Science of Fertilizing Your Fruit Trees

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Meyer's Lemon

Mango

Banana

Avocado: Kapoho

Keys to a Successful Fruit Orchard

- **Knowledge** – read, ask and try.
- **Location** – soil, drainage, topography, sunlight and wind.
- **Preparation** – till or make raised beds, amend (based on soil analysis and soil type) with compost, lime, gypsum, P, manure, peat or sand.
- **Pathways** – control traffic to paths to reduce soil compaction.
- **Plants/Variaties** – select plants adapted to your site (temperature, sunlight, day length and disease/pest. Rotate crops with different nutritional needs and attacked by different diseases/pests.
- **Weed control** and **sanitation.**
- **Plant spacing** – where fruiting occurs and size of tree.
- **Fertilize** and **irrigate** regularly as needed. Mo is not mo betta.

Plant Nutrient and Fertilizing Influenced By:

- Soil
- Air
- Water
- Plants
- Environmental conditions
- Pest and disease

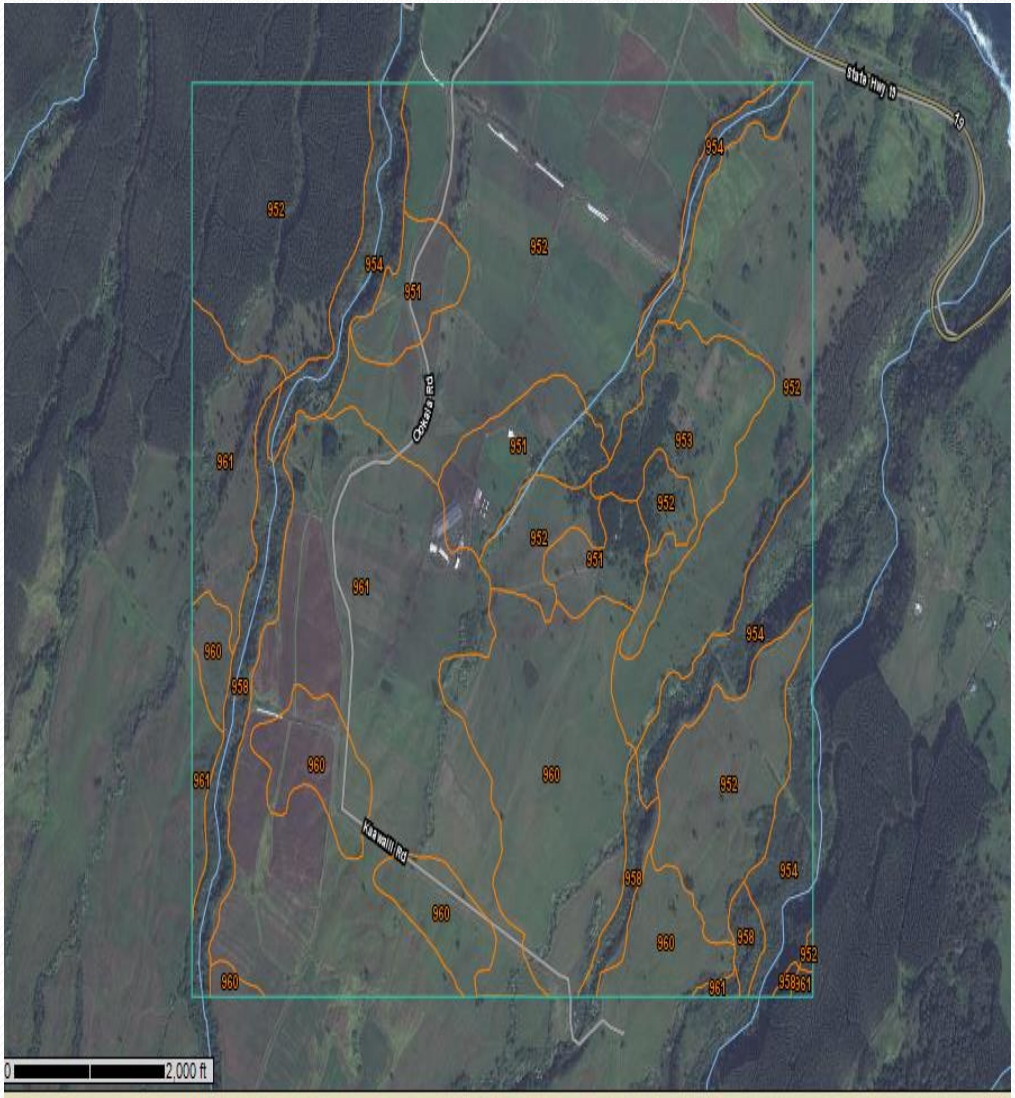
All influencing factors must be understood to prevent or correct plant nutrient deficiencies. One or more factors may be limiting plant uptake of nutrients.

