TO: COUNTY AGENTS

TOPICS COVERED IN THIS ISSUE ARE:

I. FOLIAR NUTRITION OF VEGETABLES - Does it Pay???

II. THE USE OF LIQUID FERTILIZERS ON VEGETABLE CROPS - An Excellent Reference Written by W. C. Kelly of Cornell University and Reproduced here by Permission.


I - FOLIAR NUTRITION OF VEGETABLES

The practice of supplying the minor elements like zinc, copper, manganese, iron, and boron by spraying or dusting them onto the foliage of plants has been recommended and used with success over a period of time. More recently, much has been written and said about supplying plants with nitrogen, phosphorus, and potassium by applications to the leaves of a plant. The practice has been investigated by research workers throughout the United States. Extensive studies have also been conducted at several research stations in Florida. RESULTS HAVE SHOWN RATHER CONCLUSIVELY THAT FOLIAR APPLICATIONS TO VEGETABLE CROPS OF ONE OR MORE OF THE MAJOR ELEMENTS ARE NO BETTER THAN EQUAL AMOUNTS OF THE SAME MATERIALS APPLIED TO THE SOIL.

It must be remembered that the major elements, unlike the minors, are required in relatively large amounts and many applications are generally needed to supply the needs of the plant. Even under conditions of root damage or foliage injury from frost or wind, there are no conclusive experimental results to show that spray applications of the major elements would be any better than equal applications to the soil.

Here are some direct quotes from Florida Experiment Station Annual Reports made by workers at several locations in the state on a number of vegetables. None suggest use of foliar feeding as a primary means of supplying the major nutrients to plants:

Geraldson - Bradenton, 1951 - "Extensive trials on the Station Farm in Bradenton and on the farm of "a grower" at Ruskin indicate that crops with high fertility requirements, such as the tomato, showed little or no response to foliar feeding as far as the major elements were concerned."
The traditional form of fertilizer for vegetable crops is solid, dry materials. In recent years a number of fertilizers have appeared on the market in a liquid form or as dry material to be applied as a solution. There are several types of liquid fertilizers available and each will be discussed. The four major types of liquid fertilizers are (1) liquid nitrogen materials; (2) soluble fertilizer compounds for starter solutions to be applied to transplants; (3) soluble fertilizer materials to be applied as foliage sprays; and (4) liquid formulations of complete fertilizers to be used in the same way as conventional dry mixed fertilizers.

**Liquid Nitrogen Materials**

**Types of materials.** Each nitrogen source, liquid or dry, has its own advantages and disadvantages. No one material will be the best to use all the time. There is a place in vegetable farming for all of the various types of nitrogen materials, but probably not all in a given district or on the same farm. The liquid nitrogen materials available in New York are ammoniating solutions used in mixing commercial fertilizers. The two most commonly used are 2A and 32. Solution 2A is a mixture of ammonium nitrate and ammonium in water and contains 40% nitrogen. Solution 32 is a mixture of ammonium nitrate and urea dissolved in water and contains 32% nitrogen. In the West a solution of pure ammonia containing 20% nitrogen is used to some extent. Anhydrous ammonia is usually classed as a liquid nitrogen material. This is ammonia gas liquefied under high pressures and applied deep in the soil.

**Nitrogen solutions.** The nitrogen solutions such as 2A and 32 are easy and cheap to apply since they do not require high pressure equipment. They are among the cheapest sources of nitrogen available today. Solution 32 can be applied to the surface of the soil, while Solution 2A must be covered with 1 to 2 inches of soil to prevent the escape of the ammonia gas.

**Anhydrous ammonia.** Anhydrous ammonia requires high pressure equipment since the gas is liquefied under pressures of about 225 pounds per square inch. It must be applied 6 to 9 inches deep in the soil with rather expensive metering and dispensing equipment. If the soil does not seal properly over the region of application, ammonia gas will escape and crop injury may result. Many New York soils may not seal properly due to stones. Typical stony New York soils also require extra strong machinery to apply the anhydrous ammonia. In the South and Midwest where large quantities of anhydrous ammonia are used, it is the cheapest source of nitrogen available. This is usually a custom operation in New York. To handle tank car lots of ammonia a grower must have expensive storage tanks. To make it economical he also must have a large acreage of crops. Poor results have been obtained with anhydrous ammonia because the grower neglected to apply the material early enough to allow for conversion of the ammonia to nitrate.
Foliage Fertilizer Sprays

Major nutrients. Foliage fertilizer sprays are actually dilute starter solutions applied to the leaves of the plants. The same materials that are used in formulating starter solutions are used in these foliage fertilizers. The foliage fertilizers usually have a lower total plant nutrient content than standard starter solution mixes and a higher price. In many cases the starter solution fertilizers are bought from a large fertilizer company and diluted out with other salts so that the analysis is changed and sold at a big markup. These materials are highly advertised and receive a vigorous sales campaign. It is easy to see how such campaigns can be conducted since the basic materials would cost less than $200 per ton while the finished packaged product may be sold for as high as $2000 per ton.

