COOPERATIVE EXTENSION SERVICE
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MANAGING ACID SOILS FOR PRODUCTION OF BURLEY TOBACCO

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Excessive soil acidity is considered the single greatest problem influencing yields of burley tobacco grown in Kentucky. Based on UK Soil Test Laboratory summaries, half to two-thirds of tobacco fields need to be limed each year to decrease soil acidity to recommended levels. Although strongly acid soil conditions affect the availability of other plant nutrients, the most important effects on tobacco are that solubility of manganese is increased to toxic levels and solubility of molybdenum is decreased to deficient levels. Molybdenum availability in soils and molybdenum nutrition of burley tobacco has been addressed in Cooperative Extension publication AGR-82. The following material deals primarily with manganese: the effect of excessive levels of manganese on growth of burley tobacco and management practices to alleviate manganese toxicity.

Functions of Manganese in Plants

Manganese is an essential plant nutrient. When present in adequate but not excessive amounts in the plant, it functions in photosynthesis and activates enzymes for plant growth. However, when plants contain excessive levels of manganese, the concentrations of iron, chlorophyll synthesis, rates of photosynthesis, enzyme activity, and subsequent plant growth are lowered. The latter condition, a disease commonly called manganese toxicity, is estimated to cost Kentucky tobacco growers $30 to $40 million annually due to lowered yields and quality.

Relationship of Plant Manganese and Plant Growth

Leaf Symptoms

Generally, manganese toxicity occurs early in the growing season soon after plants are transplanted and established in the field. Severely affected leaves (Fig. 1) develop a light

green or yellowish color (chlorosis) between veins while the midrib and lateral veins remain dark green. These symptoms are very similar to those for iron deficiency. Plants grow slowly and the chlorotic spots on the older leaves turn brown and eventually die and fall from the leaf. Such leaves become less sound, weigh less at harvest, and are trashy and of low quality after curing.

The specific toxicity symptoms exhibited and their location on the plant depend on the concentrations of plant manganese. In field-grown plants, visual leaf symptoms (chlorosis) usually occur when manganese concentration exceeds 400 to 500 parts/ million (ppm)in the tissue. However, reduced growth can occur at concentrations below 400 ppm (Fig. 2) even

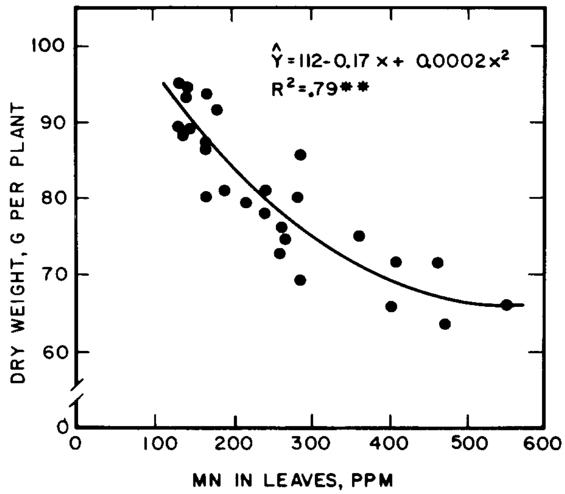

FIGURE 2.—Relationship between leaf manganese concentration and dry weight of burley tobacco in field soil culture.

though visual symptoms are absent. Under moderate conditions, plants recover from the disease about midseason and only leaves on the plants' lower portions are affected. However, the disease may be so severe under some conditions that plants become badly stunted or die. The disease is less severe in years with above normal temperatures.

Manganese Concentrations

Plant Root Symptoms

Not only does manganese toxicity affect above ground plant parts; plant roots are also affected. In general, affected roots are brown and, under severe conditions, the root tips are pruned causing increased branching of roots behind the tips. The overall volume of roots is lessened, thus decreasing the uptake of nutrients and water. Additionally, excessive levels of manganese may decrease the uptake of other nutrient cations such as iron, calcium and magnesium because manganese competes with other cations for uptake sites on plant roots and replaces calcium in cell membranes. When calcium is replaced, the disrupted membranes lose their stability and the cell contents, such as organic solutes or inorganic ions, may move out of the plant cells.

