ZINC *Protects!*

# Zinc - The Vital Micronutrient for Healthy, High-Value Crops

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ZINC

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*Field with severe deficiency of zinc in maize (also with marginally deficient copper and magnesium) showing stunted and chlorotic plants.*

*Part of the same field which has an adequate zinc status (due to bringing in relatively zinc-rich soil to fill a hollow) showing normal growth in maize plants.*

*Photos: B.J. Alloway*

Zinc is absolutely essential for the normal healthy growth and reproduction of all higher plants, animals and humans and is therefore called an "essential trace element" or a "micronutrient". Even where optimum amounts of manures and/or fertilizer nutrients (N,P and K)[1] and water requirements have been satisfied, a crop will not achieve its full potential yield if its supply of zinc is inadequate. A very wide range of crops are affected by zinc deficiency, including: cereals (rice, wheat and maize), fodder crops (sorghum and sudangrass), pulses (beans, chickpeas and soybeans), bush and tree fruits (apples, citrus, peaches), nuts (pecans), vegetables (potato, onion and sugarcane) and non-food crops such as cotton and tobacco.

When crops have a deficient supply of zinc, yield will be reduced and quality of the crop product may also suffer. Losses of up to 30% in the yield of cereal grains in crops such as maize, wheat and rice can occur as a result of "latent" or "hidden" deficiencies without the appearance of any obvious visible symptoms of stress. However, more severe deficiencies (manifested by leaf symptoms) can result in much greater yield losses and even complete crop failure. Zinc treatments have given yield responses of up to 4 tonnes/hectare in wheat and rice and up to 2 t/ha in maize[2].

## Why is Zinc Essential for Crop Growth?

Zinc is required in small but critical concentrations to allow several key plant physiological pathways to function normally. These pathways have important roles in photosynthesis and sugar formation, protein synthesis, fertility and seed production, growth regulation and defense against disease. Where zinc is deficient, these physiological functions will be impaired and the health and productivity of the plants will be adversely affected, resulting in lower yields (or even crop failure) and frequently in poorer quality crop products.

[1] Nitrogen(N), phosphorous(P) and potassium(K)

[2] World average cereal yield is 2.9 t/ha and typical yields of both wheat and rice can range from <1 to 9 t/ha depending on growing conditions and crop management

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Animals and humans also have critical zinc requirements and in areas where zinc deficiency in crops is widespread there is a high risk that the health of livestock and people will also be affected. However, in addition to the zinc content of the diet, its availability to humans and some species of farm livestock is also affected by other dietary components such as the relative amounts of calcium and phytate (a phosphorus-containing compound present in many crops, especially cereals).

Several important food crops can be seriously affected by zinc deficiency. Maize and rice are the most sensitive with wheat being moderately sensitive. Nevertheless, where soils are deficient in zinc, whatever the crop species' relative sensitivity to the problem, if the zinc supply status is inadequate, the crops will be affected by deficiency.

## Where do Zinc Deficiency Problems in Crops Occur ?

Deficiencies of zinc occur in many parts of the world on a wide range of soil types but semi-arid areas with calcareous soils, tropical regions with highly weathered soils and sandy-textured soils in several different climatic zones tend to be the most seriously affected. In addition to the amounts of zinc derived from the rocks on which the soil has developed and variable inputs from the surrounding environment, key soil factors affecting the plant-available concentrations of zinc in soils include: pH, the free calcium carbonate content, and the available phosphate status. The latter factor is often responsible for zinc deficiency being manifested for the first time in areas where new high yielding varieties of wheat are grown because they require relatively high levels of phosphate for optimum yields. When these new varieties have been grown in developing countries in East Asia, the Middle East and elsewhere, zinc deficiency was often recognized for the first time due to the more intensive methods of production.

*A stunted zinc deficient maize plant showing characteristic symptoms of wide chlorotic areas near the bases of the leaves and rosetting of the leaves due to reduced stem elongation. The narrow interveinal chorotic stripes also visible are a symptom of copper deficiency.*

*Photo: B.J. Alloway*

Briefly, the main causes of zinc deficiency in crops are: low total zinc concentrations in soils (especially sandy, calcareous and sodic soils), low availability (high pH, calcareous and sodic soils), high levels of phosphate and nitrogen and restricted root zones due to soil compaction or high water table, particularly on soils of marginal zinc status.