Foliage fertilizers are likely to contain a "magic ingredient" of some type, such as minor elements, hormones or vitamins. Small traces of minor elements in these foliage fertilizers have never been shown to be of any benefit when sprayed on plants in New York. No one has ever shown an increased yield of vegetables due to spraying vitamins or hormones on the leaves at the concentrations used in foliage fertilizers.

Only small amounts of these soluble fertilizers can be applied to the foliage since foliage is injured by excessive concentrations. The amount that can be used on most vegetables supply only 1 to 2 pounds of the major fertilizer nutrients per acre. Some cases where large amounts of spray solutions are used, the excess solution runs off and the so-called "foliage application" becomes a soil application. The sale of these materials has been greatly stimulated by work that shows absorption of certain plant nutrients by the foliage. This work has involved radioactive elements. Dramatic pictures are shown which prove without question that the nutrients were absorbed by the foliage and translocated to other plant parts. Such photographs can be made even though only minute amounts of material is presented by increasing exposure time of the film. Actually the leaf works both ways. While nutrients may be absorbed by the leaf, nutrients may also be leached out of the leaf during periods of heavy rainfall.

The fact that nutrients are translocated into the roots is of no great importance. The root is also a two-way system and nutrients may move from the root into the soil. The amount of plant nutrients that are lost to the soil from the roots and the amount leached from the leaves by rainfall is small, but so is the amount of nutrients absorbed by the foliage. Recently workers in Michigan measured the amount of foliar applied phosphorous that was translocated to the roots. Only about 3% of the phosphorous in the roots came from the foliage spray. This represented less than 5% of the total phosphorous applied to the leaves in four applications. This is like feeding a pig one grain of corn at a time.

Much of the work on foliage sprays has involved urea. Urea is a good source of nitrogen for vegetables and is commonly used in starter solutions, in dry fertilizer mixes, and as a sidedressing material. Most vegetables tolerate only about 5 pounds of urea (about 2 lbs. actual nitrogen) per acre as a foliage spray. However, potatoes and carrots tolerate as high as 20 pounds per acre in 1 application. The amount of nitrogen that can be applied to the foliage is considerably less than
in a normal sidedressing of 30 pounds of nitrogen per acre.

Nitrogen deficient plants are pale green in color and a spray with urea results in a deeper green color within a few days. However, no one has ever shown an increase in yield of any crop with an application of 5 pounds of urea per acre to the leaves. Some work by Hester and Isaacs on carrots in New Jersey showed definite plant responses to several foliage applications of 20 pounds of urea per acre. The greatest response occurred when no nitrogen was applied in the fertilizer. The yields obtained with these foliage sprays were no better than with normal soil applications of nitrate.

In the field, nutrients applied to the leaves washes off with subsequent rains and becomes effective as a soil application, not as a foliage application. In field studies it is not possible to differentiate between the foliage effect and the soil effect when fertilizer is applied to the leaves. The urea absorbed by the leaves is taken up within an hour or two after the spray is applied. There is essentially little or no uptake after that period of time even though the urea remains on the leaves. In other words, moisture is needed for uptake of nutrients on the leaves just like the roots. The material that is not taken up immediately by the leaves is then subject to washing by rainfall and subsequent uptake by the roots.

The maximum uptake of plant nutrients from the soil occurs during the period of maximum growth which lasts usually about four to six weeks. About half of the nutrients absorbed by the plant are absorbed during this short period of time. Foliage sprays for the most part are too little and too late to supply this big demand for nutrients. Restrictions in growth that occur during this period of time can never be recovered even though fertilizer is added in large amounts later. If you consider the total amount of nutrients that the crop contains you can easily see that small amounts of nutrients applied to the foliage cannot have much effect on the growth of the plants. The nutrient content of the tops of four vegetable crops for one set of analyses are given below:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Nitrogen</th>
<th>Phosphoric Acid</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>10 ton</td>
<td>100</td>
<td>35</td>
<td>175</td>
</tr>
<tr>
<td>Cabbage</td>
<td>15 ton</td>
<td>100</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Dry beans</td>
<td>30 bushel</td>
<td>95</td>
<td>30</td>
<td>55</td>
</tr>
<tr>
<td>Celery</td>
<td>350 crates</td>
<td>80</td>
<td>65</td>
<td>235</td>
</tr>
</tbody>
</table>

