Trace Yet Substantial

ESSENTIAL MICRONUTRIENTS OF PECAN

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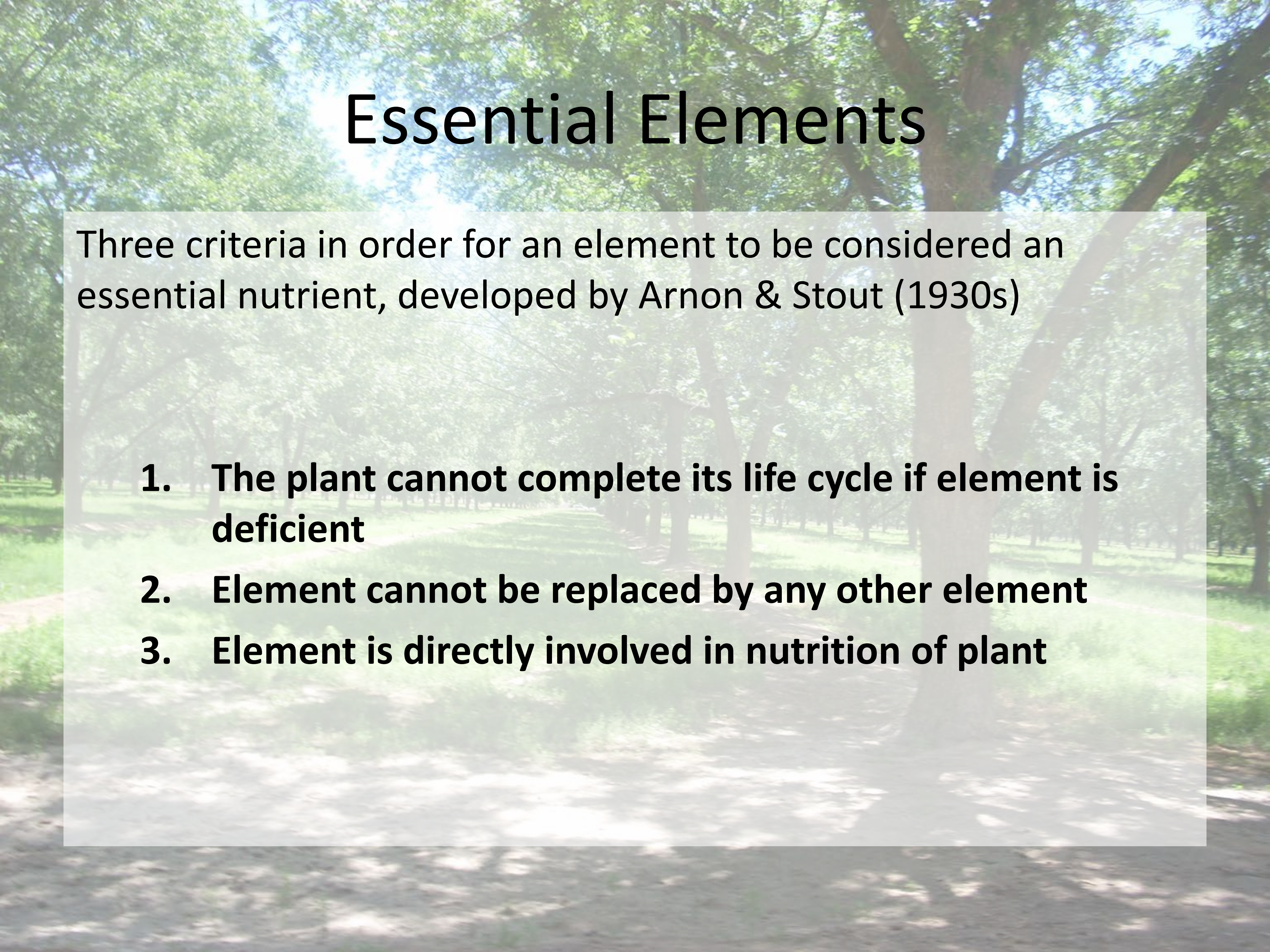


Essential Elements

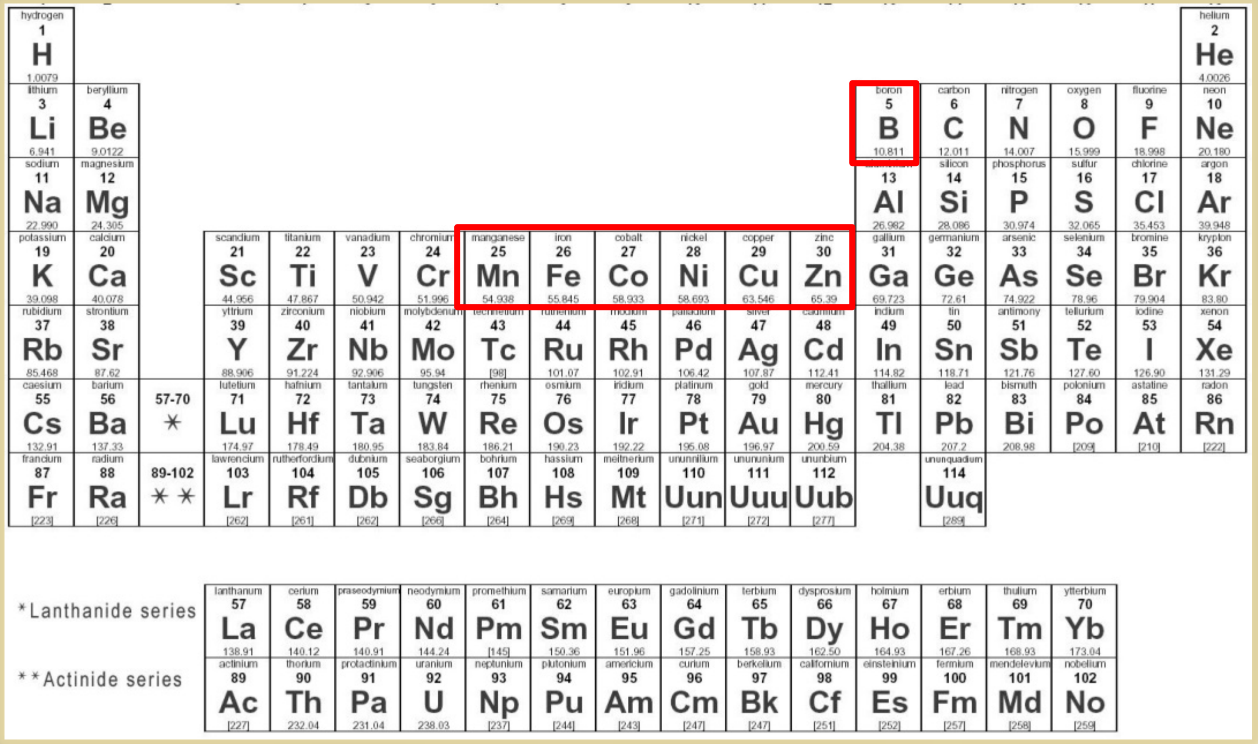
Three criteria in order for an element to be considered an essential nutrient, developed by Arnon & Stout (1930s)