In many parts of the world, such as India, Australia and the USA, where deficient soils have been treated with zinc amendments, subsequent soil testing has shown that many have an adequate zinc status for several years after treatment. This has resulted in a declining trend in the occurrence of zinc deficiency in many agricultural regions. Nevertheless, high yielding crops will have a greater zinc requirement than those grown less intensively and so the soils will require regular soil testing.

# Identification of Zinc Deficient Soils

## Soil and Plant Analysis to Ensure an Adequate Supply of Plant-Available Zinc in Soils

### *Soil Analysis*

Soil analysis can be used to diagnose problems in existing crops but is more valuable for enabling deficiencies to be predicted and remedial action taken to avoid reduced yields in subsequent crops. Soil samples for analysis can be taken at any time of the year but care is needed to ensure that a representative sample has been taken over the full area of the field. It is also important to avoid contamination of the soil (or leaf) samples by contact with zinc-plated or brass equipment. Once prepared for analysis at the laboratory, several different analytical procedures may be used, depending on local experience.

The soil tests for zinc most widely used around the world include extractions with the chelating agents DTPA[3] and EDTA[4] and salts such as ammonium acetate. Experience in India and other countries where a wide range of soil types and crops are affected by zinc deficiency has shown that the most appropriate soil tests vary for different combinations of soils and crops. Likewise, the critical (or threshold) concentrations used for the interpretation of the test results will also vary with the different soil tests and combinations of soils and crops. In general, the lower the availability of the soil zinc and the greater the sensitivity of the crop to deficiency, the higher the critical zinc concentration. For example, critical concentrations for the DTPA soil test can vary in India between 0.5 mg Zn $kg^{-1}$ to 2.0 mg Zn $kg^{-1}$ according to the soil type and the crop species and/or variety (see Table 1). Typical concentrations found in deficient soils are often less than 1mg Zn $kg^{-1}$ extractable in DTPA.

Table 1

**Soil Tests for Available Zinc**

| Soil Test Reagent | Critical (or Threshold) Concentrations (mg Zn/kg in dry soil) |
|---|---|
| DTPA (0.02M) | 0.5 - 2.0 |
| EDTA (0.05M) | < 0.6 - 1.0 |
| HCl (0.1M) | < 1.0 – 5.0 |

Table 2

**Critical Concentrations from Leaf Analysis of Crops**

| Crop | Severity of Deficiency | Critical Concentration (mg Zn/kg dry matter) |
|---|---|---|
| Wheat | Acute | < 8 |
| | Moderate | 8 – 12 |
| | Latent (hidden) | 12 – 20 |
| | No response to Zinc | > 20 |
| Rice | Deficiency | < 10 - 15 |
| Maize | Deficiency | < 20 - 22 |

### *Plant Analysis*

An alternative to soil testing is to analyze samples of leaves or grain to determine the zinc status of both the crop and the soil on which it is growing. However, it is often not possible to rectify the problem to prevent losses in the existing crop, but once diagnosed, the deficiency can be treated for future crops in time to prevent further loss of yield. Leaf sampling practices vary with regard to which leaves are sampled and this is the result of local experience. However, in all cases, after

[3] diethyltriaminepentaacetic acid
[4] ethylenediaminetetraacetic acid

sampling the leaves need to be thoroughly washed with distilled water and dried before grinding for analysis, taking care to avoid contact of the sample with external sources of zinc at all stages.

