

LIME-SULFUR FOR TOMATO PSYLLID CONTROL

BY GEORGE M. LIST



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BY GEORGE M. LIST

The spraying of tomatoes and potatoes with lime-sulfur for the control of the tomato psyllid (*Paratrioza cockerelli* Sulc.) is a comparatively new use for this old insecticide. In 1917 the writer¹ reported its effectiveness against this insect on tomatoes. Its use in that connection has been rather limited, but the results obtained during the past season in controlling the psyllid on potatoes and checking the development of psyllid yellows has created an interest and opened a field that will bring it into very general use.

Growers to use this material the most effectively should have some understanding as to how it controls psyllids, nature of the material, how best to handle it and the effects of the material on crops. The research on the psyllid project has brought out certain information that is important. While the work is by no means complete, it seems that some of the results should be presented. The information presented on the making and testing of lime-sulfur has been gained largely from its very general use as an orchard insecticide.

THE NATURE OF LIME-SULFUR AND HOW IT ACTS ON THE PSYLLID

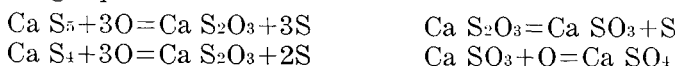
Lime-sulfur as used in spraying is made by cooking sulfur and lime together in the presence of water. These combine to form a series of salts that are the effective ingredients. The following are the salts formed:

Ca S ₅ —calcium pentasulfide	Ca ₂ O ₃ —calcium thiosulfate
Ca S ₄ —calcium tetrasulfide	Ca SO ₃ —calcium sulfite

The first three are soluble, while the last is comparatively insoluble and, with uncombined sulfur and other insoluble materials, settles out to form the "sludge" in home-made lime-sulfurs. In the commercial liquid lime-sulfurs on the market, all sludge is filtered out, leaving the first three salts in solution. This filtered material is of a cherry red or amber color, somewhat heavier than water and quite caustic to the skin. This caustic effect is an indication of the insecticidal action of the material. The immediate insecticidal effect is supposed to be due largely to the ability of the compounds present to take up large amounts of oxygen, and the caustic effect seems to be due to this strong reducing power (power to absorb oxygen) rather than to

¹Geo. M. List—A test of lime-sulfur and nicotine sulfate for the control of the tomato psyllid and effect of these materials upon plant growth.—Ninth Annual Report of the State Entomologist of Colo., for 1917. Circular No. 26, pp. 40-41.

the alkalinity of the solution. Tarter² states that "The amount of oxygen consumed depends upon reactions as represented in the following equations:



The above equations, besides showing the amount of oxygen consumed, indicate the power of the compounds to liberate free sulfur, the majority of it coming from the pentasulfide and the tetrasulfide. Free sulfur, in the finely divided form that it takes when set free, has a definite insecticidal effect upon certain insects and many of the mites. The calcium thiosulfate and calcium sulfite, found in lime-sulfur when tested alone, have shown practically no insecticidal value. It would then seem, from the chemistry of the material, that the insecticidal value that we are interested in for the control of psyllids, comes almost, if not entirely, from the ability of the pentasulfide and tetrasulfide to take up oxygen and to liberate free sulfur.

The writer in some early work¹ showed that all psyllids on tomatoes that were hit with certain strengths of the lime-sulfur were killed. This has been borne out by the results of a large number of tests made in various parts of the state during the past season. This effect is supposedly due to the chemical actions just described. Some field results were more pronounced, however, than could be attributed to the immediate effect of the spray as a contact against the insects present. Laboratory tests have indicated that there is a definite basis for such a conclusion and that there is apparently a repelling effect on the egg-laying adults and a very definite residual effect upon the scale-like nymphs that attempt to locate upon sprayed surfaces. The following results will be of interest:

REPELLENT EFFECT.—On Dec. 22 a potted potato plant with four stems of about equal size had two stems sprayed with the commercial liquid lime-sulfur used at the rate of 1 part to 40 parts of water, and the other two stems protected from the spray. When the sprayed portion was dry a cage was placed over the entire plant and approximately 150 adult psyllids added. Four days later over 400 eggs were counted on the unsprayed leaves and only 20 on the sprayed. The cage was removed at the end of 7 days. At the end of 13 days and again at the end of 18 days, small psyllids were too numerous to count accurately on the unsprayed portion and none was found on the sprayed. It was estimated that there were 400 second-instar nymphs on the unsprayed. This was repeated a number of times with potato plants, and later with sprayed and unsprayed tomato plants, with about the same results.