Soil and Fertilizer Factors Affecting Plant Available Manganese

Soil Factors

Manganese toxicity is greatly affected by soil acidity. As soil becomes more acid, greater amounts of manganese are available, and tobacco plants take up more manganese than they need for normal growth. Soil pH of 5.0-5.5 is the critical pH range for manganese availability. When the soil pH is 5.5 or higher, available manganese is oxidized to unavailable forms and toxicity seldom occurs. At pH 5.0 or lower, soil manganese is solubilized and toxicity in tobacco is likely. Between pH 5.0 and 5.5, toxicity may or may not occur in any given year. Another soil factor affecting the solubility of manganese is the oxidation-reduction potential. The oxidation-reduction potential is a measure of the relative oxidizing or reducing power of soil and is related to the oxygen levels in soil. In well-drained, well-aerated soil at pH above 6.0 much of the manganese exists as manganese oxides. However, when soils are waterlogged for 2 or 3 days, the oxygen is lost from the soil, and soil microorganisms use the chemically combined oxygen in manganese and iron oxides for their respiratory needs. This process releases manganese from non-available to available forms and increases the pool of available soil manganese. Thus, excessive moisture and a source of readily available organic matter (green manure crops) lead to high levels of available soil manganese by reduction of manganese oxides. These conditions commonly exist in tobacco fields in Kentucky each spring and early summer during the early growth stage of transplants.

Fertilizer Factors

The dominant factor influencing soil acidity and manganese availability in tobacco fields in Kentucky is the large amount of fertilizer used in tobacco production. Growers are applying an average of 2200 lb/acre of mixed fertilizer and an additional 700 lb of nitrogen fertilizers. These quantities generate large amounts of soil acids so that soil pH at midseason often is 0.6 to 1.0 pH unit below what it was before N-P-K fertilization (Fig. 3). Most of the acidity results from the conversion of soil and fertilizer ammonium to nitrate nitrogen by soil microorganisms. Because of this situation, growers need to lime tobacco soils to pH 6.4 to 6.6 so that soil pH will remain above 5.5 throughout the growing season. When soil pH drops below 5.5, one can expect not only manganese toxicity but lowered availability of other nutrients such as molybdenum, phosphorus, magnesium and calcium.

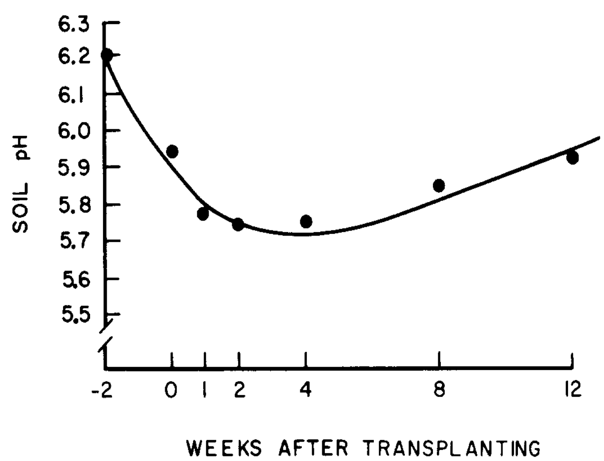

FIGURE 3.—Soil pH across the growing season in fertilized plots of burley tobacco.