1. **The plant cannot complete its life cycle if element is deficient**
2. **Element cannot be replaced by any other element**
3. **Element is directly involved in nutrition of plant**

Defining Micronutrients

- In smaller quantities within leaf tissue compared to macronutrients
  - Usually reported as parts per million (ppm), mg/kg, or µg/g

- Mostly trace metals (except Boron)
  - Iron
  - Copper
  - Zinc
  - Nickel
  - Manganese
  - Boron



hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Hidden Hunger

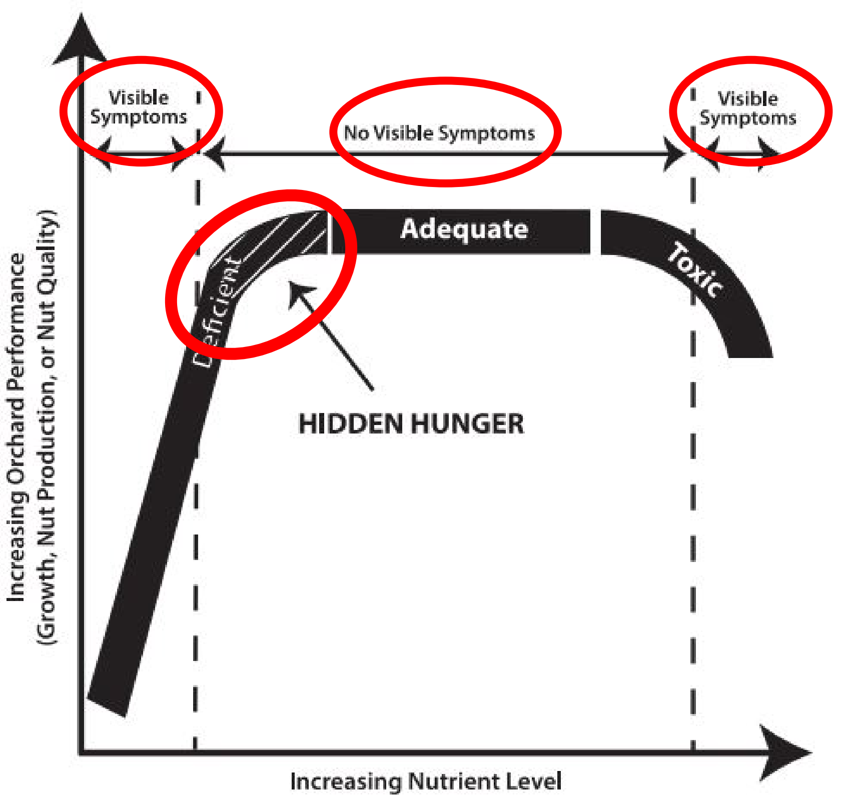


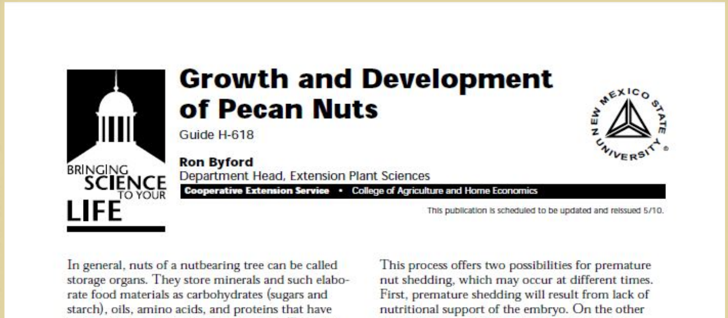
Figure 1. **Pecan trees may experience nutrient deficiency or toxicity without exhibiting any visible symptoms.**

http://aces.nmsu.edu/ces/pecans/soils-and-fertilization.html

- Nutrient is within deficient level but not showing visible symptoms of deficiency
- Tree is not performing at its optimum state
- Hidden hunger phase is where more profit and yield loss is seen

Importance of Micronutrients

- All about enzymes
- All about carbon
- All about timing



BRINGING SCIENCE TO YOUR LIFE

Growth and Development of Pecan Nuts

Guide H-618

Ron Byford
Department Head, Extension Plant Sciences

Cooperative Extension Service • College of Agriculture and Home Economics

This publication is scheduled to be updated and reissued 5/10.

