Micronutrients - Zinc

Zinc (Zn), the 25th most abundant element, is widely distributed in agricultural soils but deficiencies still have been documented with several crops. Although examples of wide spread micronutrient problems are rare in forestry, severe Zn deficiencies were found in Australian pine plantations in the 1930's. The diagnosis and treatment of "littleleaf' disease is a classic example of a micronutrient deficiency problem. Unlike the severe problems with iron, however, Zn deficiencies can be controlled relatively cheaply and easily once they are properly diagnosed.

Because of the widespread use of galvanized metal, Zn also has been added to agricultural soils through pollution. Galvanizing is the process of coating iron or steel with Zn to prevent corrosion and galvanized metal is used for many nursery applications including irrigation pipe, and sheeting for roofing and walls of buildings. The process is called "galvanizing" because the Zn coating gives the iron or steel "galvanic," or electrochemical, protection from corrosion.

Role in Plant Nutrition. Zinc has several roles in plant metabolism but knowledge of its many functions is incomplete. Like most of the essential metal micronutrients, Zn functions as an enzyme catalyst and at least four enzymes contain bound Zn. Zinc deficiencies are associated with impaired carbohydrate metabolism and protein synthesis. Impaired protein synthesis can lead to an accumulation of amino acids and amides in plant tissue which in turn can increase susceptibility to attack by high-sugar parasites such as Botrytis spp. The typical deficiency symptoms of stunting, however, can be attributed to inhibited production of auxins, specifically indoleacetic acid (IAA). This can be explained by the fact that Zn is necessary for the production of tryptophan which is one of the precursors for the synthesis of IAA.

Availability and Uptake. Zinc is the third metallic micronutrient that we have discussed but typically is found in much lower concentrations in plants than iron or manganese (Table 4). The Zn content of typical agricultural soil is between 30 and 100 ppm. Because Zn is found in many types of industrial and municipal sewage sludge, nurseries considering sewage

Table 4. The seven essential micronutrients and their typical concentrations in seedling tissue

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (ppm) Bareroot	Container
Iron	Fe	0.01	50 to 100	40 to 200
Manganese	Mn	0.005	100 to 5,000	100 to 250
Zinc	**Zn**	**0.002**	**10 to 125**	**30 to 150**
Copper	Cu	0.0006	4 to 12	4 to 20
Molybdenum	Mo	0.00001	0.05 to 0.25	0.25 to 5.00
Boron	B	0.002	10 to 100	20 to 100
Chloride	Cl	0.01	10 to 3,000	--------

sludge as a soil amendment will want to do extensive testing beforehand.

Zinc is primarily absorbed as a divalent canon (Zn^{2+}) and therefore high concentrations of other divalent cations, like Cal^{2+}, can inhibit uptake. In addition to calcareous soils, deficiencies are common in organic soils and those that have been overly compacted. High soil phosphorus or the excessive use of phosphorus fertilizers also can inhibit Zn uptake.

Soil microbes apparently increase Zn availability because seedlings have been shown to increase in Zn concentration following soil fumigation. Also, under conditions of low soil availability, *Pisolithus tinctorius* ectomycorrhizae were found to increase the amount of Zn taken up by pecan seedlings.

Diagnosis of Deficiencies and Toxicities. Zinc deficiency is much more common than toxicity and, because Zn is immobile in the plant, symptoms are most prevalent in younger tissues.

Deficiency Symptoms—Classic Zn deficiency symptoms include reduced internode elongation' ("rosetting") and stunted foliage ("littleleaf"). Chlorosis or bronzing of younger leaves is also common with broadleaved species and the characteristic interveinal chlorosis or "mottle-leaf' is so diagnostic in citrus plantations that further soil or foliar analysis is considered unnecessary. Foliar symptoms are not so clear-cut with conifer seedlings, however. In a controlled experiment with Douglas-fir and white spruce seedlings, moderate stunting was the most obvious deficiency symptom (Figure IA). Although foliar discoloration was not observed, the apical needles of the Douglas-fir seedlings were twisted (Figure 1B). Zinc deficiency also retards the normal development of seedling foliage; in radiata pine, for example, seedlings grown under low Zn fertility did not develop mature secondary needles.

