Target pH to achieve and then enter the CEC Group from the Soil CEC Grouping above. Without soil incorporation do not apply more than 300 lb S/ac in one application. The sulfur needs to be incorporated into the soil where the bacteria exist that oxidize the S into Sulfuric Acid. A better program would be to apply 30 to 80 lb/ac per application when incorporation into the soil is not possible (Turf, Citrus, etc.). Soil mineralization of sulfur requires oxygen and water.

Limestone Calculations Using Adams-Evans Buffer
by
Dr. Owen Plank
The University of Georgia

Data Entry	Enter
Target pH	6.50
Soil pH	6.00
Buffer pH	7.95
Plow Depth	6.00

ENTER VALUE HERE

191 lbs. limestone/Acre

4.4 lbs limestone/1000 ft^2

NOTE: Only enter values under blue column !

*Plow depth is in inches

Do Not Change Any Values In The Shaded Areas

6.7	1.09	0.21527
6.6	1.19	0.23748
6.5	1.29	0.26018
6.4	1.39	0.28327
6.3	1.49	0.30703
6.2	1.59	0.33141
6.1	1.69	0.35468
6	1.79	0.38230
5.9	1.89	0.40884
5.8	1.99	0.43668
5.7	2.09	0.46502
5.6	2.19	0.49488
5.5	2.29	0.52581
5.4	2.39	0.55797
5.3	2.49	0.59198
5.2	2.59	0.62795
5.1	2.69	0.66603
5	2.79	0.70735
4.9	2.89	0.75304
4.8	2.99	0.80148
4.7	3.09	0.85751
4.6	3.19	0.92391
4.51	3.28	1.00000
4.4	3.39	1.10923

1.39	0.28018
1.79	0.38230

This calculator was kindly provided by Dr. Owen Plank The University of Georgia

Adams Evans Limestone Calculator - Dr. Owen Plank, UGA

FIELD NAME	TURF I.D.	TURF TYPE	BpH	pH	Target pH	Pl Dep.	LIMESTONE (lbs Cal or Dolomitic)
1	SOD	ZOYSIA	7.90	5.9	6.5	6.0	436
2	SOD	FLORITAM GRASS	7.85	5.5	6.5	6.0	907
3	SOD	ZOYSIA	7.85	4.9	6.5	6.0	1,175
4	SOD	BERMUDA SOD	7.75	5.4	6.5	6.0	1,598
5	SOD	FLORITAM GRASS	7.85	5.5	6.5	6.0	907
6	SOD	ZOYSIA	7.90	6.3	6.5	6.0	193
7	SPORTS	Celebration	7.90	6.0	6.5	6.0	383
8	SPORTS	Celebration	7.90	6.8	6.5	6.0	
9	SPORTS	Celebration	7.85	6.5	6.5	6.0	
10	SPORTS	Celebration	7.95	6.0	6.5	6.0	191

The information above is the estimated amount of Dolomitic Limetone required to elevate the soil pH to the target range as listed. For most row crops, use the 6" depth as the goal. pH goals would vary by crop. The BpH is the buffer pH and is a value determined by the soils ability to resist pH change. The higher the buffer pH, the easier to change the soil pH and the lower....it becomes harder. All the cells above are open fields so data can be entered the example above is for a SOD farm and Sports Complex.

ROOT INTERCEPTION, MASS FLOW AND DIFFUSION OF NUTRIENTS TO PLANT ROOTS DURING PEAK GROWING CONDITIONS

NUTRIENT	Peak Daily Amount absorbed		Interception	Mass Flow	Diffusion
	kg/ha	lb/ac	lb/ac	lb/ac	lb/ac
	kg/1,000	lb/1,000	lb/1,000	lb/1,000	lb/1,000
Nitrogen	2.050	1.834	0.021	1.620	0.410
	0.047	0.042	0.000	0.037	0.009
Phosphorus	0.200	0.179	0.005	0.010	0.185
	0.005	0.004	0.000	0.000	0.004
Potassium	2.214	1.981	0.045	0.397	1.771
	0.051	0.045	0.001	0.009	0.041
Calcium	0.917	0.820	0.229	0.688	
	0.021	0.019	0.032	0.079	
Magnesium	0.220	0.197	0.073	0.147	
	0.005	0.005	0.002	0.011	
Sulfur	0.220	0.197	0.010	0.210	
	0.005	0.005	0.000	0.015	
INTERCEPTION	As roots elongate through the soil, the roots directly encounter and intercept some of the available nutrient Roots occupy a very small percentage of the soil ~ 1.0%. The quantity of nutrients intercepted is about equ to the soil volume occupied by roots. Roots must continually grow to provide root hair supply. Calcium or potassium problems will greatly limit growth and result in multiple nutrient problems.				
MASS FLOW	When roots become resident in the soil region, solutes in the soil solution are moved to the roots by mass flow caused by the convection flow of water to roots. Transpiration is the major driving force for mass flow Both water and solutes are moved to the root surface. The greater the concentration of solutes in the soil solution, the greater the quantity brought to the roots surface in a given water volumeMass flow may be interrupted during conditions where root growth is reduced.				
DIFFUSION	The movement of ions from regions of higher concentrations to regions of lower concentrations in the soil solution. Mass Flow and Diffusion account for approximately 99% of nutrient movement to roots. Only a small amount of the phosphorus and potassium are in the soil solution at any given time, therefore, diffusion is the most important mechanism of movement of these nutrients.Diffusion may be interrupted under conditions not favorable to Mass Flow or if unavailable (non-ionic) nutrient forms are predominant, or if flooded or dry soil conditions prevail.				