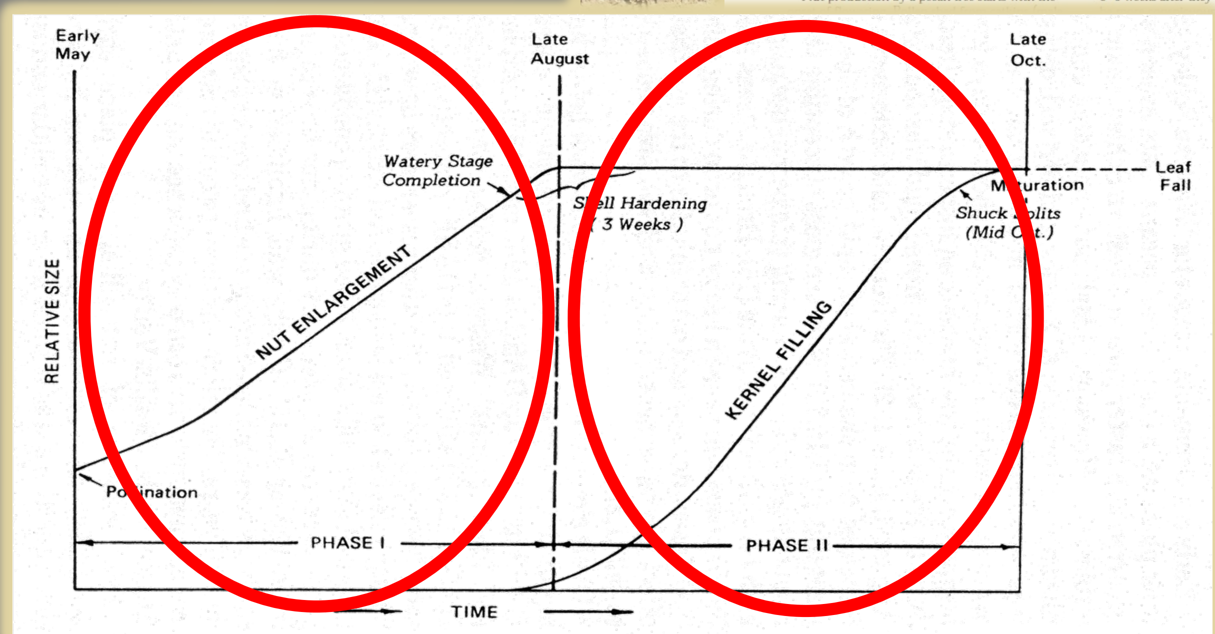
In general, nuts of a nutbearing tree can be called storage organs. They store minerals and such elaborate food materials as carbohydrates (sugars and starch), oils, amino acids, and proteins that have been produced by the leaves of the tree. These materials are stored for future use by the nut embryo to sustain respiration, to permit germination, and to maintain the seedling until it has produced enough leaf area to become self-sufficient.

Nut production by a pecan tree starts with the

This process offers two possibilities for premature nut shedding, which may occur at different times. First, premature shedding will result from lack of nutritional support of the embryo. On the other hand, if the egg cell is not fertilized, premature shedding will also occur. Research workers do not agree on how soon fertilization occurs after pollination. There is general agreement, however, that pistillate flowers that are not fertilized fall off within 5–6 weeks after they were receptive. June drop may
than the previous drop be-
rger.
otal nut crop is shed during
ops. Environmental stresses
rop. Researchers have shown
urs with cross-pollination
tion takes place. Good polli-
an orchards.
ent starts with pollination and
vo distinct phases throughout
difficult to put an exact date
nding of these two phases. Be-
ather conditions, growing de-
etter estimate.
pollination (early to mid-
g (or until the end of the
n completes the sizing of the
The end of the water stage
middle and end of August

n the shell hardening (or end
uck splits. The kernel devel-
g this phase, ending when
e sutures.

re and Home Economics on the



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Soil Interaction

- Micronutrients (trace metals) decrease in availability as soil pH increases
  - Soil pH is a limiting factor
  - Alkaline & Calcareous soils
  - Semi-arid and arid parts of United States and Mexico

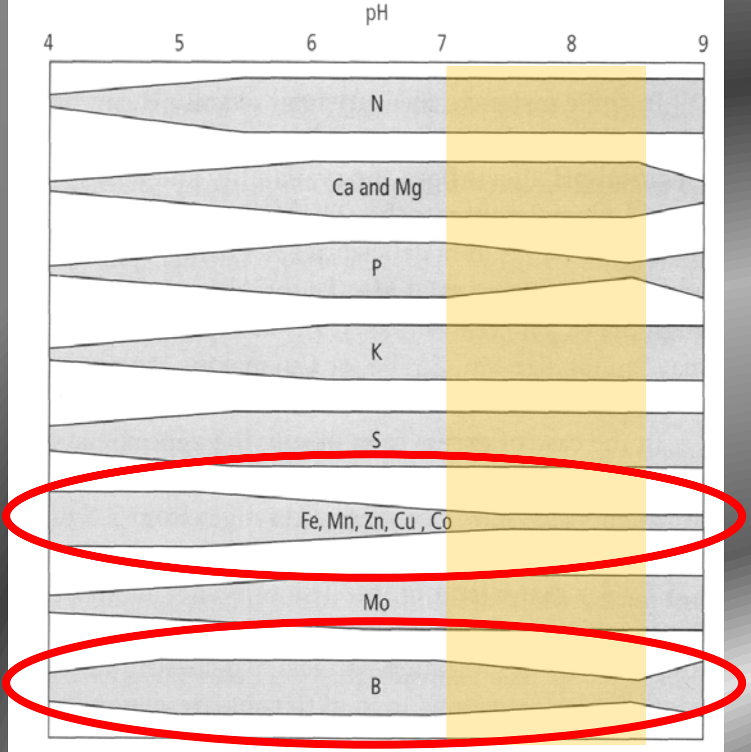


Figure 24.1 Effect of soil pH on relative availability of plant nutrients. A broad bar indicates high relative availability while a narrow bar indicates low availability.