Toxicity Symptoms—Excessive amounts of Zn are extremely rare in natural soils. Zinc toxicity is more of a problem in soils contaminated by industrial pollution or

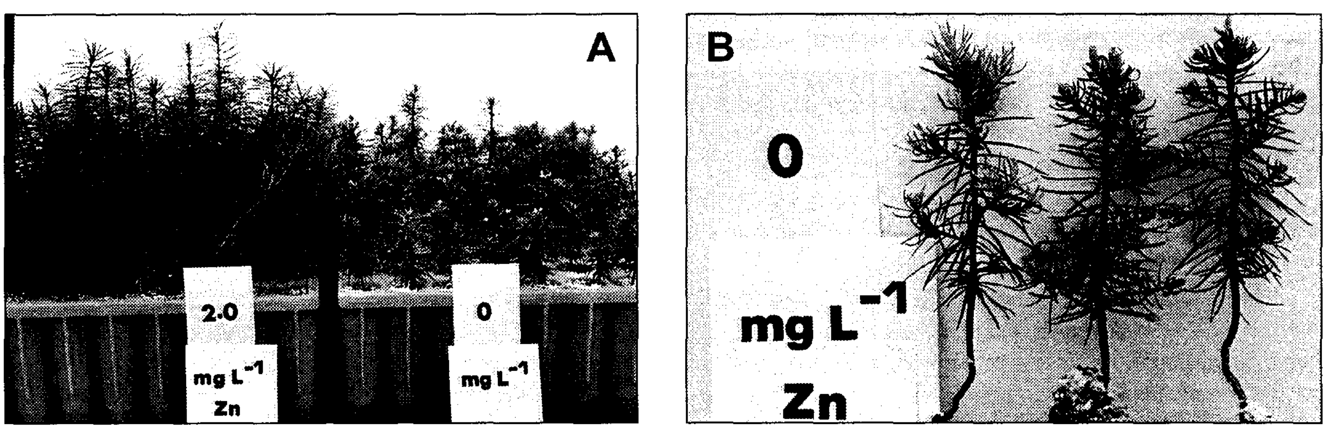

Figure 1. Compared to normal seedlings on the left, the block of Douglas-fir seedlings on the right exhibit the typical deficiency symptom of stunted terminal shoots (A). Shortened internodes ("rosetting") and stunted, distorted needles ("littleleaf") also are diagnostic (B) (from van den Driessche 1989)

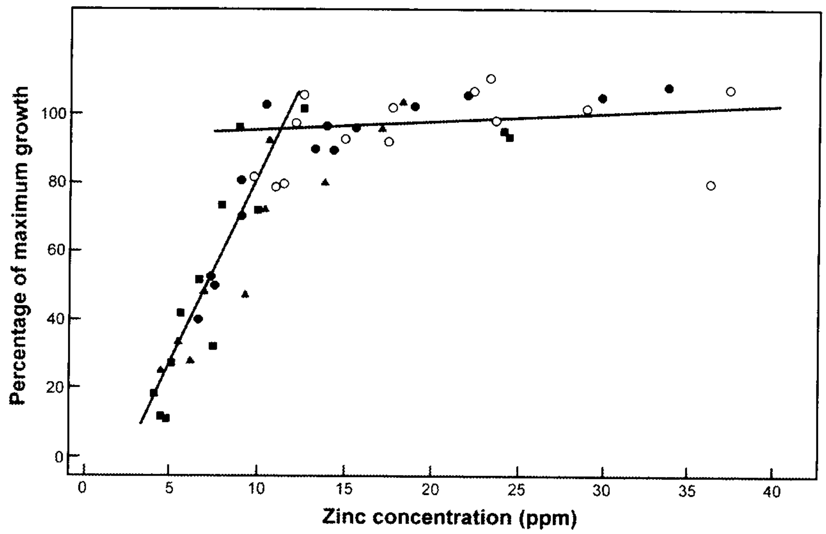

Figure 2. Shoot dry weight of Radiata pine seedlings increased steadily with additional zinc until around 11 parts per million (ppm) (modified from McGrath and Robson 1984)