Table 3

**Zinc-containing Materials Available for the Treatment of Zinc Deficiency**

| |
|---|
| Zinc sulphate ($ZnSO_4.H_2O$) 35% Zn |
| Zinc sulphate ($ZnSO_4.7H_2O$) 22% Zn |
| Basic zinc sulphate ($ZnSO_4$. $Zn(OH)_2$) 55% Zn |
| Zinc oxide (ZnO) 67-80% Zn |
| Zinc carbonate ($ZnCO_3$) 52-65% Zn |
| Zinc chloride ($ZnCl_2$) 45% Zn |
| Zinc frits (Zn silicate) variable Zn contents |
| Zinc EDTA (chelate) 12-14% Zn |
| Zinc polyflavonoid (chelate) 10% Zn |
| Zinc lignosulphonate (chelate) 5% Zn |
| Zincated fertilizers (various Zn contents) |
| Multi-micronutrient mixtures (various Zn contents) |

Critical (or threshold) concentrations in leaf dry matter will also vary according to the species of plant and the position of the leaves on the plant. In general, critical leaf values range from 15 mg Zn $kg^{-1}$ in rice, 20 mg Zn $kg^{-1}$ in wheat, and 22 mg Zn $kg^{-1}$ in maize and groundnut. For the whole young plant, values include 8 mg Zn $kg^{-1}$ for sorghum, 22 mg Zn $kg^{-1}$ in rice and 25 mg Zn $kg^{-1}$ in wheat and chickpea. However, differences can also occur between different varieties of these crops. Under normal circumstances, excessive amounts of zinc are rarely found in agricultural soils as a result of crop fertilisation. Adverse effects of excess zinc on crop production are often only encountered where leaf concentrations exceed 300 mg Zn/kg (dry matter) but this also depends on the soil conditions and the crop species/variety.

On the basis of the information in Tables 1 and 2 or, preferably, after consultation with local experienced agronomists, it should be possible to detect areas of crop-growing land which are likely to give rise to zinc deficiency in crops.

# Treating Zinc Deficient Soils and Crops

## Supplying Zinc to Crops - Treatment of Deficiencies

Zinc salts, such as zinc sulphate ($ZnSO_4.7H_2O$) and other simple compounds are the most commonly used and cost-effective form of soil amendment applied either on its own or mixed with fertilizer. Zinc sulphate can also be used as a foliar treatment for crops (normally with calcium hydroxide to neutralise acidity) but chelated forms of zinc are more frequently used for this purpose. In addition to zinc salts, other industrial by-product materials containing zinc are also used in various parts of the world. These are often more slow-release forms of the metal and only gradually dissolve in the soil. In some cases they can also supply other micronutrients such as copper.

Application rates of these amendments will also vary depending on the form of zinc applied, soil conditions, the crop and the method of application. For soil applications, they can range from 2.5 kg Zn $ha^{-1}$ to 22 kg Zn $ha^{-1}$ for inorganic forms such as $ZnSO_4$ and 0.3-6 kg Zn $ha^{-1}$ for chelated forms. Local agronomists will have found the most suitable treatment for the soils and crops in their area. Many areas with severe problems which have been treated now have a greatly improved available zinc status. The residual effect of zinc treatments can last several years. However, with higher yielding crops, the available zinc reserves may be more rapidly depleted and therefore need to be monitored by regular soil testing.