Iron

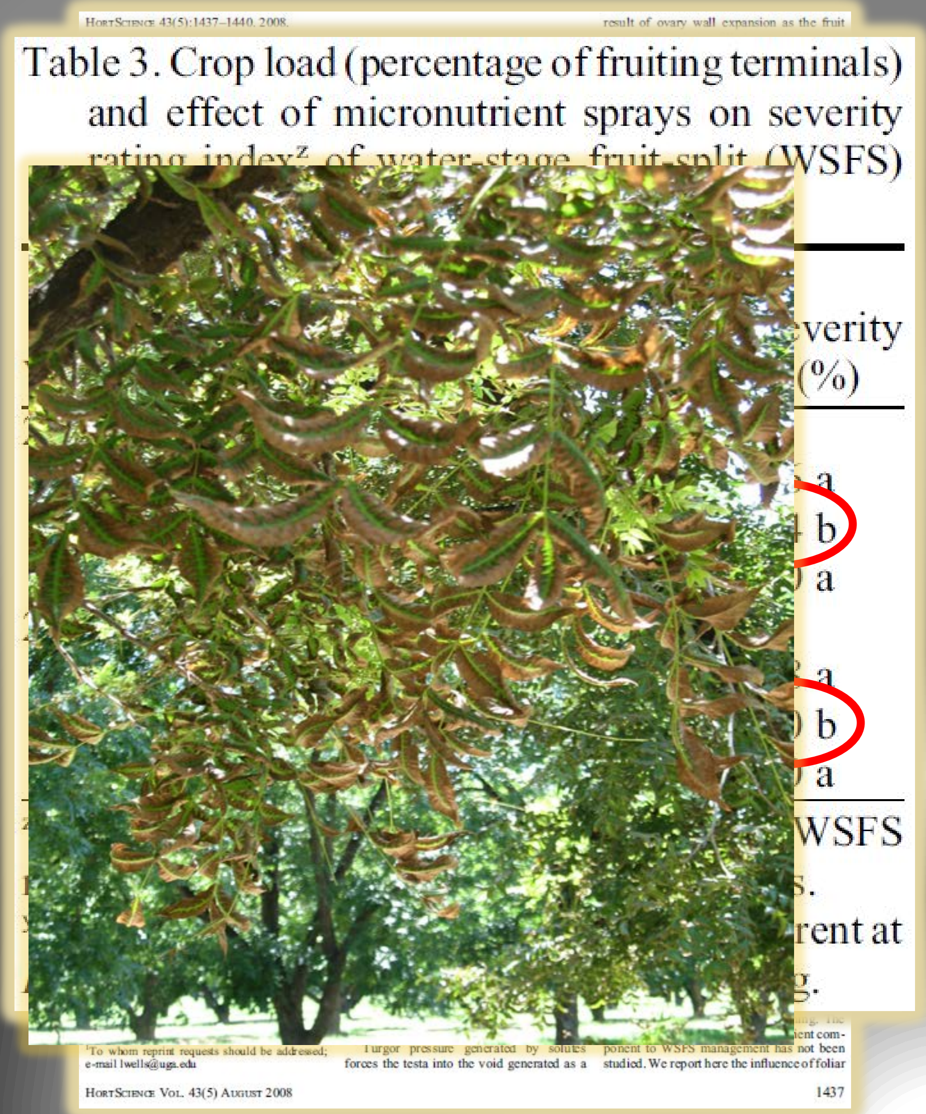
- Function in plants
  - Component of electron transport in respiration
  - Light dependent reactions of photosynthesis
- Excess manganese and copper can cause iron deficiency
  - Antagonists
- Interveinal chlorosis in youngest leaves
- Sharp distinction between veins and interveinal areas
- Overwatering worsens problem

Copper

- Functions
  - Electron transport in Photosystem I
  - Enzymes in photosynthesis
  - Detoxifies free radicals
- Deficiency
  - Visible symptoms rare
  - Shoot dieback
  - Interveinal chlorosis, bleached young leaves
  - Dwarfed leaflets
- Excess nitrogen can cause deficiency

Boron

- Functions
  - In soil as boric acid $B(OH)_3$
  - Electron acceptor
  - Influences potassium (K^+) movement
  - Flower & fruit development
  - Deficiency is less common in our growing regions
  - Toxicity is more likely



HortScience 43(5):1437–1440. 2008.

result of ovary wall expansion as the fruit

Table 3. Crop load (percentage of fruiting terminals) and effect of micronutrient sprays on severity rating index^z of water-stage fruit-split (WSFS)

[1]To whom reprint requests should be addressed; e-mail lwells@uga.edu

Turgor pressure generated by solutes forces the testa into the void generated as a

ponent to WSFS management has not been studied. We report here the influence of foliar

HortScience Vol. 43(5) August 2008 1437

Zinc

- Functions
  - Catalytic, coactive, and structural role in enzyme reactions
- Absorbed as monovalent cation ($ZnOH^+$) in high pH soils
  - Useless
- Deficient pecans
  - Rosette
  - Shoot dieback