Soil

- Soil Series – Soilweb app or NRCS website to get data for your location.
- Available Soil Nutrients – soil analysis from UH Agricultural Diagnostic Service Center.
- Tilth – high soil strength limits rooting. Fertilizers leach in cloddy soils.
- Organic Matter – increases nutrient retention.

Soil physical and chemical properties influence root development and the uptake of soil nutrients and applied fertilizers.

SoilWeb Map for Big Island Dairy



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
951	Ookala medial silty clay loam, 0 to 10 percent slopes	79.4	5.9%
952	Ookala medial silty clay loam, 10 to 20 percent slopes	530.0	39.5%
953	Ookala medial silty clay loam, 20 to 35 percent slopes	52.8	3.9%
954	Ookala-Rock outcrop complex, 35 to 100 percent slopes	114.1	8.5%
958	Honokaa-Rock outcrop complex, 35 to 100 percent slopes	54.8	4.1%
960	Honokaa hydrous silty clay loam, warm, 0 to 10 percent slopes	200.6	15.0%
961	Honokaa hydrous silty clay loam, warm, 10 to 20 percent slopes	310.0	23.1%
Totals for Area of Interest		**1,341.7**	**100.0%**

Plants

- Root system (fibrous, tap, shallow/deep).
- Desired plant parts to harvest or display – leaves/foliage, fruits, roots/stems, and/or flowers.
- Plant adaptation to specific environments – *e.i.* reduced conditions (taro, rice), acidic soils (eucalyptus, azaleas, pineapple).
- Leaf type and branch structure.
- Tissue for nutrient analysis is crop dependent. Usually the younger leaves.

Some Plant Nutrients often Limiting in Hawaiian Soils

- **N** –Limiting in all soils except those amended heavily with manures and other slow release N fertilizers.
- **P** –Often limiting in tropical soils but past agronomic practices can result in high soil P. High P inhibits uptake of Zn.
- **K** –Can be ample in some soils irrigated with groundwater, and low in soils with high rainfall. Most important nutrient for fruit trees.
- **Ca** – Often limiting in rainy areas but excessive where coral deposits present.
- **Mg** – Adequate to excessive in many tropical soils. Excessive amounts can interferes with the uptake of K. Macadamia likes Mg but not coffee.

Other Important Nutrients

- **S** – Usually not limiting if close to sea. S present in seawater and vog.
- **Zn** – Most limiting micronutrient in Hawaii.
- **Fe** – Hawaii soil have high Fe but oxidized and not readily plant available. Citrus and pineapple sensitive to low Fe. Soil with pH>6.2 have low Fe.
- **Mn** – Never found to be deficient in our soils but can be excessive in acidic soils (pH<5.5). Excess Mn affects uptake of Fe and Zn.
- **B** – Usually adequate in most soils except in Histosols for some fruiting crops. Macadamia sensitive.
- **Cu** – No response in field trials even with low soil test levels. Most Cu additions of 10 lb/acre resulted in lower yields.

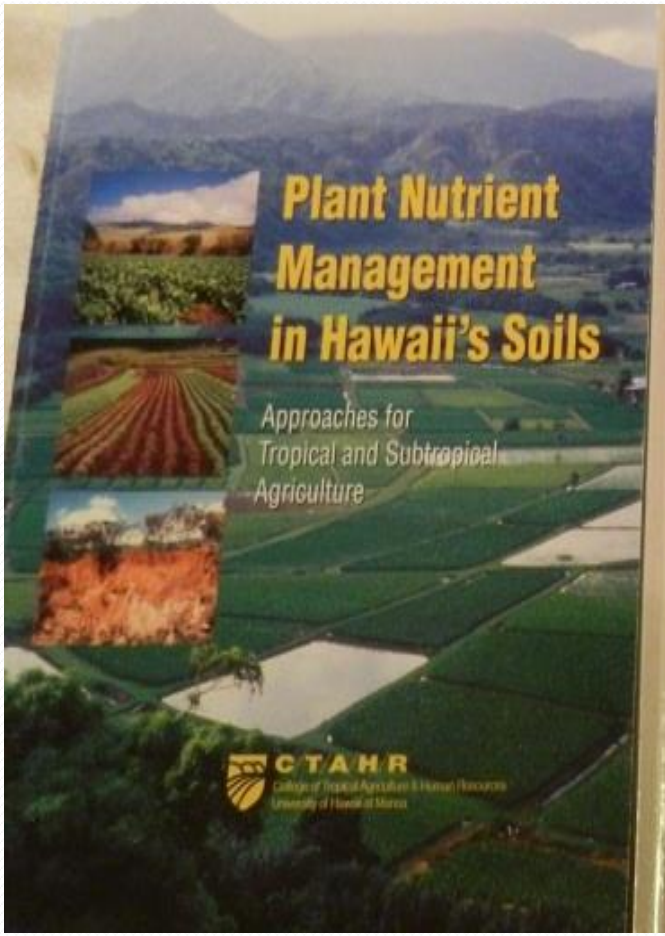
Common soil nutrient interactions adversely affecting plant health