## Extent of Crop Zinc Deficiency Problems in the World

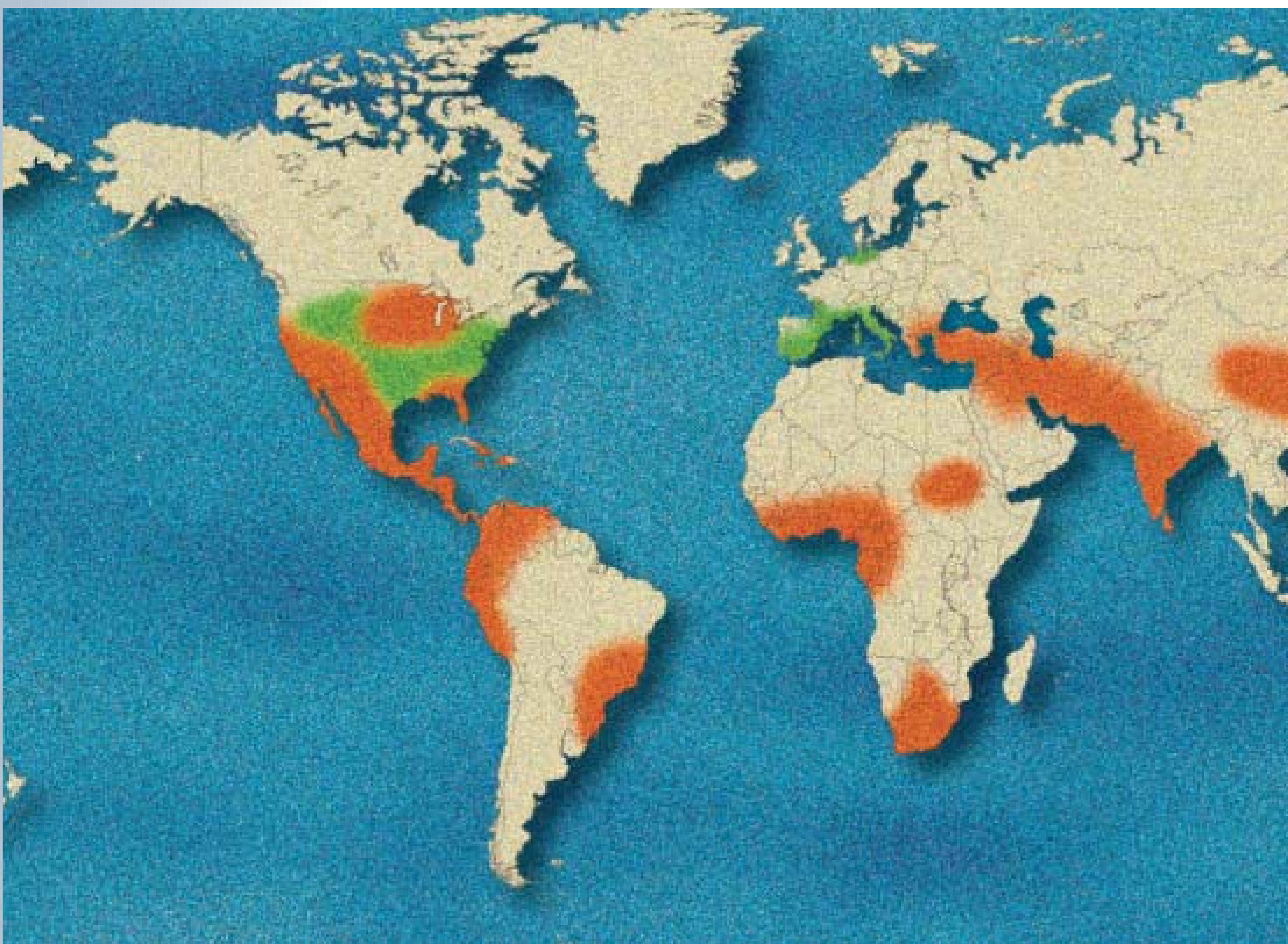
A study for the Food and Agriculture Organization of the United Nations (FAO) involving 190 field trials in 15 countries around the world by Sillanpää[1] showed that zinc deficiency was the most commonly occurring micronutrient deficiency problem. Zinc deficiency was recorded in 49% of the trials and 25% of these were acute forms with visible symptoms and 24% were latent or hidden deficiencies confirmed by yield responses to zinc amendments. In India and Pakistan, between 50 and 70% of crop-growing soils are affected by zinc deficiency.

Figure 1 shows the general distribution of the problem but localized deficiencies can occur in many other parts of the world where crops are grown and the soil factors mentioned above occur.

[1] Sillanpää, M. *Micronutrient assessment at the country level: an international study.* FAO Soils Bulletin No. 63, Food and Agriculture Organisation of the United Nations, Rome, 1990.