Zinc

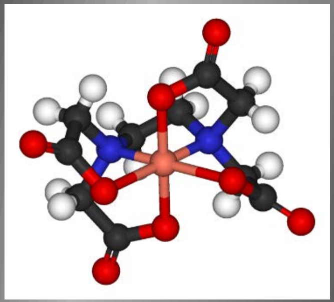
FOLIAR APPLIED ZINC SULFATE

- Typically four to five sprays per season
  - 1st at leaf burst (leaves opening)
  - 2nd 7 days after first spray
  - 3rd 7 days after second spray
  - 4th 14 days after third spray
  - 5th 14-21 days after fourth spray
    - 2 – 3 lb zinc sulfate (36% Zn) plus 3 pt of urea or UAN32 per 100 gal of water
- New flushes of growth should receive a zinc spray
- Fall applications are ineffective

SOIL APPLIED ZINC EDTA

- Chelated zinc is protected from fixation by soil minerals by chelate molecules, increasing soil solution zinc concentrations and plant availability
- Pecan fertigation
  - Young pecan trees: 2 to 4 gal/ac ZnEDTA (9% Zn)
  - Bearing pecan trees: 4 to 8 gal/ac ZnEDTA

Zinc EDTA

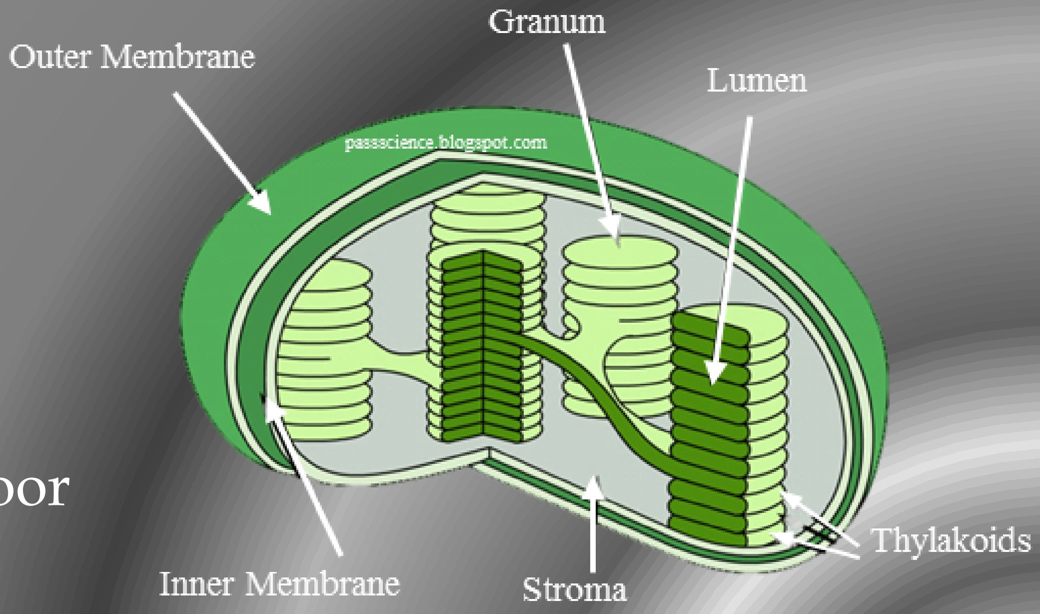


● Nitrogen
● Oxygen
● Carbon
● Hydrogen
● Zinc

Manganese

- Function in plants
  - Vital role in photosynthesis
  - Capturing light energy
  - Biosynthesis of chlorophyll
- Deficiency
  - general pale color
  - interveinal chlorosis/necrosis of young leaves
- Toxicity
  - delayed budbreak/poor development early
  - defoliation followed by re-growth of large leaves

Chloroplast



Manganese Deficiency

Photo courtesy of Charles Rohla
Noble Foundation – Oklahoma, USA

Photo courtesy of Dr. Jim Walworth
University of Arizona – Tucson, USA

Nickel

- Functions
  - Enzyme reactions
  - Critical in nitrogen movement
    - Urease for Urea
  - Understanding still limited
- Ni deficiency disrupts primary/secondary metabolism
- Primary metabolism – during early Spring growth
  - Four major pathways:
    - Ureide Pathway
    - Urea Cycle
    - Krebs Cycle
    - Shikimic Acid Pathway
- Secondary metabolism – protection from pests and disease
  - Three chemical groups:
    - Terpenes
    - Phenolics
    - Nitrogen-containing compounds

HortScience 39(6):1238–1242. 2004.

Mouse-ear of Pecan: A Nickel Deficiency

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Additional index words. nutrient disorder, zinc toxicity, flowering, profit, yields, stress, growth, micronutrients

Abstract. **Mouse-ear (ME) is a potentially severe anomalous growth disorder affecting pecan [*Carya illinoinensis* (Wangenh.) K. Koch] trees. It is especially severe in second generation sites throughout much of the Gulf Coast Coastal Plain of the southeastern U.S., but can also occur in potted nursery trees. Orchard and greenhouse studies on trees treated with either Cu or Ni indicated that foliar applied Ni corrects ME. ME symptoms were prevented, in both orchard and greenhouse trees, by a single mid-October foliar spray of Ni (nickel sulfate), whereas nontreated control trees exhibited severe ME. Similarly, post budbreak spring spray applications of Ni to foliage of shoots of orchard trees exhibiting severe ME prevented ME symptoms on subsequent growth, but did not correct morphological distortions of foliage developed before Ni treatment. Foliar application of Cu in mid-October to greenhouse seedling trees increased ME severity the following spring. Post budbreak application of Ni to these Cu treated MEed seedling trees prevented ME symptoms in post Ni application growth, but did not alter morphology of foliage exhibiting ME before Ni treatment. Thus, high leaf Cu concentrations appear to be capable of disrupting Ni dependent physiological processes. Foliar application of Ni to ME prone trees in mid-October or soon after budbreak, is an effective means of preventing or minimizing ME. These studies indicate that ME in pecan is due to a Ni deficiency at budbreak. It also supports the role of Ni as an essential plant nutrient element.**

