surfaces but it was difficult to thoroughly cover the lower surfaces. Nevertheless, the disease was held in check, only appearing late at one end of a single house. The chief difficulty experienced by the growers was that the fruit was heavily covered with the dust and each tomato had to be wiped off before marketing.

Geo. Wade used a different type of duster that did not deliver the dust in sufficient quantities, nor could the dust be directed against the lower surfaces of the leaves as efficiently. In this case the disease was not held in check to any appreciable extent.

Joe Shane did not start his applications until the plants had developed five or six clusters of fruit. The leaves were heavily spotted with the disease at the time. However, by the use of the American Beauty duster, he managed to prevent the destruction of the upper leaves and ripen his crop properly.

This evidence indicates that neither copper-lime dust nor soda-bordeaux will absolutely control leaf mold but the use of either of these materials is economical. They retard the disease sufficiently to permit the proper ripening of the tomatoes. It is also true that both the dust and the spray must be applied thoroughly and with the proper apparatus. The duster must deliver a sufficient quantity of dust to completely fill the house. The spray must be applied with at least 200 pounds pressure. In either case care must be exercised to direct the spray or dust against the lower surfaces of the leaves.

EXCESS SOLUBLE SALTS AS THE CAUSE OF VEGETABLE DISEASES IN GREENHOUSES.

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In many greenhouses of Indiana, lettuce, grown in ground beds, is often affected in a peculiar manner. The growth is stunted and though the plants remain in the soil for ten weeks or more they never attain more than one-third to one-half the normal size. Ordinarily they do not die but simply stand still, though in a few instances lettuce plants have died. Under similar conditions, tomato and cucumber plants are also affected in the same way.

Lettuce plants have been examined in scores of cases. The leaves are small, usually dark green and very tough. The roots are brown, the tips usually being killed, and their development sparse (fig. 1). Nematodes are not associated with this trouble and as a matter of fact nematodes do not cause any serious injury to lettuce though they may kill tomatoes and cucumbers.

The roots, the stems and leaves of these diseased plants have been examined repeatedly and thoroughly, but no fungus or bacterial pathogen has been found associated with them.

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Fig. 1—Various types of lettuce plants developed in soil areas containing excess soluble salts. The plant in the center is more typical of this condition.

Another peculiarity of this disease is that it usually appears in spots in the bed (figs. 2 and 3). These spots are irregular in size and shape, and are always surrounded by perfectly normal plants. Indeed, it is not uncommon to find groups of normal plants growing in the midst of the affected area.

Fig. 2—A spot of poor lettuce in the Wood greenhouse at Madison, Indiana. This area showed the higher concentrations of soluble salts in the soil. Another case of poor lettuce on too rich soil.

So far as has been determined, there is but one other trouble that can be confused with this one in question. In certain greenhouses there are tiny white millipedes, known as Scutigerella (Scolopendrella), that eat the tips of the young feeding roots. When such plants are removed from the soil, the tap root will be found to be almost completely stripped of rootlets. In addition, the tap root is scored with numerous tiny brown channels where the millipedes have eaten the tissue. Perhaps the best means of distinguishing this trouble is to examine the soil about the infested plants for the pest. There is almost invariably one or more about each plant.

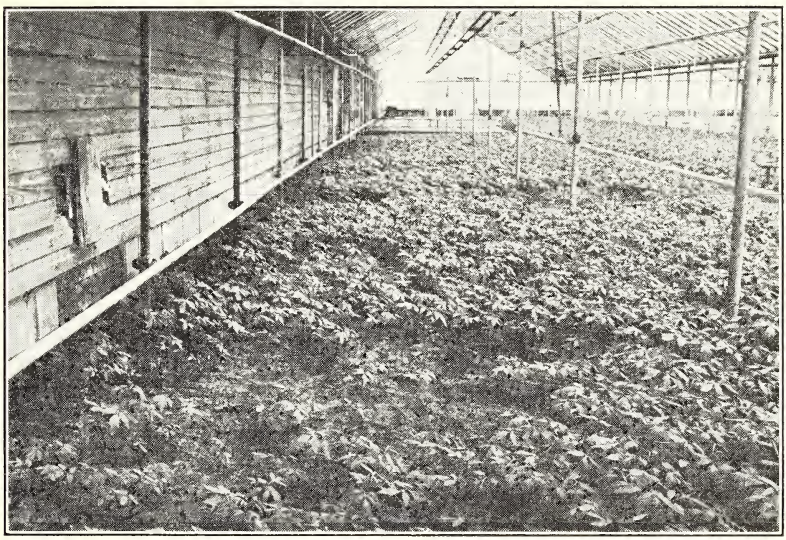

Fig. 3—Young tomato plants stunted and destroyed by excess soluble salts in a ground bed.

When a thorough examination of the trouble demonstrated that it was not caused by a pathogen, we came to the conclusion that the trouble must be in the soil.[1] Accordingly, composite samples were taken in this way: The surface two or three inches of soil was removed in three or more places in the area of poor plants and similar number where the plants were normal. Immediately after this other samples were taken six inches or more beneath the surface at the same points where the top samples were taken. The top soil samples were mixed together and about a half pint removed for the laboratory tests. The same method was used to secure the composite sample of bottom soil, as it was termed. We have found that the time of previous watering is important. Wherever possible, we take the samples when the soil has

[1] Brown, H. D., Baldwin, I. L., Conner, S. D. Greenhouse Soil Sterilization. Purdue Agr. Exp. Station Bul. 266:23-27, 1922.

not been watered for a few days. We find that watering will wash out the soluble salts so that the result may not indicate the true state of affairs.