²Tarter, H. V.—Chemical investigations of the lime-sulphur spray. Research Bulletin No. 3, Oregon Agr. Exp. Sta.

These show a definite residual effect from the lime-sulfur extending over a considerable period of time.

In most cases third and fourth-instar nymphs were transferred. These should be more resistant to a spray residue on the foliage than the younger ones. In the one test where the transfer was made 16 days after treatment and in the second check, first and second-instar nymphs were used. No entirely satisfactory explanation for this much desired effect of the spray can be given. It may come from some of the sulfide sulfur compounds that have not completely broken down, or from the very fine particles of sulfur set free. The evidence indicates that this "delayed" toxicity comes from the sublimation or oxidization of the very finely divided sulfur precipitated out of the soluble sulfide sulfurs in the liquid spray. This, if the work has been thoro, is deposited in an almost continuous film and is in much finer particles than any other form of free sulfur. The flat, scale-like form of the psyllid nymphs brings their bodies in close contact with the sprayed surface. Whatever the action may be, it is rather slow in its effect. The insects first become sluggish, then gradually lose their characteristic light-green color, becoming yellowish and later brownish in color. Some of the larger ones remain alive as much as 5 or 10 days after a change in color is noted. In a few cases individuals lived until the adults emerged, but their wings failed to unfold and death occurred before feeding took place.

A more extensive test of this residual effect was obtained from the spraying work done on tomatoes in the commercial greenhouse mentioned above. On Dec. 27, when the first three rows were sprayed, eggs were very numerous, often several hundred could be counted on a single leaf. The lime-sulfur prevented many of these from hatching, but very few of the small nymphs hatching were able to survive on the sprayed foliage. The plants were removed from the house Jan. 8 and could not be watched longer, but at that time dead first-instar nymphs were numerous and scarcely a live one could be detected.

These results corroborate many observations made in the field experimental plots during the summer. They have such an important bearing upon field work, especially the number of applications and their timing, that they are very significant. The apparent repelling effect of the lime-sulfur on the egg-laying adults and this residual effect upon nymphs that attempt to locate on sprayed surfaces, make it possible to use the spray as a "preventive," which is of the utmost importance in the cases of an insect that carries a toxin or causes a diseased condition in the plant. (See page 14.)

THE EFFECT OF LIME-SULFUR ON THE TOMATO AND POTATO PLANTS

Any insecticide for satisfactory plant spraying must not only be effective against the insect, but safe to use upon the plants involved. Lime-sulfur, under certain conditions, has been known to be injurious to vegetation, but on the whole is considered a satisfactory spray. Lime-sulphur, followed even in 20 or 30 days with an oil spray, is almost certain to cause "sulfur shock." The application of sulfur sprays while plants are suffering from drouth, or following a drying hot wind, or during extremely hot weather, is much more likely to cause injury. The writer, in 1917, called attention to an apparent checking of growth of tomatoes sprayed with lime-sulfur. It was stated, in regard to the strength of 1 part of the liquid lime-sulfur to 33 parts of water, that "The injury of the solution to the plant was rather too great, however, to recommend its use. The leaves did not show burning, but became very dark green in color and curled at the edges. Growth was stopped for about 10 days and the plants had a very stunted appearance. At the end of this time new growth started and developed very rapidly, the plants seeming to be stimulated. . . . The strengths of 1 to 40 and 45 seemed to have been almost, if not quite, as effective as 1 to 33, without so much apparent injury to the plants, altho the growth was checked for a short time. The material then seemed to act as a stimulant, as the plants grew rapidly, even more rapidly than checks, some of which had very few, if any, psyllids on them."