A Mouse-ear (ME) is a growth abnormality of pecan [*Carya illinoinensis* (Wangenh.) K. Koch] first reported in 1918 by Marz (1918). It was initially exhibited by yard trees within certain Florida, southern Mississippi, and southeastern Georgia cities (Demaree, 1926). The disorder was initially attributed to spring cold injury before budbreak, but was later attributed to a disease pathogen (Demaree, 1926). It was evident in pecan orchards by the 1930's and is now a common anomaly. Gammon and Sharpe (1956) concluded that the problem was a manganese deficiency; however, soil or foliar application of Mn to affected trees does not correct ME in contemporary orchards. Mouse-ear symptoms range from mild morphological distortion of leaflets to gross deformity of shoot, foliar, and reproductive organs (Wood et al., 2003a).

There has been considerable establishment of second generation pecan orchards and replacement of missing orchard trees over the last 20 years in the southeastern U.S. It is common for these newly transplanted trees to exhibit ME symptoms the second or third year after transplanting. In many cases symptoms are so severe that transplants die. This replant-associated form of ME is a serious economic problem for many orchard operations throughout the Georgia pecan belt and certain orchards within the Gulf Coast Coastal Plain of the southeastern U.S.

Mouse-ear symptomology, as recently described by Wood et al. (2003a), implicates a micro nutrient deficiency or imbalance as the causal factor. This conclusion was further supported by observations by Wood et al. (2003b) that soil applied Cu at time of transplanting corrected ME on a second generation site. Trees exhibiting mild to moderate ME growing on a first generation site were largely cured of ME by the third year after topical application of Cu to the soil; however, foliar applications of Cu generally had little or no influence on ME severity. Neither foliar or soil application of Cu to severely MEed trees were efficacious for reducing symptoms. It was also noted that on a first generation orchard site, soil application of high amounts of either P or S corrected ME symptoms three years after application. Wood et al. (2004a) also noted a strong statistical linkage between Cu and Zn in regards to ME severity, thus implicating a Zn induced temporary deficiency of Cu as the likely cause of ME. However, these findings did not exclude deficiencies of other divalent metallic cations (e.g., Ni, Co, Ti, or V) as being the cause of ME.

Wood et al. (2004a, 2004b) observed a strong relationship between ME severity and soil Zn content, thus implicating Zn as a contributing factor to ME. Because Zn, Cu and Ni ion uptake from soils by feeder roots appear to share the same ion channels for entry into the root vascular system (Kochian, 1991), it becomes apparent that ME might be caused by either a Ni or Cu deficiency that is being induced by excessive soil Zn on second generations sites and by low soil Ni or Cu on first generation sites. The present study evaluates whether severe ME can be corrected by foliar applications of either Ni or Cu and concludes that ME is caused by Ni deficiency.

Materials and Methods

Field studies. Severely affected ME trees were treated in commercial orchards throughout the Gulf Coast Coastal Plain of Georgia. Soil types among affected orchards differed substantially, but were almost always either sandy loams or sands. Affected trees were found on sites previously supporting pecan orchards or were replacement trees in existing mature orchards. Although, ME affected trees sometime occurred on sites where pecan had not previously grown. In the latter case, these soils possessed very low cation exchange capacities. Most of the affected cultivars were 'Desirable' and were from 5 to 10 years old. The rootstocks are unknown, but are likely seedlings of 'Elliott', a commonly used seed source for pecan rootstock in the southeastern U.S.

Fall application. The ability of fall foliar application of either Cu or Ni to correct ME was evaluated in several orchards. The experiment consists of three micro nutrient treatments (Control, Cu and Ni) applied 15 Oct. as a foliar spray to major branches of severely MEed 'Desirable' trees. Individual trees served as replicates comprised of all three micro nutrient treatments. Treatments were spatially separated within the tree canopy so as to avoid cross-contamination of sprays. All treatments contained reagent grade urea (at 4.8 g·L^{-1}) and a nonionic surfactant (2.5 mL·L^{-1}) as additives. The Cu source was CuSO$_4$ • 5 H$_2$O at a concentration of 4 g·L^{-1} (1 g·L^{-1} Cu). The Ni source was NiSO$_4$ • 6 H$_2$O at a concentration of 3.5 g·L^{-1} (0.8 g·L^{-1} Ni). Both salts used in this experiment, and in the following experiments, were 99% A.C.S. reagent grade (Aldrich, Milwaukee, Wisconsin). Control treatments received only reagent grade urea and surfactant. Sprays were applied to foliage till run-off. There were 20 replications dispersed over two orchard sites. The experiment was a RCB design comprised of three treatments with single tree blocks. Treatments were evaluated the following spring (1 May) for severity of ME. Severity was based on the following scale; 1 = no symptoms, 2 = between 1% and 25% of number of leaflets per shoot exhibiting blunting; 3 = 26% to 50% of number of leaflets per shoot exhibiting blunting; 4 = >50% of number of leaflets per shoot exhibiting blunting; 5 = cupping of blunted leaflets; 6 = necrosis of leaflet tips; 7 = dark green zone near leaflet tip; 8 = stunted shoots; 9 = multiple new shoots (i.e., witches broom); 10 = dead shoot. Data were statistically analyzed for mean separation of treatments by use of JMP (SAS, Cary, N.C; SAS Institute, 2002). Nickel content of foliage was determined by ICP spectroscopic analysis using standard techniques. Several leaves were collected per treatment in June, bulked, rinsed in 0.1 M HCl, triple rinsed in deionized water, dried at 55 C, ground in a ceramic mortar and pestle before processing for analysis.