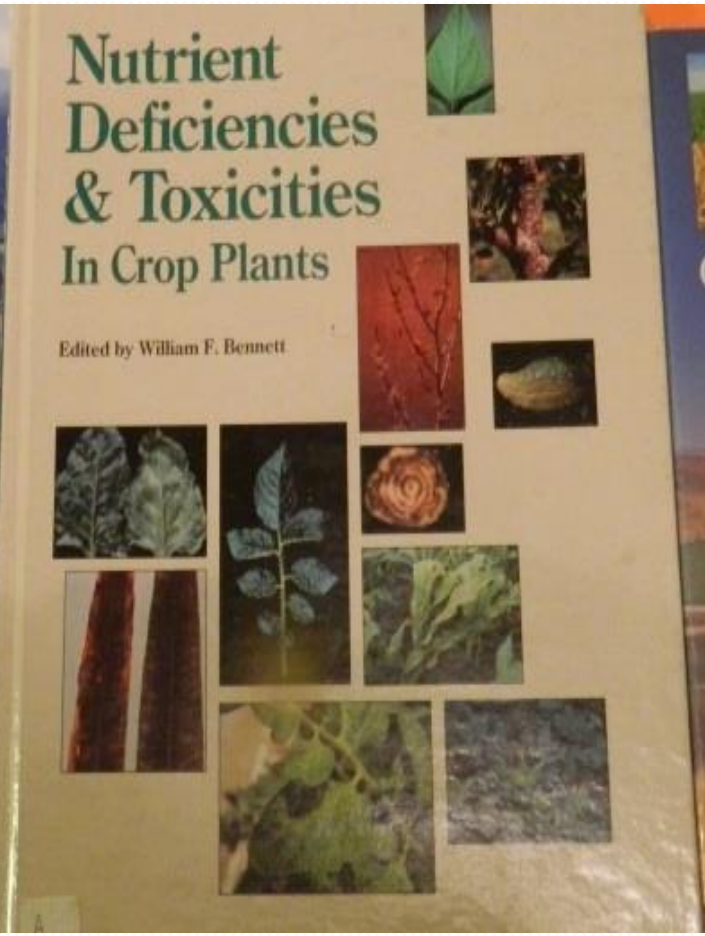
- Excess P inhibits the plant uptake of Zn and other micronutrients. Zn is the most limiting micronutrient. Most fertilizer mix contains too much P resulting in over application.
- High Mg limits K uptake. For many crops, >350 ppm Mg results in low tissue K despite high soil K. Do not apply Mg containing fertilizers or dolomite without soil AND tissue analyses. Most Hawaiian soils contains ample or excess Mg.
- The balance among Ca, Mg and K essential on uptake of each. Excessive Mg results in a cohesive soil. Ca softens the soil.
- Low soil pH of <5.5 can result in excess soluble Mn that adversely affects the uptake of Fe and Zn.
- Poorly drained (reduced) soil can have high Mn and Fe that inhibit Zn uptake even with soil pH >5.5.
- Low soil pH of <5.0 can result in excess soluble Al and adversely affect the roots resulting in poor uptake of all nutrients.

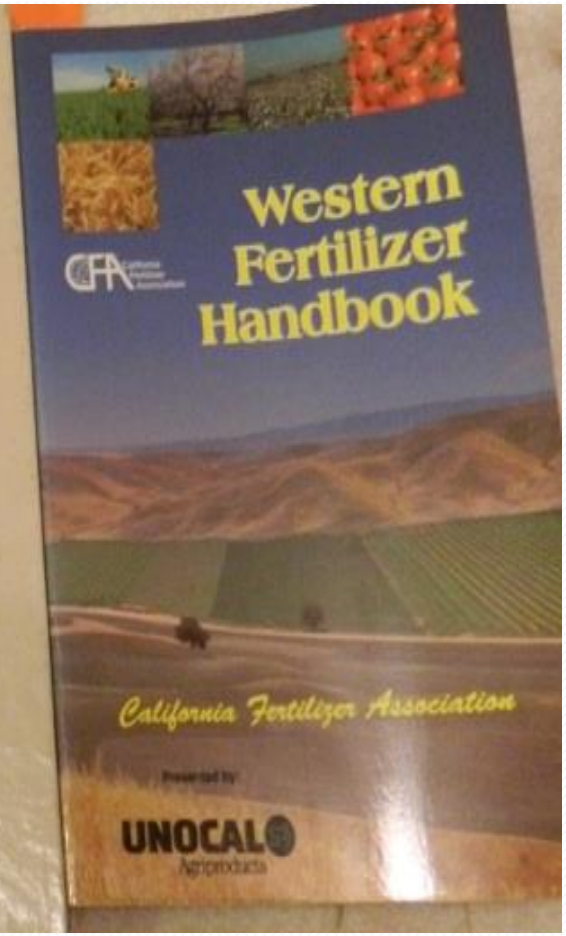
Excellent/Inexpensive Book for Growing Plants in Hawaiian Soils

- **Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture** by James A. Silva and Raymond S. Uchida (Editors), CTAHR, 2000, 158 pages (ISBN 1-929295-08-8).
- **$14** for paper back book.

