

Fertilizer Injury to Lettuce

damage reproduced by application of toxic concentrations of inorganic commercial fertilizer materials or animal manure

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Greenhouse and field studies of a disease of lettuce that has caused considerable damage to commercial plantings in California revealed the relative toxicity to lettuce of several fertilizers.

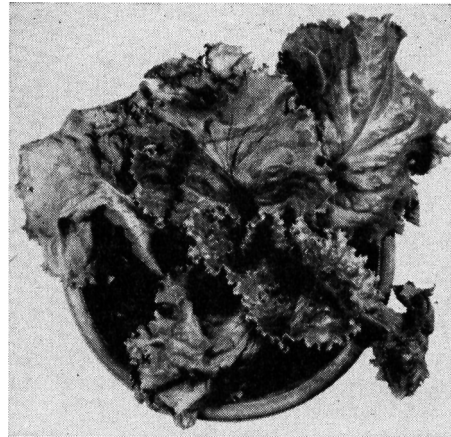
Fertilizers containing ammonium hydroxide and free ammonia were most toxic but certain other materials containing nitrites, nitric acid, or phosphoric acid were also toxic. Materials composed of neutral salts such as ammonium sulfate, ammonium nitrate, or calcium nitrate were relatively innocuous.

The occurrence of the disease appeared to be correlated with cold, water-logged soil conditions or with moderate to heavy applications of fertilizers—or both—but all of the factors that influence development of the disease were not determined.

Characteristic above-ground symptoms of the disease include wilting, which may be temporary and confined to the outer frame leaves or—in more severe cases—the plant may die. The leaves of affected plants are usually a lusterless dark or gray-green color. The outer frame leaves sometimes develop yellowed V-shaped sectors that later may become necrotic.

The above-ground symptoms are always associated with damage of the root

system. Small rootlets, larger lateral roots, and sometimes the tap root may be killed. In most cases the larger roots are not killed completely but exhibit various degrees of yellowing or browning, rifting, and corking. These may oc-



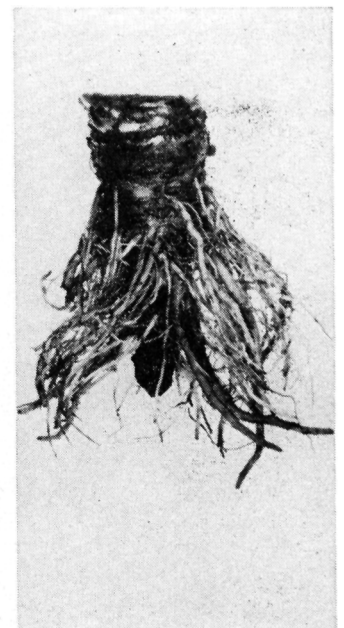
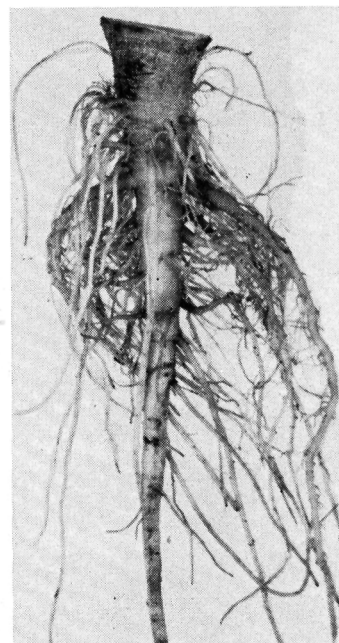
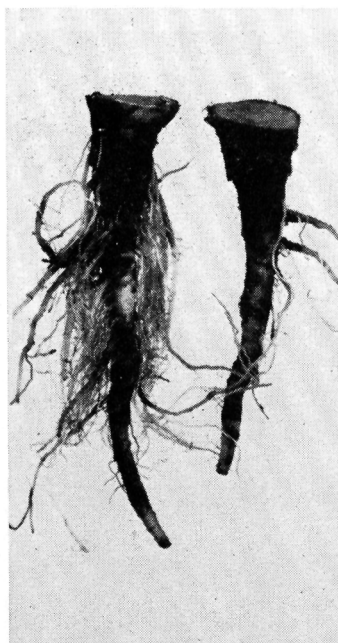
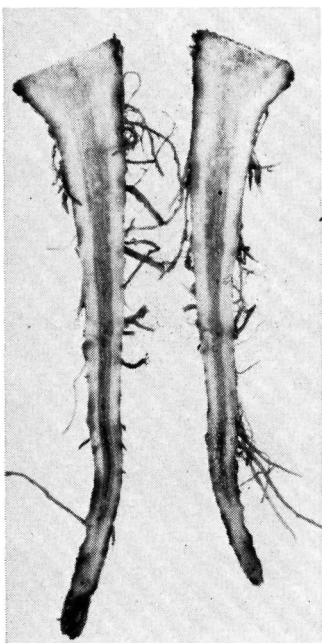
cur in isolated portions of the root or may involve practically the whole root system. Often associated with the external damage of the roots is a yellow, red, or brown discoloration of the central xylem core of the root. In cases of severe damage the xylem tissues may collapse, resulting in a cavity that may extend into the crown.