Spring application. This experiment addressed Cu or Ni applied to expanding shoots

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Received for publication 22 Aug. 2003. Accepted for publication 8 Mar. 2004.

[1] Corresponding author; e-mail bwwood@saa.ars.usda.gov.

Nickel Research

- Study in San Simon, Arizona began in 2016.
- Farmer's Investment Company
- 16 acres total
- 2 Treatments

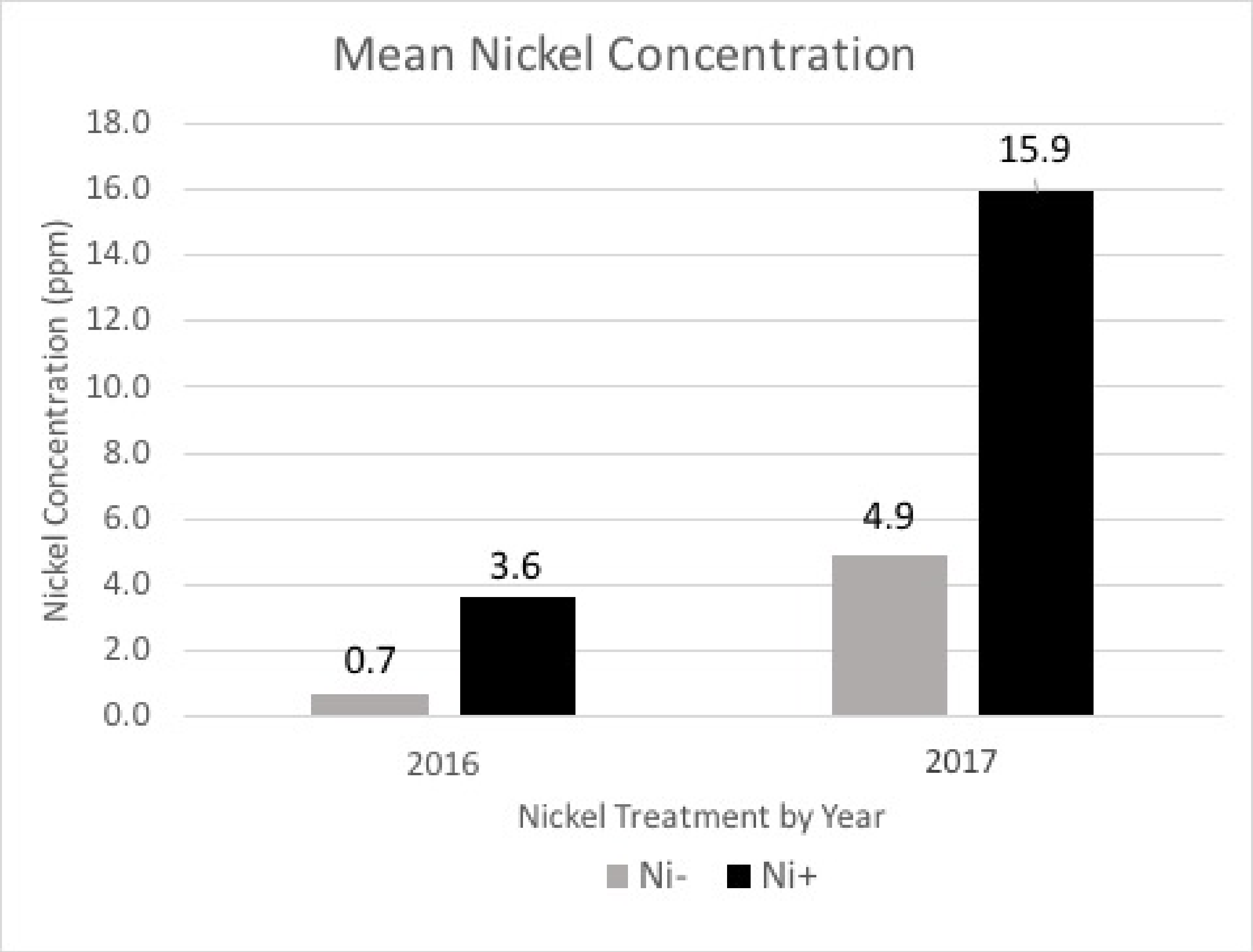
  (NI+ AND NI-)
- 3 Replications
- Complete Randomized Design
- Nickel Sulfate (10%)

  (HUMAGRO, GILBERT, AZ)