ROOT INTERCEPTION, MASS FLOW AND DIFFUSION OF NUTRIENTS TO PLANT ROOTS DURING AN AVERAGE DAY					
Enter the days from planting until harvest. For nutrient use the season is ~80% of the period.				300	Days
NUTRIENT	Avg. Daily Amount absorbed		Interception	Mass Flow	Diffusion
	kg/ha kg/1,000	lb/ac lb/1,000	lb/ac lb/1,000	lb/ac lb/1,000	lb/ac lb/1,000
Nitrogen	0.820	0.734	0.008	0.648	0.164
	0.019	0.017	0.0002	0.015	0.004
Phosphorus	0.100	0.089	0.003	0.005	0.093
	0.002	0.002	0.0001	0.000	0.002
Potassium	0.820	0.734	0.016	0.148	0.656
	0.019	0.017	0.0004	0.003	0.015
Calcium	0.367	0.328	0.073	0.293	
	0.008	0.008	0.0126	0.032	
Magnesium	0.100	0.089	0.033	0.066	
	0.002	0.002	0.0008	0.005	
Sulfur	0.100	0.089	0.005	0.095	
	0.002	0.002	0.0001	0.007	
INTERCEPTION	As roots elongate through the soil, the roots directly encounter and intercept some of the available nutrients. Roots occupy a very small percentage of the soil ~ 1.0%. The quantity of nutrients intercepted is about equal to the soil volume occupied by roots. Roots must continually grow to provide root hair supply. Calcium or potassium problems will greatly limit growth and result in multiple nutrient problems.				
MASS FLOW	When roots become resident in the soil region, solutes in the soil solution are moved to the roots by mass flow caused by the convection flow of water to roots. Transpiration is the major driving force for mass flow. Both water and solutes are moved to the root surface. The greater the concentration of solutes in the soil solution, the greater the quantity brought to the roots surface in a given water volume. Mass flow may be interrupted during conditions where root growth is reduced.				
DIFFUSION	The movement of ions from regions of higher concentrations to regions of lower concentrations in the soil solution. Mass Flow and Diffusion account for approximately 99% of nutrient movement to roots. Only a small amount of the phosphorus and potassium are in the soil solution at any given time, therefore, diffusion is the most important mechanism of movement of these nutrients. Diffusion may be interrupted under conditions not favorable to Mass Flow or if unavailable (non-ionic) nutrient forms are predominant, or if flooded or dry soil conditions prevail.				

CCS PIPELINE

Double click the icon below to get the conversion needed

CONVERSION TABLE

NUTRIENT UPTAKE VIA ROOTS

NUTRIENT UPTAKE BY	Oranges				
ROOT INTERCEPTION, MASS FLOW AND DIFFUSION OF NUTRIENTS TO PLANT ROOTS DURING A GROWING SEASON					
NUTRIENT (Enter Kg/Ha) See: Imbeded Conv. Tables	Annual Amount absorbed		Interception	Mass Flow	Diffusion
	kg/ha kg/1,000	lb/ac lb/1,000	lb/ac lb/1,000	lb/ac lb/1,000	lb/ac lb/1,000
Nitrogen	246	220	2.46	194.34	49.20
	5.6	5.1	0.06	4.46	1.13
Phosphorus	30	27	0.60	1.50	27.90
	0.7	0.6	0.02	0.03	0.64
Potassium	246	220	4.92	44.28	196.80
	5.6	5.1	0.12	1.01	4.52
Calcium	110	98	22.00	88.00	
	2.5	2.3	3.79	9.47	
Magnesium	30	27	9.90	20.10	
	0.7	0.6	0.23	1.53	
Sulfur	30	27	1.35	28.65	
	0.7	0.6	0.03	2.03	

INTERCEPTION

As roots elongate through the soil, the roots directly encounter and intercept some of the available nutrients. Roots occupy a very small percentage of the soil ~ 1.0%. The quantity of nutrients intercepted is about equal to the soil volume occupied by roots. Roots must continually grow to provide root hair supply. Calcium or potassium problems will greatly limit growth and result in multiple nutrient problems.

MASS FLOW

When roots become resident in the soil region, solutes in the soil solution are moved to the roots by mass flow caused by the convection flow of water to roots. Transpiration is the major driving force for mass flow. Both water and solutes are moved to the root surface. The greater the concentration of solutes in the soil solution, the greater the quantity brought to the roots surface in a given water volume. Mass flow may be interrupted during conditions where root growth is reduced.

DIFFUSION

The movement of ions from regions of higher concentrations to regions of lower concentrations in the soil solution. Mass Flow and Diffusion account for approximately 99% of nutrient movement to roots. Only a small amount of the phosphorus and potassium are in the soil solution at any given time, therefore, diffusion is the most important mechanism of movement of these nutrients. Diffusion may be interrupted under conditions not favorable to Mass Flow or if unavailable (non-ionic) nutrient forms are predominant, or if flooded or dry soil conditions prevail.

In the case of some nutrients (ie. Calcium, Magnesium, etc.) there may be more in solution than the crop needs to absorb during the full growing season resulting in a higher amount available due to mass flow. Normally nutrients like calcium and magnesium are in abundant supply and more than enough is plant available, however, tissue testing should be conducted early in the growth cycle to insure deficiencies do not occur. Make no assumptions on nutrient availability....TEST the soil and plant tissue early so effective corrections can be made.

Adsorb vs. Absorb

Adsorb ~ attached to the surface area/matrix.

Absorb ~ attached within the area/matrix.

Adsorbed things usually are much more easily detached and made plant/organism available.

Absorbed things are usually less available and supply long term material needs from the soil Nutrient and organic bank.