Useful Books







Soil extractants estimate amount of nutrients that are plant available – use UH lab!!!

- Different methods use different extractants which results in different results for the same soil.
- Tropical and temperate soils require different methods to provide usable results. Regression among these methods may not be linear hence can be difficult to interpret and transfer.
- The lab results need to be calibrated to field yield results.
- Some methods use volume instead of soil weight.
- The extraction time and buffering pH may differ for some methods even with the same extractants.
- Longer shaking or sit times can significantly affect pH results.

Basic Soil Analysis from UH ADSC

- **Cost $12 for pH, P, K, Ca and Mg**
- Extra cost for other elements (S, Mn, Fe, Zn, Cu, Na and B) and EC; see website for current costs. I recommend using tissue analysis for micronutrients.
- Other nutrients in your soil can be estimated using existing soil data from NRCS and UH.
- Sites close to ocean or irrigated with well water should be tested for EC and Na to estimate salinity and sodicity.
- Important to use UH lab because their methods are calibrated to Hawaii's acidic, Fe oxide tropical soils. Most mainland labs are for neutral/basic, silicate soils.
- Most soil analysis kits and gardener's pH meters provide erroneous readings for tropical soils.

Tropical soils vs temperate soils

- Soil charges are more pH dependent in tropical soils where the CEC changes with pH.
- The difference of pH with KCl and distilled water is a indication of the magnitude of pH dependent charge.
- The pH dependent charges are attributed to oxides and amorphous material like allophane in tropical soils.
- Oxides in tropical soils have high surface areas and adsorb and fix P. It can also reduce the activity of preemergence herbicides like Goal.
- Tropical soils have particle density of about 3.0 g/cm^3 due to iron oxide while silicate temperate soil are closer to 2.65 g/cm^3.
- Often agronomic practices used in temperate soils may not work in tropical soils because soil chemical and physical properties differences.

Modified Adequate Soil Levels for Most Ag Important Hawaiian Soils using UH Lab

(adequate levels are dependent also on the rooting depth)

	Concentration
pH	5.7 – 6.1
P	30 – 60 ppm
K	200 – 300 ppm
Ca	1500 – 2500 ppm
Mg	150 – 300 ppm

Adequate soil levels is only a guide

- Even if nutrient is at adequate level, additional might be needed because of nutrient interactions.
- Having too much in the soil is worst than being deficient. More difficult to remove than add nutrients. Lime and apply P carefully. Excess N and K more easy to correct. Any nutrient in excess amounts can induce an imbalance.
- Monitor tissue levels to determine if soil levels are sufficient, or out of balance. Soil analysis is not enough because uptake differ among crops and sometimes different for varieties of the same crop.

Crop Growth Rate vs Soil Release Rate

- The adequate soil level doesn't measure the soil nutrient release rate only the soil capacity.
- A fast growing crop like radish or Manoa lettuce often need more nutrients than the soil can release in the short six-week period.
- Starter fertilizers are recommended in many annual crops even when soil nutrient levels are sufficient. Perennial crops, like trees, with an established root system and a larger root volume have a lower fertilizer requirement. The soil sampling depth should represent the nutrients in the rooting depth.

Tissue Sampling and Analysis
(refer aforementioned UH book)

- The tissue to sample and adequate concentrations are crop dependent hence refer to UH book or do online search.
- The tissue analysis will tell you how successful you were in fertilizing your crop.
- Usually tissue analysis not useful to schedule fertilizer for current crop. Often too late when deficiency is detected.
- Studying the soil along with the tissue analyses will provide clues to nutrient imbalances and interaction.
- Tissue samples can be sent to any certified lab unlike the soil samples. Collect tissue prior to flowering.

Nutrient Deficiency Symptoms

- Do online search of pictures of specific plants to identify your symptoms. Take pictures and ask experts.
- N – Yellowing of older leaves.
- P – Purple tinted leaves.
- K – Brown leaf edges of older leaves.
- Micronutrients – usually occur in younger leaves. Often mistaken for herbicide damage.

Often symptoms may be due to or confounded by pesticide, drought stress, insect, disease, or heat, cold or wind damage.

Fertilizing

- **Sources** – organic and inorganic; slow release and control release; liquids and solids; foliar and soil applied.
- **Crop requirement** based on potential crop yield, what available in the soil and rate of soil release to meet crop needs.
- **Timing** of amounts relative to growth stage.
- **Frequency** of applications for increase plant uptake and efficiency.