It is significant that no cases of such injury have been found in sandy soil nor in places where an efficient underdrainage was provided. One method of underdrainage that has been found quite effective is to use an eighteen-inch layer of cinders covered by a foot or 18 inches of soil. These conditions are significant, as will be seen later, since they verify our opinion concerning excess soluble salts and the control of this trouble.

The method used to determine soluble salts is as follows: Use 100 gr. dry soil; add 100 cc. distilled water; shake at intervals for an hour or more, then shake thoroughly and quickly pour into a filter which will hold the entire amount. The first liquid that comes through is thrown away or returned to the filter. After a short time the solution will come through perfectly clear. A measured quantity of the solution is evaporated to dryness on a steam or water bath and weighed. This dry material is calculated to percentage of the dry soil.

Some samples of greenhouse soil have contained over one per cent of soluble salts. As a result of testing a large number of greenhouse soils which have given trouble, it has been concluded that when such soils show over .25 per cent soluble salts by the above procedure, there is danger of damage to young plants. It is recognized that there may be some colloidal material in the residue determined in this way, but such a per cent is nevertheless dangerous.

Garden and field soils in humid climates seldom show over .05 per cent soluble salts and never give trouble for this reason except in unusual instances. In arid regions excess soluble salts occur in soils and are known as "alkali." If we stop to think, ground beds in greenhouses are irrigated soils in regions of no rain. If there is good underdrainage in greenhouses and they are sprinkled thoroughly, the excess salts will be washed out. In like manner, in irrigated regions of low rainfall the remedy for alkali is underdrainage and heavy irrigation to wash out the alkali. The best time to leach greenhouse soils is just after the last crop has been taken off in the spring or summer. If greenhouse beds do not have a good sand, gravel or cinder sub-surface, it will be profitable to thoroughly tile each bed with a good outlet. Tile such as are used for soil sterilization will be sufficient if provided with an outlet.

Soluble salts accumulate from the residues of manure, fertilizer and the water used, as well as solution from the soil itself. They accumulate near the surface because the moisture is evaporating from the surface of the soil and a heavy watering will dissolve the salts as deeply as the soil is wet. The capillary rise of the water brings this soluble material to the surface where it is left after the moisture evaporates and the top soil dries out.

TABLE I. Tests for excess salts in greenhouse soils where lettuce was doing poorly and no pathogens were associated with the trouble.

Name	Location	Per Cent Soluble Salts under good lettuce		Per Cent Soluble Salts under poor lettuce	
		Top 3″	6″ below surface	Top 3″	6″ below surface
Markert and Zeck	Logansport	.22%	.25%	.33%	.70%
R. E. Wood	Madison	.25%	.....	.33%	.....
Chris Peaper	Indianapolis	.13%	.....	.97%	.....
Kops Bros	South Bend	.....	.....	.33%	.52%
Peaper Bros	Indianapolis	.10%	.....	.30%	.....
Purdue Greenhouses	Lafayette	.15%	.....	.30%	.....
Lindley	Springfield, Ill.	.25%	.29%	.26%	.36%
B. F. Schilling	Lafayette	.14%	.....	.35%	.....
Moore	Marion	.....	.....	.40%	.26%

It will be seen from Table I that the soil producing the poor lettuce always has considerably more soluble salts. Of course in these cases of lettuce development, growth of the plants is merely relative. It is probable that in certain cases the lettuce on the good soil might have done better, but in each case there was a decided difference in the growth of the good and poor plants. Take the case of Peaper at Indianapolis, where the poor soil had .97 per cent soluble salts as compared with .13 per cent in the good soil. The poor lettuce was completely stunted and would make no growth whereas the good lettuce was large and normally developed. It is significant, however, that the poor plants always appear in soils having a considerably higher percentage of soluble salts. When greenhouse soils were tested that did not show a higher percentage of soluble salts under the poor lettuce, other causes were always found.

It is probable that this trouble is not due to actual toxicity of the soluble salts, which are largely nitrates, chlorides, and sulphates. However, the nature of the growth of the lettuce plants does not seem to indicate this. The leaves remain green and apparently healthy but the growth is stunted. It appears as if the excessive concentration of soluble salts has increased the osmotic tension in the soil solution till it closely approximates that within the cells of the plant, particularly the roots. Under such condition the plant will have great difficulty in obtaining sufficient water for its growth.

This conception is further borne out by conditions obtaining when the surface layers accumulate very high concentrations of salts. At such times the stems of the plants dry out in a narrow area at the surface of the soil. This has been seen also in onion seedlings on muck soils during dry weather. Under such conditions, the solution actually becomes concentrated enough to draw the water from the tissues, resulting in an effect similar to the damping off disease.

It is well known by practical greenhouse men that old greenhouse soils left out in the open for several years will be greatly improved. The heavy rainfall of this climate would wash out the excess soluble salts. This would be the most probable explanation for such improvement.

Emmett Wood, of Madison, Indiana, has found that steaming his soil will dissipate the excess salts owing to the large amounts of water from the condensed steam. At Fort Wayne a gardener had trouble with excess salts and was able to cure the difficulty by heavy applications of water. So often the sub-soil is a heavy clay and the gardeners know from experience that copious watering would be disastrous, hence the recommendation to use tile drains to permit leaching without water-logging the soil.