Soil pH

Cultural Practices to Control Manganese Toxicity In Tobacco

Liming Acid Soils

The best way to control manganese toxicity is to lime soils used for tobacco to pH 6.4 to 6.6. Limestone will correct soil acidity more effectively if applied and thoroughly mixed with the soil one to three years ahead of the crop. Summer and fall are good times to apply lime since the soil is dry, dealers in agricultural lime are not as busy and the lime applied can react over the winter. Greater effort should be given to insure proper mixing with soil when lime is applied close to the time of transplanting the tobacco crop. If applications are made two or more years ahead of the crop, the entire application may be applied to the soil surface. When liming needs are not determined until the fall or early spring before transplanting on strongly acid soil (water pH 5.5 or below), half the lime should be plowed down and the other half disked in after plowing. Since soil acidity must be corrected in a relatively short period under these conditions, the kind and quality of the liming material, particularly its fineness, is of great importance. While liming soils before transplanting is best, sometimes manganese toxicity can be alleviated by liming after transplanting. A fast-dissolving source of limestone such as finely ground or pelleted lime should be used. A broadcast application of about 1000 lb/acre over the top of plants followed by cultivation to work it in the soil is the method most likely to be successful. Liming acid soils is essential, but excessive liming should be avoided. When soils become neutral, or basic (pH 7.0 and higher), phosphorus will revert to insoluble forms and some minor elements will be less available for plant growth.

Nitrate Nitrogen and Molybdenum

Use of nitrate sources of nitrogen and molybdenum aid the control of manganese toxicity. Table 1 shows the effects of these two N sources when they are applied to an acid soil deficient in molybdenum and shows how they affect plant manganese concentration of burley plants 50 days after transplanting. Average plant manganese concentrations for the calcium nitrate source were about half those for urea. Adding molybdenum in the presence of urea cut manganese concentration in half. The lowered manganese concentrations in this study likely resulted from increased plant growth due to improved molybdenum availability in the presence of molybdenum fertilizer and calcium. Also the calcium from calcium nitrate may have had a small neutralizing effect on soil acids, thereby lowering manganese solubility. (Figure 4) shows that a plant molybdenum concentration of about 0.4 ppm appears to be associated with minimum levels of plant manganese.

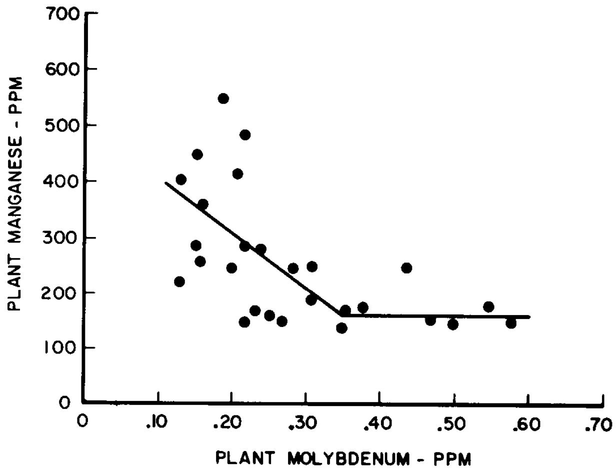

FIGURE 4.—Relationship of leaf manganese and molybdenum concentration in field grown burley tobacco approximately 50 days after transplanting.

Use of Sod Crops

Use of sod crops in rotation with tobacco is thought to lessen the incidence of manganese toxicity. Plowing under a good sod will enhance the development of granular soil structure that tobacco roots can readily penetrate. The continuous production of tobacco in one location often leads to deteriorated soil structure, less soil aeration, increased danger of manganese toxicity and increased risk for incidence of such diseases as black root rot and black shank. Ideally, a good plan is a crop rotation of 2 years tobacco, with a winter cover crop between crops of tobacco.

Table 1. Effect of molybdenum and source of nitrogen on concentration in field grown burley tobacco approximately 50 days after transplanting.

Nitrogen Fertilizer	Rate of sodium molybdate, lb/acre				
	0.0	**0.5**	**1.0**	**2.0**	**Average**
	---Concentration of manganese, ppm---				
Calcium nitrate	386	409	410	367	393
Urea	1089	943	775	572	845
Average	738	676	593	469	

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