Organic vs Inorganic Fertilizers

- Use both. Organic to remediate soils and provide slow release nutrients while inorganic for quick release nutrients for rapid crop response.
- Organics must be decomposed then mineralized to the inorganic form before plant uptake. Hence organics are slow release. In the end, it is made available to the plant in the inorganic form.
- Organics less likely to “burn” the crop because it contains less soluble salts and active ingredient.
- Organics can chelate and make less available toxic soil amounts of Mn and Al.
- Organics have many trace elements hence a good source of micronutrients at low concentrations. Some inorganics have trace elements added.
- Note that Urea is an organic compound because it contains carbon but not approved for organic farming.

Nutrient Content in Fertilizers

- **N – P_2O_5 – K_2O** Numbers on fertilizer bag/container refer to nitrogen, P and K (latter in the oxide forms) as percentage. A 20 lb bag of 16-4-4 will contain (20 x 0.16) or 3.2 lb of N along with 0.8 lb each of P_2O_5 and K_2O.
- Use to calculate fertilizer cost of the element you want and compare with other sources. Higher analysis product often is cheaper on the unit element basis because of shipping cost.
- Most scientific publication refer to the elemental form. (Atomic weight of P=31, K=39 and O=16)
  $P = 0.3261 \times P_2O_5$
  $K = 0.8301 \times K_2O$

Sources – Organic, Slow Release

(Red bold is what I use)

- **Cover crops and green manure** – **legumes and sunhemp** to fix N while rye and buck wheat for green manure. Both protect the soil from erosion and suppress weeds.
- **Manures** – **chicken** (4-3-1), **cow** (2-1-3), horse (2-1-3). Stinky, fresh manure good source of N, bird droppings high in P and ruminant manures good source of K.
- **Other animal waste** – blood meal (13-2-0), **fish emulsion** (5-2-2-5S). Bone meal (3-2-0.5-24Ca), **worm casting** (0.5-0.5-0.5)
- **Plant waste** – **compost** (1-0.8-1), kelp (1-0.2-2), **wood ashes** (0-1.6-5-15Ca)

Sunhemp

Inorganic Fertilizer – Simple Solids

- **N** – ammonium sulfate (21-0-0:24S), **urea** (46-0-0), calcium nitrate (15.5-0-0:19Ca)
- **P** – Treble (0-45-0:12Ca), superphosphate (0-20-0:12S:20Ca), **MAP** (11-55-0), DAP (18-46-0)
- **K** – **KCl** (0-0-60), KNO_3 (13-0-45), K_2SO_4 (0-0-50:18S), $K_2SO_4.2MgSO_4$ (0-0-22:11Mg:18S)
- **Ca** – **gypsum** (17S:22Ca), **$CaCO_3$** (40Ca), $CaSO_4$ calcium sulfate is not gypsum.

Inorganic Sources - Liquids

- **N** – UAN-32, CAN-17, dissolved urea or ammonium sulfate
- **P** – poly ammonium phosphate (10-34-0)
- **K** – dissolved KCl
- **Ca** – CAN-17

These liquids used to fertigate in drip irrigated fields in Hawaii.

Controlled Release Solids

Semi-Permeable Coating

- **Polymer-coated** – Osmocote, Nutricote, Nutri-Pak, Polyon, APEX
- **Sulphur-coated** – SCU, Trikote

Release rate dependent on coating thickness as well as temperature, moisture and microbial digesting. Less expense controlled release fertilizers only coat N.

Other Controlled Release Fertilizers

- N inhibitors – N Serve
- Chelated – Avail, many micronutrients
- Humic acid

Mixes for Soil Applications

- Many specialty blends made for crops such as sugarcane, banana and coffee. May not be best for your plants.
- Blends with the same analyses (same numbers) can be different where the N maybe from urea or ammonium nitrate or the K_2O maybe KCl or K_2SO_4.
- Some blend organic with inorganic and others controlled release N with regular P and K.
- Some pelletized fertilizer have NPK in each pellet while others have separate particle for each nutrient.
- Check if the blend have trace or micro-nutrients. Good to have some Fe and Zn, but Mg, S, B and Mn are usually not needed.

Common Mixes/Blends

- **16-16-16** -- Good started fertilizer. Ok as a general fertilizer in pots or in the fields with low P. Some have trace elements.
- **10-30-10** -- Often only used in a new area with no previous crop. It can put too much P if used after every crop, and it can result in excess soil P within 4 years of use.
- **10-20-20** – Called a fruit tree fertilizer because of the high K. However, the P may be too high for many crops and soils. The ratio of K_2O:N of 2 is excellent for fruits.
- **22-0-32, 20-0-30** – The former referred to as A1 by BEI. The latter is CPS with 0.5% Zn. Excellent for most fruiting plants after using a starter of 16-16-16.
- **15-0-30** – New mix with Zn will be available soon in Hawaii
- for fruiting plants.