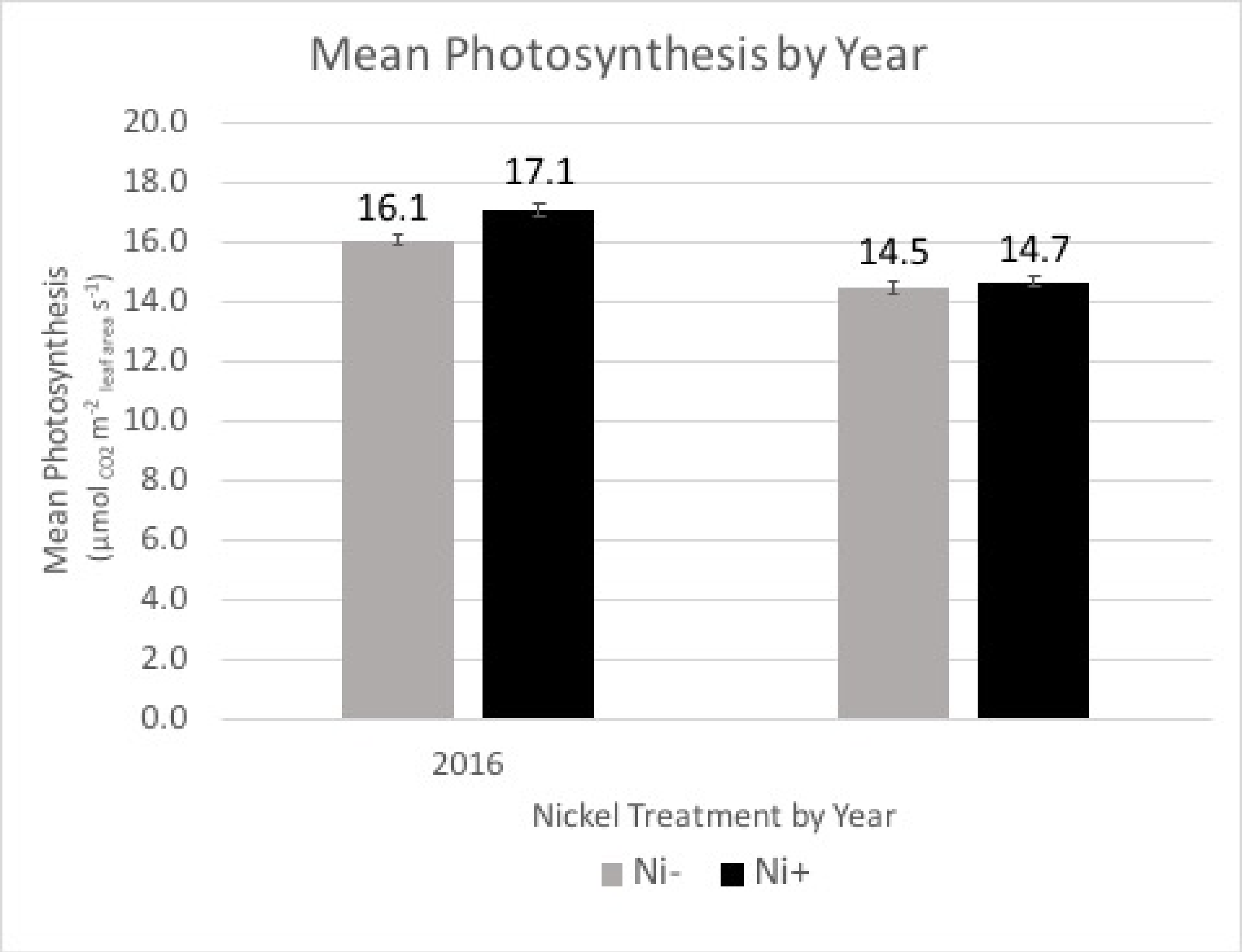
Nickel Research

- 2 foliar applications in 2016 & 2017
- Rate: 1 quart per acre
- Completed by July
- Observations recorded:
  - Trunk Caliper
  - Visual “Mouse-Ear Symptoms”
  - Photosynthesis (Li-COR 6400 XT)
    - LOT’S OF THEM!
  - SPAD (Greenness)
  - Mid-Day Stem Water Potential (MDSWP)
  - Soil Analysis
  - Leaf Analysis
  - Yield

Nickel Research Results



Nickel Research Results



NUTRIENT LEVELS FOR BEARING TREES (LATE JULY/EARLY AUGUST)

Nutrient	**Pecan**
Nitrogen (N)	2.5 – 3.0%
Phosphorous (P)	0.12 – 0.19%
Potassium (K)	1.2 – 2.5%
Calcium (Ca)	1.0 – 2.5%
Magnesium (Mg)	0.30 – 0.60%
Manganese (Mn)	100 – 600 ppm
Boron (B)	50 – 250 ppm
Zinc (Zn)	30 – 150 ppm
Copper (Cu)	8 – 20 ppm
Nickel (Ni)	> 2.5 ppm
Iron (Fe)	50 – 250 ppm

MICRONUTRIENTS

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Copper (Cu)	8 – 20 ppm	
Nickel (Ni)	> 2.5 ppm	(3 – 5 ppm)
Iron (Fe)	50 – 250 ppm	

MICRONUTRIENTS

Summary

- For pecan trees growing in alkaline calcareous soils, one of the most important limiting factors is the availability of the micronutrients for optimal performance
- Even though we have this much understanding of the function of these micronutrients, it is very complex and the interactions of these micronutrients is even more complex
- Not simply ′X′ versus ‘Y′
- Still highly recommended to perform leaf analysis annually in end-July/early-August to determine concentrations for pecan growing your specific location
- If you are applying foliar micronutrients be sure to request an acid wash of the leaves prior to analysis

Acknowledgements

- Arizona Department of Agriculture
- Specialty Crops Block Grant Program (SCBGP-FB-04)
- Dr. Jim Walworth
- Farmer's Investment Company
- HumaGro Bio Huma Netics, Inc.

Nickel Research Blocks

How to fix Iron Deficiency

- Foliar applied amino acid chelate
  - Not foliar EDTA
- Soil applied EDDHA has been affective
- Acidify through shanking or drip lines has shown some benefits
- Not recommend foliar or soil applied ferrous sulfate