This same effect has been noted especially on tomatoes under greenhouse conditions in the more recent work. In some cases with the more concentrated strengths there has been some definite burning.

Injury to potatoes has not been so apparent as to tomatoes, but it is a factor that must be kept in mind. The margin of safety between the strength that will kill the psyllids and the strength that will not injure the plants is small. The material, therefore, should be used carefully. The strength of the stock material should be known and dilutions accurately made. The attitude that is so often met, that if a "little is good, more is better," might bring results that would be as serious as no control of the insect.

The psyllid problem is one that over the last several years has varied a great deal in intensity. Studies are under way that we hope will enable us to predict, before injury actually results, the degree of infestation to be expected. Until this can be done and we know more of the effect of the material on plants under the different conditions, we would caution against spraying before a definite need is apparent.

LIME-SULFUR PREPARATIONS ON THE MARKET

CONCENTRATED LIQUID LIME-SULFUR.—The guarantee of commercial concentrates is generally about 33 degrees Baume. At this test they weigh 10.78 pounds to the gallon, as compared with 8.33 pounds for water. They are cherry red in color. Their efficiency is most accurately measured by the amount of polysulfide sulfur in solution. Some manufacturers give a guarantee as to this. Of 16 samples recently tested, the Baume reading varied from 29.45 degrees to 34.5 degrees, with an average of 33.03. The sulfide sulfur content (on volume) varied from 28.5 to 34 percent, with an average of 31.8. The proper sulfide sulfur content for the dilute spray is thought to be about 0.75 percent. One part of the above made up of 40 parts of spray, would carry 0.79 percent sulfide sulfur, a little higher than necessary. It should not be used stronger and for non-irrigated potatoes 1 part to 45 parts of water, which would give a sulfide sulfur content of 0.706 percent, would be advisable. This, or even a slightly greater dilution, should be used on tomatoes. Most of the field tests to date have been with these liquid concentrates. On account of the uniformly good results obtained, and the standardization that has been followed, these are generally to be preferred over the lime-sulfur preparations discussed later.

DRY LIME-SULFURS.—There are a number of dry powered materials on the market as substitutes for the liquid lime-sulfur. These are for the most part liquid lime-sulfurs with most of the water removed. It is thought by most workers that the drying process breaks down some of the polysulfide compounds to less effective forms. They are, however, usually evaluated on the basis of their sulfide sulfur content, the same as the liquids. It takes on the average about 5 pounds to equal 1 gallon of the standard concentrated liquid. On this basis of comparison, they are usually more expensive than the liquid unless a great saving can be made on the freight. They are more convenient to ship, store and handle, but never have come into as general use as the liquid. If they are to be used the recommended dilution for the psyllid work is 1 pound to 8 gallons of water, for potatoes, and 1 to 9 or 10 for tomatoes.

HOME-MADE LIME-SULFUR

Lime-sulfur solutions can be made at home by cooking together fresh stone lime and sulfur. This is a practice that has been followed successfully for certain orchard spraying. Since the strength cannot be quite as accurately determined, we are inclined to favor the use of standardized commercial materials until such a time as we may have more detailed information on the possible injury to potatoes and tomatoes from too great

strengths of lime-sulfur. However, since potato growers in some of the more outlying sections of the state find the price including freight and trucking almost prohibitive, and a few of them used the home-made material successfully last season, the following is given on the making and diluting of it:

Theoretically lime and sulfur unite in the proportion of 1 part of lime to 2.28 parts of sulfur by weight. Commercial lime is never pure, so the proportions of 1 part of lime to 2 parts of sulfur has been found to give the greatest amount of pentasulfide with the least waste.