Foliar Fertilizers

- Orchids and pineapple rely primarily on foliar fertilizers. Pineapple like acid soils but have excess Mn that inhibits the plant uptake of Fe.
- Most liquid fertilizers and those forming solutions can be applied foliage.
- Concentration important to avoid phytotoxic effects. Usually 0.5 to 2 fl. oz./gallon of product ok. Some seedlings are very sensitive.
- Many mixes are available such as Miracle Grow products and soluble 20-20-20 made by several companies.
- Micro-nutrients are often applied to leaves hence avoiding soil interactions and adsorption.

Local Companies Selling Fertilizers

- **Pacific Agricultural Sale and Services, Inc**., 91-262 Olai St., Kapolei, HI 96707, tel. 808-682-5113
- **BEI Hawaii**, 311 Pacific St. #B, Honolulu, HI 96817, tel. 808-532-7401
- **Crop Protection Service**, 92-1770 Kunia Rd., Kunia, HI 96759, tel. 808-454-0041
- **Others** – Home Depot, Lowes, City Mill, garden shops and nurseries

Home Depot - BEI

Home Depot – Pacific Ag.

Home Depot – MiracleGro

Make Your Own Blends

- N – urea, P – MAP, K – KCl, Ca – gypsum and Lime in 50 lb bags.
- Make a blend with the above fertilizers depending on the type of crop. Blends will not store well.
- For potting media, I use controlled-release N with regular PK (14-14-14), compost, gypsum and lime.
- In potted plants, I use controlled-release NPK (Apex) 14-14-14 with 3-month release rate or the cheaper mix with only N as controlled-released. Compost is top dressed once a month. Large potted plants receive a blend of urea, MAP, KCl and gypsum at a volume ratio of 3:1:3:2.
- For orchids and anthurium, I use soluble 20-20-20 spray and controlled-release N with regular PK. I also apply dry compost if media is only rocks.
- For trees, I use a 1:1 blend of urea and KCl.

Amendments

- pH <5.7 – lime with $CaCO_3$ (ag grade lime). Peat moss is acidic at about pH 4.0-4.5 so I use some in my potting mix.
- pH<5.7 and soil Ca<1500 ppm – use both lime to increase pH and gypsum for quick Ca response.
- pH>5.7 and soil Ca <1500 ppm – use gypsum. Also use it if soil S is low.
- pH>6.2 – use ammonium sulfate as N source to acidify the soil. Fe sulfate, S and phosphoric acid could also be used but can have negative side effects.
- High Mg soils (>350 ppm) – add gypsum to make soil friable and improve K uptake.
- Low soil Mg (<100 ppm) – dolomite, Kmag, MgO. Mg deficiency is very rare in most Hawaiian soils. Excess is the norm.

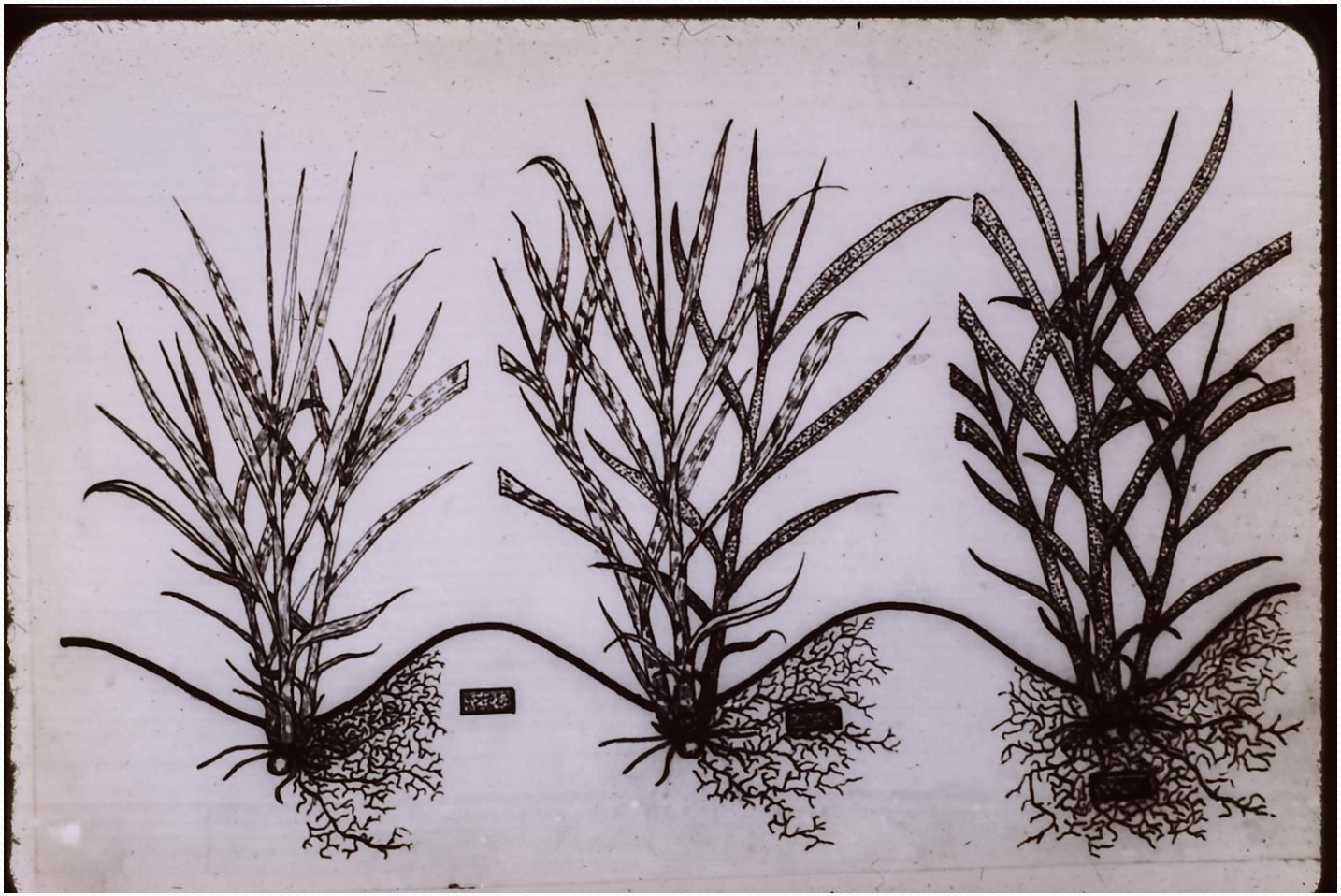
Amounts of fertilizers to apply influenced by:

- Yield potential as affected climatic and seasonal factors such as solar radiation, temperature and rainfall .
- Growth stage. Establishment stage requires more P and Ca; leafy stage needs more N; fruiting/maturity stages benefits with more K.
- Critical stages are expected time of flowering and harvesting. Leafy greens are the easiest to fertilize.

Fertilizer Placement to Existing Plants

- Close as possible to active roots often mixed in the soil before planting. Existing plants usually at the edge of leaf canopy (drip line). Placement of less mobile nutrients like P more critical than N.
- Avoid placing high analysis, soluble fertilizer too close to stem/trunk.
- Minimize contact of solid fertilizer with plant foliage. Wash off as soon as possible.
- Water incorporate fertilizers to existing plants. Need rainfall or irrigation to move fertilizer to roots. Fertilizers ineffective during drought. Soil incorporation by tilling can damage roots.

Pre-plant Placement of P

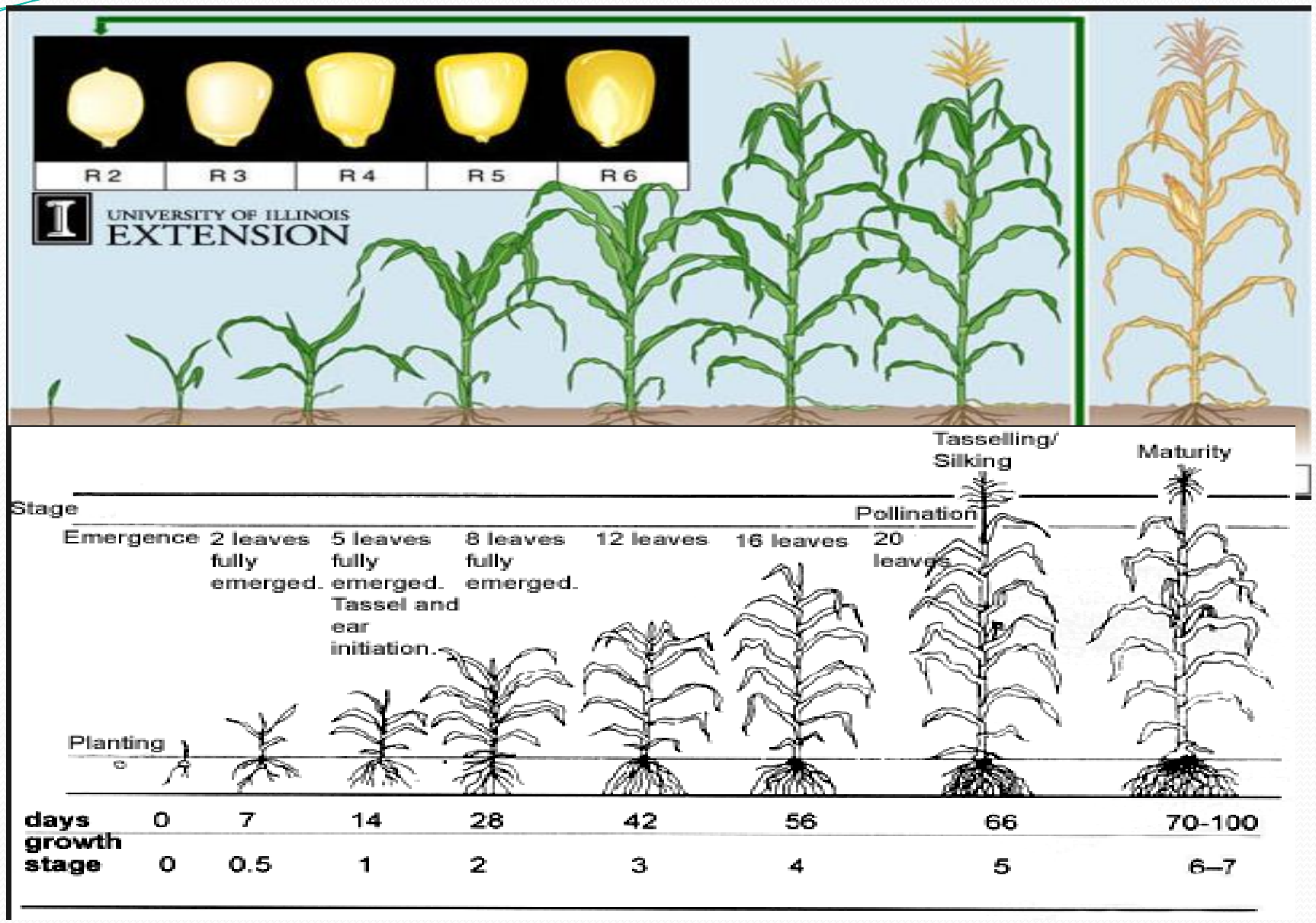


Band application of P in the planting furrow gave the best plant response. Similar results for corn and other row crops.

Estimated Corn Uptake (above ground) of Nutrients - 160 bu/acre Crop

	Nutrients (lb/acre)		
	Grain	Stover	Total
N	109.0	62.0	171.0
P	22.7	9.5	32.2
K	37.0	93.0	130.0
Ca	0.7	34.3	35.0
Mg	7.6	27.0	34.6
S	6.8	7.5	14.3

Corn Growth Stages



Typical Fertilization Schedule for Corn

		Pounds/acre			
Appl.	DAP	N	P_2O_5	K_2O	Gypsum
1	0	30	30	30	300
2	14	40	40	40	
3	28	50		50	
4	40	70		70	
Total		**190**	**70**	**190**	**300**

Fertilizing Examples - Perennial

- **Coffee, avocado, mango** – perennial (fruits) – N early before flowering then more K after flowering through fruit development. 4-6 applications/year. Annual total 200-50-300 lb/A for low yields and 300-50-450 lb/A for high yields. P based on soil analysis but little required once trees established. Gypsum may be needed if soil Mg is above 350 ppm or soil Ca low.
- **Citrus** – perennial (fruits) – like above but continually flowering. May need to apply foliar Fe.

Potted Plants

- Use slow release or control release fertilizers to minimize ”burning.”
- Liquid/soluble fertilizers are easy to apply. Too high concentrations can cause “burning.”