where sewage sludge with a high content of Zn was used as a soil amendment. Localized problems also can occur where low pH water leaches Zn from galvanized tanks or pipes. Water in new tanks can contain as much as 7 to 8 ppm but this level would not cause problems unless Zn was allowed to accumulate in soils or growing media.

Monitoring Zinc in Nurseries. The availability of Zn to nursery crops can be monitored by chemical analysis of soils, growing media, and seedling tissue.

Analysis of Soil or Growing Media-Availability of Zn is related to pH, and most deficiencies occur above pH 6.0. As mentioned earlier, plants can develop deficiencies on calcareous soils which can be diagnosed either by the high pH or by the excessive calcium content. Diagnosing or predicting Zn availability with soil testing is imprecise because of the difficulty of predicting biological extraction by plants using chemical extraction in the laboratory. Although the diethylenetriaminepentaacetic acid (DTPA) chelating agent has been used successfully as a soil extractant for diagnosing Zn problems, analysis of seedling tissue is a more reliable test.

Tissue Analysis—The normal Zn concentration for seedling tissue can range between 10 and 150 ppm (Table 5), although foliar levels can vary widely by soil type and plant species. Some plants, including birches, poplars, and willows, accumulate excess Zn which can confound interpretation of foliar test results. This emphasizes the need for nurseries to develop their own standards for foliar nutrient levels. The actual physiological requirement for Zn is probably much lower. Controlled tests have shown that healthy Douglas-fir and white spruce container seedlings can be grown with Zn foliar contents of only 0.2 to 2 ppm. With radiata pine seedlings, primary needles at the shoot apex are considered the best tissue to analyze for diagnosing Zn deficiency. In these controlled tests, the critical concentration for optimum growth was 11 ppm (Fig. 2).

Zinc Management. Growers can insure an adequate supply of Zn by maintaining a slightly acid pH and, when warranted, applying fertilizer.

pH Maintenance—as mentioned earlier, Zn becomes less available under high pH conditions. Alkaline irrigation water can cause high pH in soils or growing media. This condition is easy to correct in container nurseries using artificial growing media by injecting a small quantity of mild acid into the irrigation water. The procedure for determining how much acid to use is described in detail in Volume Four: Seedling Nutrition and Irrigation of the Container Tree Nursery Manual.

Merely acidifying the water has not solved high pH problems in bareroot nurseries, however, and therefore soil amendments often are needed. The pH of naturally alkaline or over-limed soils can be lowered with sulfur applications although this can take many years. Calcareous soils are particularly difficult to treat. Not only are these soils highly buffered, but the excess calcium ions that result from sulfur amendments can still cause problems even after soil pH has gone down.

The situation is completely different in container nurseries. Typical peat-vermiculite growing media contain minimal amounts of Zn or other micronutrients, and most are organically bound so they are released slowly. Growers should be cautious of other potential growing media components, however. For example, media containing ground tires have been tested with horticultural crops but were found to have Zn levels of more than 200 ppm. Therefore, container growers should use a standard growing medium, maintain a target pH of 5.5 to 6.5 and provide a continuous supply of Zn through fertilization.

Fertilization-Fortunately, even severe Zn deficiencies have been easy to correct. For example, the stunting in the Australian pine plantations was even be cured by driving galvanized nails into the bole.