The following formula is the most generally used in home work:

Lump or stone lime.....	50 pounds
Commercial ground sulfur.....	100 pounds
Water, enough to make.....	50 gallons

The method of operation and addition of the materials can be varied to suit conditions. The following three methods are in use:

1. Place the required amount of water into the cooking vessel and bring almost to the boiling point. Mix the sulfur with hot water and 10 percent of the lime to form a thick cream or paste. When the water is almost ready to boil add sufficient of the lime to bring it to the boiling point, then add lime and parts of the lime and sulfur paste alternately in such quantities that the heat for cooking and from the slaking lime keeps the solution boiling all the time.

2. Mix the lime and sulfur in dry form and then shovel this mixture into the cooking tank, after first having brought the required amount of water to the boiling point. The heat generated by slaking the lime is taken advantage of to hasten the cooking.

3. Heat about one-third of the required amount of water and to this add the lime. As soon as the lime starts slaking add the sulfur, which should have been previously mixed with enough water to make a thick paste. Then add the remainder of the water, having it hot if possible.

It usually requires 15 or 20 minutes to add the materials, then the cooking should be constant for 50 or 55 minutes after the lime has finished slaking. A slow, steady boil is to be preferred. Care should be taken to prevent overheating and foaming. The material should be constantly stirred, especially during the early part of the cooking. Any water boiled away should be replaced, as the full amount is necessary for the most complete combination of the lime and sulfur. If it is found that 5 gallons are boiled away in the cooking, it will be found best with

the second batch to add this much extra in the beginning rather than to check the boiling by adding water during the cooking period.

MATERIALS

LIME.—It is essential to have a high-grade, freshly burned stone lime (CaO), known also as lump lime or quicklime. It should be from 95 to 98 percent pure. The most objectionable impurity is magnesium, which forms insoluble compounds and greatly increases the sludge. The magnesium oxide should not exceed 5 percent, and many limes that can be purchased under a guarantee contain much less than this.

A high-grade hydrated lime can be used with fair results, but it is necessary to use one-third more by weight than is given in the formula for stone lime. This will greatly increase the amount of sludge. The hydrated lime is not recommended.

Air-slaked lime should never be used.

SULFUR.—The commercial ground sulfur is usually cheaper than the flowers of sulfur and if well ground is equally satisfactory. It should be from 98 to 99 percent pure. Many of the better sulfurs now on the market are practically 100 percent pure.

HEAT

If steam pressure is available it furnishes the best source of heat for cooking. It may be applied by means of a closed coil in the tank or by releasing the steam thru a perforated coil or pipes directly into the liquid. This last has the advantage of furnishing at least a part of the necessary agitation and usually enough steam is condensed to keep the volume of water about constant. Farm food-cooking boilers are often used satisfactorily in steam cooking.

Direct fire may be used, the cooking being done in large iron kettles or in metal bottom vats. Satisfactory vats can be made from heavy planks for the sides and heavy sheet iron for the bottom. Fuel can be conserved by building the kettles or vats into a furnace. It is advantageous to cover the cooking vessel during cooking except an opening thru which the liquid can be stirred.

STRAINING THE PRODUCT

All lime-sulfur, when first made, carries some sludge or solid particles. As soon as the cooking has been completed the lime-sulfur concentrate should be drawn off, strained and placed into storage receptacles. A 20 to 30-mesh screen (brass or tinned iron, never copper) will remove the particles that will interfere in spraying. A loosely woven burlap cloth can be used. The sludge that passes thru such screens is not seriously objectionable.

STORAGE

The lime-sulfur concentrate may be made up and stored until needed. Metal barrels are excellent for this. If oil barrels are used and they contain much oil, they should first be steamed out or rinsed out with gasolene. The stored lime-sulfur should be protected from the air, since exposure causes crystals and a crust formation. The barrels should be completely filled and corked. In open containers a thin layer of medium to heavy oil can be used as a protective cover. This should be skimmed off before using the lime-sulfur.