- Apply small amounts each application. A gallon pot will need about 0.25-1.0 tsp of a solid mix.
- Monthly fertilizer applications are desirable because of the confined root system. Less frequently when using slow or control release fertilizers.
- Every 1-2 week foliar feeding interval is desirable; less if used in combination with solids.

lb/Acre to lb/Tree Fertilizer Calculations

- Determine radius of tree. Area = $\prod r^2$
- Product lb/A = 250 lb/A
- Radius = 10 ft; hence area = 3.14 x 100 = 314 ft^2
- 250 lb/A = 250 lb/43,560 ft^2 = (lb/tree)/314 ft^2/tree
- 1.8 lb/tree

Review question 1

- Type of fertilizer good for fruit trees at 1-3, 3-5 and 5+ year of age. The key is the expected date of flowering. Prior to flowering, a balance 1:1 K^2O to N fertilizer with P if soil is deficient in P. Near flowering, increase ratio to 1.25 to 1.5 to induce flowering. With fruits, increase ratio to 1.5 to 2.0 for best quality. Always modify based on soil and tissue analyses. Continue to fertilize to harvest to maintain tree health for next year's crop. Fertilize at least 4-6 times per year. The total amounts to apply is dependent on the expect yield and soil reserves of nutrients.

Review question 2

- When and how much soil amendment to apply? The soil and tissue analyses will indicate if soil amendment is required and what type. The amount is dependent on the initial soil levels and the desired levels. Soil liming curves are available for many soil series. Never apply too much; slightly less is better. The solubility of the product is very important for timely reaction and provide crop response. Solubility is a function of particle size and chemical structure. Gypsum is 81 times more soluble than $CaCO_3$ lime.

Review question 3

- Why do I need control release fertilizer? Control release fertilizer can cost 3 to 5 times more than regular fertilizers. It is best for Histosols where the soil consist of some organic matter and mostly rocks where regular fertilizers will leach. Andisols do not need control release fertilizer except of N in the rainy periods. Some saving can be achieved in less application cost, but the key is to get increased yields. Without increased yield, it is not cost effective to use controlled release fertilizers.