Injury of lettuce caused by toxic concentrations of fertilizer. Above—Wilting of outer frame leaves induced by the application of chicken manure. Below: Left—Discoloration of central xylem core of root induced by application of concentrated ammoniated ammonium nitrate solution. Center—External browning and corking of root surface induced by chicken manure applied very close to roots (2 roots on left). On the right is a normal root (untreated) from the same experiment. Right—Field specimen showing injury of lateral roots and the tap root.

Isolations from injured lettuce roots collected from several locations in the Salinas Valley have given inconsistent results. In most cases, no organisms were isolated from roots showing only slight damage. In some cases, dilution-plate cultures made from severely injured roots yielded several bacterial organisms. Three of these unidentified organisms that have been isolated most frequently were used for inoculations—by means of needle punctures—of roots of healthy lettuce plants growing in steam-sterilized soil in the greenhouse, but no root damage resulted. The inconsistent results from isolations and the negative results from inoculations indicated that the bacterial organisms that were occasionally present in damaged lettuce roots were secondary invaders following injury from some other cause.

Greenhouse experiments were made

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CLOVER

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application, but the composition continued to increase with added phosphorus. This continued increase represents luxury uptake. If the point where yield no longer increases is taken as the critical level, all values below that point are clearly deficient and those above that point represent adequate supply. On this basis 0.19% total phosphorus in the entire clover tops at bloom stage may be taken as the critical value. Plants with composition at or above this level would not be expected to respond to fertilization. Values below this point would indicate need of applying phosphate fertilizer before the next growing season.

Clover leaves were also taken for analysis and showed critical values of 0.177% total phosphorus and 0.098% phosphorus soluble in 2% acetic acid.

The stage of growth at which plants are analyzed is important because phosphorus content declines with advancing maturity. Young succulent plants taken prior to bloom would be expected to show a critical level somewhat higher than those reported.

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with several different nitrogenous fertilizer materials and methods of application to determine the relative toxicity of the compounds to lettuce roots. The lettuce variety Great Lakes was used in all tests. Four materials, ammonium sulphate, calcium nitrate, liquid ammoniated ammonium nitrate—containing 28% ammoniacal and 12% nitrate nitrogen—and urea were applied as dilute solutions—10 milligrams per milliliter—to one-month-old plants growing in 6" pots of steam-sterilized Yolo loam soil.

Each material was applied to three groups of five pots each at rates of 80, 160, and 320 pounds of nitrogen per acre. The requisite amounts of the respective solutions were poured on the surface of the soil. One month later the plants were removed from the pots, and the main root was sliced lengthwise and examined for damage. No apparent injury resulted from any of these treatments.

In another greenhouse trial, the same nitrogenous fertilizer materials were applied at the rates of 50 and 100 pounds per acre in the dry or undiluted form to the roots in the bottom of the pots.

This was done by upending the pots, dumping out the mass of soil and plant roots, applying the fertilizer to the exposed plant roots, and returning the soil and plants to the pots. The plants were examined for root injury six days later. All treatments showed severe injury and death of rootlets that had been in direct contact with the fertilizer materials. The ammoniated ammonium nitrate solution also caused pronounced discoloration and injury of the xylem core of the main root at rates of both 50 and 100 pounds per acre.

The experiment was repeated with the same four materials and, in addition, sodium nitrite and concentrated phosphoric acid. Dried chicken manure that had been ground into a powder also was applied in a similar manner, but at higher rates of 2, 4, 8, and 16 tons per acre. Examination of roots to determine the degree of internal damage was made 12 days after the materials were applied.

All materials caused some damage when applied directly to exposed roots. However, ammoniated ammonium nitrate and sodium nitrite were considerably more toxic than were urea, ammonium sulfate, or calcium nitrate. Phosphoric acid induced a similar-appearing breakdown of the internal root tissues and, in addition, caused a necrotic flecking of the older leaves. Chicken manure induced damage that was similar to that induced by the more toxic fertilizer materials.

Eleven separate field trials were conducted near Salinas to study the relative toxicity of five commercial nitrogenous fertilizer materials commonly used on lettuce in that area. The soils varied in texture from sandy loam to clay. The relative alkalinity-acidity—pH—ranged from an acidity of 6.2 to an alkalinity of 8.0 but only two of them were below neutral pH 7.0.

Plots were located in fields where random sampling of plants indicated that little or no injury had resulted from previous fertilizer applications. The materials were applied at several different rates—expressed as pounds of nitrogen per acre—to plants about one-half grown in a way that simulated a commercial side-dress application.