Zinc fertilizers come in two types: inorganic salts or organic compounds known as chelates (Table 5). Zinc sulfate is the most common inorganic fertilizer and can be applied as either a soil or foliar application. Zinc chelate consists of Zn2+ ions surrounded by an organic shell that maintains availability under adverse soil conditions, such as high pH, and is effective either as a foliar spray or soil incorporation. Chelation also helps protect against overfertilization because Zn2+ ions are slowly released from the organic complex. Unlike iron, which is available in several types of chelates, Zn is not as affected by pH so the EDTA chelate works well under all conditions.

In bareroot nurseries, Zn sulfate has been effective on many agricultural soils. Zinc is relatively immobile in the soil, however, so incorporation or banding is recommended. Application rates vary considerably with crop species, type of fertilizer, and application method but 10 kg/ha (8.9 lb/ha) of Zn sulfate heptahydrate (Table 5) was found to be effective in bareroot nurseries in British Columbia. Although more expensive, Zn chelates would be justified under calcareous soil conditions where inorganic Zn is quickly chemically bound and rendered unavailable to the crop. In containers, foliar applications of either Zn sulfate or Zn chelate work well.

The balance of micronutrients is often more important than the actual concentration of any one. Therefore, some growers prefer to use micronutrient mixes which can be either incorporated into the growing medium or injected into the irrigation system. Although the actual Zn concentration can vary considerably between the various products, all supply adequate levels (Table 5). Frits are slow-release fertilizers that consist of a mix of micronutrients impregnated in a glass powder which have release rates of up to one year. However, Zn frits were found to be much less effective than other fertilizer sources. In container nurseries, fertigation is recommended whenever possible because it insures that a uniform amount of Zn will be available throughout the growing season.

Irrigation water can supply adequate levels of several micronutrients, or significant levels of competing and complexing ions such as calcium, iron, or bicarbonate. Therefore, growers will want to test their water or even consult an expert before designing a fertigation program.

The most comprehensive list of Zn fertilizers and their US suppliers can be found in the Farm Chemicals Handbook. In Canada, Plant Products Co. Ltd. offers a wide variety of chelated fertilizers.

Summary. In conclusion, zinc availability is not usually a problem in nurseries with good quality soil

Table 5. Some common fertilizers containing Zinc (Zn)

Fertilizer	Chemical Notation	Zn (%)	Use in Nurseries
	Single Nutrient Fertilizers		
Zn sulfate monohydrate	$ZnS0_4 \bullet H_2O$	35	Foliar or soil applications
Zn sulfate heptahydrate	$ZnS0_4 \bullet 7\ H_2O$	23	Foliar or soil applications
Basic Zn sulfate	$ZnS0_4 \bullet 4\ Zn(OH)_2$	55	Foliar or soil applications
Zn oxide	ZnO	78	Foliar or soil applications
Zn frits	ZnO_2	1.5 to 14	Only for soil applications
Zn chelate	ZnEDTA	14	Foliar or soil applications
	Multinutrient Fertilizers		
Soluble Trace Element Mix – STEM®	Zn as $Zn\ SO_4$	4.5	Foliar or soil applications
Micromax®	Zn as $Zn\ SO_4$	1.0	Incorporation in growing media
Plant-Prod ® Chelated Micronutrient Mix	Zn as EDTA	0.4	Foliar or soil applications
Compound 111®	Zn as EDTA	0.075	Incorporation in growing media
Osmocote Plus®	Zn as $Zn\ S0_4$	0.05	Incorporation in growing media

except in areas that have been affected by industrial pollution or sewage sludge. Diagnosis of zinc deficiency can often be made based on the characteristic stunting or rosetting of seedling foliage. Maintaining a slightly acid pH in the soil or growing medium will insure good Zn availability and, compared to iron, correcting Zn deficiencies is relatively easy with either zinc sulfate or chelate fertilizers. Because the balance of micronutrients is so important, growers should consider using a micronutrient mix to prevent either deficiencies or toxicities.

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