Even if foliage applications of fertilizer were completely absorbed by the plant, how much of the total nutrient content could be furnished by such spraying? The amount that can be furnished by sprays is so small that a grower is not warranted in spending appreciable amount of money per acre to apply the material. Some argue
that as long as he has to spray the crop with insecticides and fungicides, why not
dump some of these materials in the tank, too? However, with the results that the
majority of Experiment Station workers have obtained, the yield responses from these
materials would not pay for the labor of dumping it into the tank if the material was
furnished free of charge.

Some careful experiments were conducted in Delaware to eliminate the effects of
foliage fertilizer washing down to the soil. Tomato plants were grown in sand cul­
tures that were protected so that none of the run-off could enter the root zone.
Repeated foliage sprays could not furnish enough plant nutrients for normal tomato
growth under these conditions. The foliage is not an efficient nutrient absorbing
surface.

One possible use of foliage spray applications is to obtain a better color of
the foliage of the crops shortly before harvest. If the foliage is a pale green
color due to lack of nitrogen, the color can be improved in a few days by a urea
spray. If the foliage is pale due to some other cause, the nitrogen or urea sprays
will not influence the color of the leaves.

Minor elements. In Florida and elsewhere, minor element sprays are used or
many crops as standard practices on certain soils. The materials used are standard
fertilizer materials applied at concentrations established by research in the area.
Appreciable amounts, usually 3 to 5 pounds of specific salts are applied to the
foliage of the vegetables. These sprays are necessary due to the nature of the
soil in those areas. Fortunately, in New York we do not have any of this type of
soil. Vegetable minor element needs can be satisfied by standard soil applications
in most cases. The only exception is the magnesium chlorosis of Utah strains of
celery on alkaline mucks. It cannot be economically corrected by soil application,
but responds well to spray applications of magnesium sulfate. There is some justifi­
cation for minor element foliage sprays in New York as an emergency when soil
applications were not made. In cases where this is necessary, the specific minor
element compound should be applied at rates high enough to do some good. The
traces of minor elements present in these foliage fertilizers will not be enough to
do the job.

Liquid Complete Fertilizers

Comparison of liquid and dry fertilizers. Most of the publicity on these
materials has come from the midwest where a few growers are using standard analysis
fertilizers applied as a liquid instead of dry materials. These are applied at the
same rates per acre as dry fertilizers. That is, 500 pounds of a 5-10-10 liquid
formulation is exactly comparable to 500 pounds of a 5-10-10 dry mix. The main
advantages attributed to this type of fertilizer are the convenience in handling
liquids and the ease of application with simple equipment. The liquid can be hauled
in tank trucks and handled with pumps and applied with easily calibrated inexpensive
equipment. Apparently a grower near the source of manufacture can obtain these
materials at a price competitive with dry fertilizers. However, in New York, most
of these materials are much more expensive than dry fertilizers. Actually the main
impetus in the use of liquid fertilizer is not due to poor results with dry fertil­
izer, but to poor machinery for distributing the dry fertilizer. Growers object to
frequent filling, the bridging and clogging, etc. that result with most types of
fertilizer distributors. The designs of machines to dispense liquids are simpler
and there are fewer things to go wrong with the machinery.
How do these liquid fertilizers differ from dry fertilizers? Why can't we just dump regular 5-10-10 in the tank and apply it to the soil? The nitrogen and potash in liquid fertilizers are usually exactly the same materials as in dry fertilizers. All sources of nitrogen used in fertilizers (except organics, such as tankage) are completely water soluble. Therefore, they can be applied either as a liquid or as a dry material. The potash materials used in dry fertilizer are all water soluble, both the chloride and sulfate. These same materials can be used in the liquid fertilizer. The only real difference in the liquid and dry fertilizers is the source of phosphorous.

Forms of phosphorous. Most phosphorous sources are insoluble. The term "available phosphorus" in a fertilizer includes water soluble phosphorous and citric acid soluble phosphorous. Both of these forms are considered to be available to plants when applied to the soil. In the liquid fertilizers only the water soluble phosphates are used. The most commonly used sources of soluble phosphorous are mono-ammonium phosphate, di-ammonium phosphate, mono-phosphate, and di-phosphate. Mono-calcium phosphate is also water soluble, but is not used in liquid fertilizers. Actually, the sources of phosphorous in these liquid fertilizers are exactly the same as those used in starter solutions and foliage sprays.