Observations for internal root injury were made at seven- to 43-day intervals after application. Although the amount and severity of damage resulting from the application of different materials varied from trial to trial, the relative toxicity of the materials was fairly constant.

Ammoniated ammonium nitrate and aqua ammonia—both contain free ammonia—were much more damaging than the other materials. Ammonium sulfate and calcium nitrate were relatively nontoxic, but both caused some typical root

damage at the higher rates, especially when 43 days had elapsed since application. The increase in amount of damage resulting from increased length of time after application, however, was most striking with urea. One explanation of this phenomenon might be that urea itself is relatively nontoxic, but that the toxicity is due to breakdown products from urea produced by microbial or chemical action in the soil.

To verify the indication that fertilizer materials that contain free ammonia, or other materials that are highly acidic, are more toxic than the neutral salts, two additional field tests were made. In each test five milliliters of different water dilutions of five fertilizer materials were injected with a hypodermic syringe directly into the root zone of 20 plants.

Relative Toxicity of Different Concentrations of Fertilizer Solution to Lettuce Roots^a

Material before dilution	Concentration as applied ^a (percentage N or P ₂ O ₅)	Number of plants of 20 classified according to extent of injury of central xylem core ^b			
		None	Slight	Moderate	Severe
Control no treatment		20	0	0	0
Aqua ammonia	20.0	0	0	1	19
(20% N)	10.0	0	0	1	19
	5.0	0	1	8	11
	2.5	3	5	9	3
Ammoniated ammonium	40.0	0	0	0	20
nitrate	20.0	0	0	3	17
(20% N)	10.0	0	2	0	18
	5.0	12	6	0	2
	2.5	15	3	2	0
Ammonium nitrate	20.0	18	2	0	0
(20% N)	10.0	18	2	0	0
	5.0	20	0	0	0
	2.5	20	0	0	0
Nitric acid	15.0	0	0	3	17
(15.5% N)	5.0	2	2	6	10
	2.5	6	14	0	0
Phosphoric acid	54.0	0	2	5	13
(54% P ₂ O ₅)	27.0	1	4	10	5
	10.8	8	6	6	0
	6.75	14	4	2	0

^a Five ml of each solution under test was applied with a hypodermic syringe at a depth of 7" directly into the root zones of 20 plants.

^b Examinations of the roots to determine extent of injury of the central xylem core were made five days after the materials were applied.

The results—which were an average of the two trials—show that aqua ammonia is slightly more toxic than ammoniated ammonium nitrate at the higher dilutions. Ammonium nitrate solution, which contains no free ammonia but contains as much nitrogen as the aqua ammonia formulation—20%—caused very little damage even when applied in the concentrated form. This is further evidence that the toxicity of aqua ammonia and of the 40% nitrogen formulation is due largely to free ammonia.

Tests of nitric and phosphoric acid indicate that both materials are toxic. However, they lost more of the toxicity

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at lower dilutions than did aqua ammonia.

As a further test to determine whether or not the toxicity of aqua ammonia is due to free ammonia, 100 milliliter portions of aqua ammonia containing 5% nitrogen were treated with different amounts of concentrated nitric acid and compared with untreated aqua ammonia of the same concentration by injecting five milliliters of each formulation into the root zone of 20 plants as in the earlier test. The data from this experiment show that if enough nitric acid was added to partially or completely neutralize the free

ammonia, the toxicity was greatly reduced. Similar results were obtained by the addition of phosphoric acid, and it is likely that the addition of any acid that would result in the formation of a highly ionized ammonium salt would give similar results.

The relative toxicities of monosodium phosphate, sodium chloride, sodium sulfate, sodium nitrate, sodium nitrite, and magnesium sulfate were compared by injecting five milliliters of a saturated solution of each salt into the soil of the root zones of two 20-plant groups. The only material that caused any discoloration of the central xylem core of the root was sodium nitrite.

Although the results strongly indicate that free ammonia is the toxic component of aqua ammonia, there was a possibility that high pH—itsself—might be the actual cause of root injury. To test this possibility, 2.0, 1.0, 0.1, and 0.01 normal sodium hydroxide solutions were prepared and five milliliters of each in-

jected into the soil of the root zones of four 20-plant groups as described previously. Although injection of these solutions resulted in injury and death of the roots that were directly contacted, there was no evident internal root damage or discoloration. Apparently, sodium hydroxide was not absorbed and translocated as were the materials that caused the internal root damage.

The extent of damage resulting from ammonia or nitrite derived from decomposing nitrogenous organic matter probably is influenced to a large extent by soil environmental conditions, especially temperature and aeration. The results of these studies and reports from other research workers tend to explain why the disease of lettuce investigated is more likely to be found in cold, waterlogged soils.

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