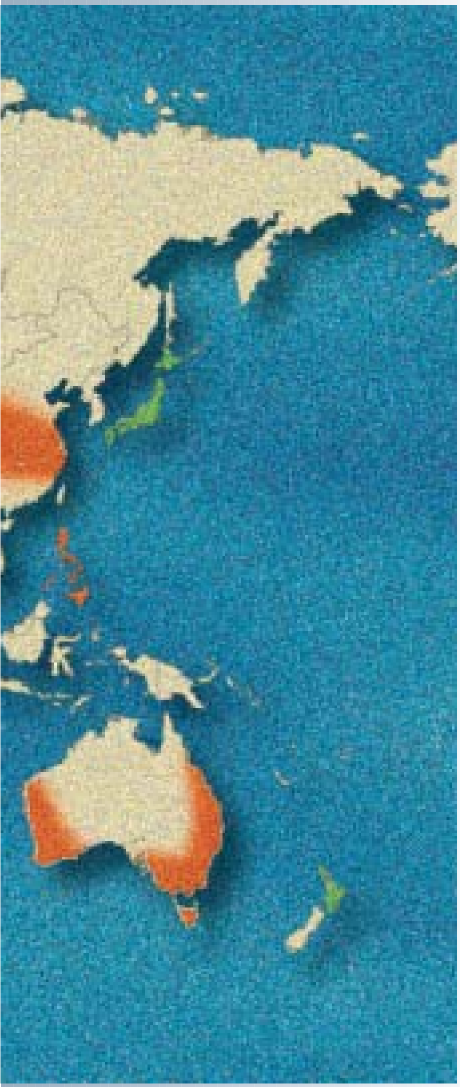
Figure 1

## World zinc deficiency in soil: major areas of reported problems



Based on data from Robson, A.D. (editor) *Zinc in Soils and Plants*. Kluwer Academic Publishers, Dordrecht, Boston and London, 1993. Other areas may also be affected to varying extents.

# Areas with highest risk of zinc deficiency in crops



## Australia

Most of the coastal land (cultivated belt) in the country: Victoria, South Australia, Queensland, Northern New South Wales, South West of Western Australia, coastal areas and islands of Tasmania.

## New Zealand

Shallow Niue Soils.

## United States of America

Most of the cultivated areas in California, Arizona, Midwest states, Florida (but most of the country affected to a certain extent in 40 states).

## Central and South America

Most of the cultivated areas (on highly weathered soils) particularly the Central Plateau of Brazil, Llanos Orientales in Colombia and Venezuela, Costa Rica, Guatemala, Mexico, Peru, NW Puerto Rico, French Guinea).

## East Asia (India, Pakistan, Bangladesh)

Widespread deficiencies throughout (50-70% of India and Pakistan) In Bangladesh, 2 million ha of paddy rice soils are zinc deficient.

## China, Japan and Philippines

Over 8 million ha in SE Asia suffer from deficiency.

China - calcareous and/or loessial soils - including Yellow River, Yangtze, and rice soils throughout Northern China, which is more deficient than Southern China).

Japan - Reported in rice.

Philippines - 500,000 ha of rice soils deficient.

## Africa

Common in West Africa, NE, SW and W Nigeria, Zimbabwe, Malagasy, Congo, Sierra Leone, Gezira region of Sudan, SW Cape Province in South Africa.

## Middle East

Iran, Iraq, Syria and Turkey, calcareous course textured soils or arid/semi-arid areas most at risk. Current guestimate is that 50% of the area is zinc deficient.

## Europe

Unevenly distributed but mainly in southern Europe (with calcareous soils). Problems have been reported in sandy soils in South Western France and Northern Germany on sandy soils and various soil types in Romania.

# THINK ZINC!

Zinc deficiency in crops of different types is a major problem in many parts of the world and leads to serious inefficiencies in crop production, especially with new, high yielding varieties of crops which require relatively expensive inputs of fertilizers, pesticides and irrigation in order to attain their optimum yield. Where zinc has been shown to be deficient by soil tests, plant analysis or diagnostic symptoms, the problem can easily be rectified.

Relatively small amounts of zinc compounds such as zinc sulphate can cure the deficiency and last for several years before they need to be repeated. This treatment is highly cost effective when the costs of the zinc application and the value of the extra yield are considered.

It pays for farmers and their advisors to "think zinc" for good yields and high value crops.

*Zinc deficiency in citrus trees. Upper photo shows part of a zinc deficient tree. Lower photo shows detail of chlorotic citrus leaves from the tree.*

*Photos: V.M. Shorrocks*

## References and Further Reading

The information in this brochure has been compiled from a wide range of literature sources and from the author's personal experience but the following references are particularly relevant to zinc deficiency problems in crops:


Mortvedt, J.J., P.M. Giordano and W. Lindsay (editors) *Micronutrients in Agriculture.* Soil Science Society of America, Inc. Madison, Wisconsin, 1972.

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