NICKEL

Nickel deficiency was pinpointed as the problem by research leader Bruce Wood and plant pathologists Charles Reilly and Andrew Nyczepir at ARS' Southeastern Fruit and Tree Nut Research Laboratory in Byron, Ga.
A foliar fertilizer, called NICKEL PLUS, has been developed by NIPAN, LLC of Valdosta, Ga. Wood and his colleagues saw there was a lack of nickel uptake by the plants even if there was an abundance of nickel in the soil. Heavy metals such as zinc, manganese, iron, cadmium and copper compete with nickel for uptake channels in the feeder roots of the pecan tree. Additionally, lighter metals such as magnesium also act to indirectly limit nickel uptake. It was found that nickel deficiency had usually been induced by excessive accumulation of other elements due to decades of fertilizer applications.

Deficiency also disrupted the citric acid cycle, the second stage of respiration, where Ni-D foliage contained very low levels of citrate compared to Ni-S foliage. Disruption of carbon metabolism was also via accumulation of lactic and oxalic acids. The results indicate that mouse-ear, a key morphological symptom, is likely linked to the toxic accumulation of oxalic and lactic acids in the rapidly growing tips and margins of leaflets. Our results support the role of Ni as an essential plant nutrient element.

Pecan trees that don't absorb enough nickel from the soil are prone to a disease, called mouse-ear,that causes abnormal tree growth and development, Agricultural Research Service scientists in Byron, Ga., have discovered.

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, 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 non-treated 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 ofNi 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**,** (WOOD Bruce W; REILLY Charles; NYCZEPIR Andrew P)

Nickel is required by the urease enzyme in plants for the efficient conversion of urea to ammonia. The disorder occurs most frequently on newly transplanted trees in established orchards, but can also occur on sites where pecan has not previously been grown.

Mouse-ear first appears on the spring growth flush. The most common symptom of mouse-ear is a rounded or blunt leaflet tip (Figure 3). Affected leaves and leaflets are often smaller than healthy foliage. The rounded leaflet tips result from the buildup of lactic acid to the point of toxicity in the leaf tissues.

Figure 3. Mouse ear symptoms of pecan.

Other symptoms of mouse-ear include dwarfing of tree organs, poorly developed root systems, rosetting (Figure 4), delayed bud break, loss of apical dominance, necrosis of leaflet tips (Figure 5), and reduced photoassimilation. Symptoms may occur throughout the entire tree or sporadically throughout the canopy, often evident only on a single major limb or terminal shoot (Figure 6). Mouse-ear may consistently reappear from year to year or appear only occasionally on the same trees. The degree of severity within the tree canopy typically increases with canopy height.

Figure 4. Rosetting of pecan due to nickel deficiency.

Figure 5. Necrotic leaf tips in pecan tissue due to the build-up of lactic acid, resulting from a nickel deficiency.

Figure 6. Pecan tree suffering from severe nickel deficiency.

A variety of abiotic and biotic factors may influence mouse-ear. Severely affected orchards typically have high soil levels of zinc, calcium, magnesium, and phosphorous but low copper and nickel. These orchard soils are also normally acidic and sandy in texture, with low cation exchange capacities. Nematodes are commonly associated with the roots of affected trees as well.

Easily correct mouse-ear by applying nickel as a foliar spray in early-mid April when the developing foliage is in the parachute stage, or shortly thereafter, since nickel is not absorbed well by young leaves until the plant is in the parachute stage. In severe cases, make an additional application in late September or early October to prevent mouse-ear in the following initial spring flush. The nickel will be stored in the buds and stem tissues over the winter, where it will be available to the tree at bud break. Follow all label directions when using foliar nickel sprays. In order to manage orchards for the prevention of mouse-ear, take the following steps:

P Monitor leaf tissue and soil samples regularly for the availability of nickel to pecan trees.

P Do not make excessive applications of zinc to mouse-ear prone orchards. Zinc competes with and inhibits the uptake of nickel by pecan roots from orchard soils. Only apply foliar zinc when zinc levels in the leaf are less than 50 ppm or when visual symptoms of zinc deficiency are present in the orchard. Repeated foliar applications of zinc to the orchard result in substantial accumulation of zinc in the soil, mainly concentrated around the base of trees due to the rinsing of foliar applied zinc down the scaffold limbs and trunk. Do not allow soil zinc levels to increase in sandy or acidic soils already low in nickel.

P Maintain adequate soil moisture at bud break. Since nickel is at relatively low levels in most orchard soils, and its absorption by the tree is among the lowest of many nutrients, it is important to maintain soil moisture in order to facilitate root uptake.

P Maintain soil pH of 6.5-6.8 for efficient uptake of available soil nickel.

P Mouse-ear prone sites should not receive excessive applications of nitrogen unless applying nickel to the foliage.

P Avoid excessive applications of calcium and magnesium to mouse-ear prone sites. Most of the calcium and magnesium applied to orchard soils is in the form of dolomitic lime; therefore, take care not to over-lime orchard soils.

P Carefully manage phosphorous, iron, and copper levels in orchard soils, especially on sandy or acidic sites. These nutrients affect the uptake of nickel by pecan roots. Additionally, they may alter the availability of nickel within the pecan leaf.

P Correct nickel deficiency via foliar sprays and not by soil application.

In short the symptoms of Ni deficiency that is visible on leaves; 1.) Chlorosis - it is associated with abnormal pale or yellowish-green, foliage during shoot, leaf or canopy expansion. This symptom appears to be the earliest visual indicator of acute deficiency; although it is not definitive because of other nutrient deficiencies (e.g., Fe and S) also producing similar types of chlorosis. 2.) Reduced size an altered shape - this is the first reasonable indicator along with blunting of apical tips. In pecan nuts, this leaf blunting is such that the normally acute apex becomes obtuse, producing a shape similar to the ear of a mouse. 3.) Transitory dark green at leaf tip - the apical tips of affected spring folaige exhibit a small dark green zone just below the apical tip. This color distinction disappears with leaf age. The green zone is most noticeable during the first few weeks after bud break. 4.) Cupping and wrinkling of the leaves - cell expansion in the margins of leaves or leaflets, especially towards the apex is reduced to the point that there is cupping and wrinkling of the lamina. Affected folaige also feels thicker and less pliable, tending to be brittle. Foliage during this stage exhibits a Bonsai-like appearance. The latter characteristic also possesses great diagnostic power for Ni deficiency. 5.) Absence of laminar development - Severely affected foliage can be such that leaf lamina development is completely arrested, displaying a miniature vascular array. 6.) Winged petiole - the degree of malformation of the wings on leaf petioles increases with degree of severity.

Correction of Ni Deficiency

Previous work by Wood et al. showed that Ni deficiency in pecan nuts is easily corrected by foliar application of Ni salts. Observations by Wood et al., (2004 a,b) in terms of inconsistent partial reduction of ME-LE symptoms by application of Cu or P or S was subsequently found to be a N deficiency. S apparently increase soil Ni availability due to reduction in soil pH. One or two applications of Ni to foliage during the early canopy expansion phase, and soon after bud break at a concentration of 10-100mg Ni L^{-1} (plus urea and a surfactant) corrects deficiencies and ensures normal growth of tissues and organs (B.W. Wood, C.C. Reilly, A.P. Nyczepir).