The most common source of phosphorous in dry fertilizer is 20% super-phosphate. This is generally considered to be an insoluble material, but this is not entirely true. Superphosphate is half gypsum which is insoluble. The available phosphate in superphosphate is about 90% water soluble mono-calcium phosphate. The rest of the available phosphate is the citric acid soluble di-calcium phosphate. Therefore, even 20% superphosphate furnishes large amounts of water soluble phosphate to vegetables when applied to the soil. A part of the nitrogen used in mixed fertilizers comes from the nitrogen solutions previously mentioned. These solutions are added to the superphosphate as a cheap source of nitrogen. This is called ammoniation and involves some rather complex chemical reactions. When a nitrogen solution is added to superphosphate, chemical reactions occur so that only about 50% of the available phosphorous in superphosphate is water soluble. This now represents mono-ammonium phosphate rather than mono-calcium phosphate. The other 50% is citrate soluble di-calcium phosphate. In regular dry fertilizers usually about half the total phosphorous is water soluble.

Some companies are producing extra high analysis fertilizer such as 10-20-20 in which the source of phosphorous is ammonium phosphate. These fertilizers with an ammonophos base could be completely dissolved in water to produce a liquid fertilizer. There are usually a few insoluble impurities in a regular fertilizer and a small residue might be left on the bottom of the tank. Since these materials differ only in phosphorous, let us consider some of these various types of phosphorous. Water soluble phosphorous applied to the soil in either liquid or dry fertilizer is rapidly taken up by vegetables providing roots are present in the zone of application.

Phosphorous availability. Phosphorous is rapidly fixed by the soil and tied up in relatively unavailable forms. The particular form in which it is tied up depends on the soil reaction. In very acid soils, aluminum and iron phosphates are formed and in alkaline soils, tri-calcium phosphate is formed. While water soluble phosphate may be rapidly taken up by the plant, it also may be rapidly fixed by the soil and rendered unavailable to the plant. The citrate soluble phosphate, di-calcium phosphate, is slightly soluble in water and slowly dissolves in the soil solution. This material supplies water soluble phosphorous over a somewhat longer period of time than the completely soluble materials. The plant therefore has a continuing source of phosphorous when some of these citrate soluble sources are used.
Some manufacturers make granulated superphosphate and granulated fertilizer. The principle behind this practice is that granulation slows down the rate of solution, so that the nutrients are available over a longer period of time. Granulation tends to prevent the immediate soil fixation of large quantities of soluble phosphate. Some recent work comparing granulated and powdered superphosphate in the laboratory has shown that the granulated superphosphate is superior. Immediately upon addition to the soil, more water soluble phosphate could be extracted from the soil where the powdered superphosphate had been added. After waiting two or three weeks, more water soluble phosphate was found in the soil where the granulated superphosphate had been added. The theory advanced was that the area immediately around each particle of granulated material was saturated in so far as the soil's capacity to tie up the phosphorous was concerned. Here was a zone where water soluble phosphate could exist without being fixed rapidly. Some of the companies manufacturing high analysis fertilizer with an ammophos base are pelleting or granulating the fertilizer to slow down the solubility of the ammophos and prevent rapid fixation. The amount and rate of fixation of phosphorous by the soil varies with the soil type and no one material will be superior on all soil types.

**Liquid fertilizers in dry soil.** Some claim that liquid fertilizers are already in solution and would be more available in a dry soil. If water is limiting vegetable growth only water will give increases in growth. The water used in liquid fertilizers is usually less than 100 gallons per acre. An average loam soil that is dry enough to need irrigation contains about 25,000 gallons of water per acre in the furrow slice. How then can 100 gallons of water be of any possible benefit to vegetable growth?

**Future of liquid fertilizers.** There is a place for all forms of fertilizer materials. As far as supplying plant nutrients are concerned there is no great advantage in either liquid or dry forms. The main thing to consider is the cost of the fertilizer on a plant nutrient basis and the ease of handling and application. While we have traditionally used dry fertilizers, there is no reason we should have to use them if we can obtain liquid mixes as cheap and handle them more efficiently. However, expensive storage facilities are needed for liquids and it is rather unlikely that liquid fertilizers will replace dry fertilizers to a very great extent. You must consider too that for the most part the water soluble sources of phosphorous are more expensive to manufacture than ordinary superphosphate. It will probably be some time before the two are strictly competitive over a very large part of the country. While liquid fertilizers are a novelty, this is no basis for paying excessive prices for plant nutrients that can be supplied much cheaper with conventional fertilizer materials.