DILUTION

It has been shown that the effective portions of lime-sulfur are the combinations of sulfur and calcium of the lime known as pentasulfides. The sulfur in these combinations is spoken of as the sulfide sulfur. The most accurate dilution is made on the basis of this sulfide sulfur content. A practical test has been developed to determine this content, but it is most too complicated to be used by individuals making only their own supply of lime-sulfur. If community plants should be established and any are interested, they will find the method described in Colo. Exp. Sta. Bul. No. 352.

The sulfide sulfur compounds in solution in the liquid increases its density or weight. The amount of such soluble materials can be determined quite accurately by an instrument that determines this density. Such an instrument is known as a hydrometer. It works on the principle that an object will sink in any liquid until it displaces its own weight of that liquid. The stem of the hydrometer is graduated for measurement. There are two standard scales of graduation, the specific gravity scale and the Baume scale. Hydrometers with the Baume scale are used almost exclusively in testing lime-sulfur.

A hydrometer outfit consists of the hydrometer and a tall glass cylinder in which the liquid can be tested. Such an outfit is not expensive and can be ordered from dealers in chemical supplies or laboratory apparatus.

In ordering, specify an instrument with the Baume scale for lime-sulfur testing.

In testing, use only the clear liquid, which should be at a temperature of about 60 degrees F. Each batch cooked should be tested before using, as there is often a great variation. The formula given should make a material testing 26 to 28 degrees Baume, but the variation may be from 20 to 28 degrees Baume.

Under no circumstances attempt to use a home-made lime-sulfur without diluting according to test.

Table II—Formula for diluting home-made lime-sulfur for potato spraying.

Density of solution, degrees Baume.	Equivalent in specific gravity	Dilution for potato spray. To 1 gal. of concentrate add — gallons of water.	Dilution for potato spray. For 50 gallons of spray use.	Density of solution, degrees Baume.	Equivalent in specific gravity.	Dilution for potato spray. To 1 gal. of concentrate add — gallons of water.	Dilution for potato spray. For 50 gallons of spray use.
30	1.2609	27.50	1 gal. 7 pts.	22	1.1789	17	3 gal.
29	1.2500	26.25	1 gal. 7 pts.	21	1.1694	15.75	3 gal. 1 pt.
28	1.2393	24.75	2 gal.	20	1.1600	14.50	3 gal. 3 pts.
27	1.2288	23.50	2 gal 1 pt.	19	1.1508	13.50	3 gal. 5 pts.
26	1.2185	22.25	2 gal. 2 pts.	18	1.1417	12.75	3 gal. 7 pts.
25	1.2083	20.73	2 gal 3 pts.	17	1.1328	12	4 gal. 1 pt.
24	1.1983	19.50	2 gal. 5 pts.	16	1.1240	11.25	4 gal. 4 pts.
23	1.1885	18.25	2 gal. 6 pts.	15	1.1154	10.25	2 gal. 7 pts.

After the density of the concentrate is determined, the proper rate of dilution for spraying purposes is ascertained by referring to a table of dilutions as shown in Table II. This table has been developed from the original dilution table developed by P. J. Parrott of the New York Agr. Exp. Sta., but corrected according to the work of the writer³ to consider only the sulfide sulfur content of home-made lime-sulfurs.

PRECAUTIONS

Pumps used with lime-sulfur should be washed out each night after using. Pumps with brass working parts will have a scaly crust formed over the brass after continued use. The openings in the nozzle discs are eaten out rapidly so a sufficient supply should be kept on hand for replacement. Lime-sulfur will blacken lead paint. Lime-sulfur is caustic to the skin and will produce ulcers if the skin is constantly wet. A weak iodine solution placed on the skin will destroy the caustic effect of the lime-sulfur in such sores. Gloves or vaseline on the hands will protect against lime-sulfur around the nails. It is very irritating to the eyes. Goggles can be worn to advantage while spraying and while making lime-sulfur.

SUMMARY

The killing effect of lime-sulfur comes largely from the power of the calcium pentasulfide and calcium tetrasulfide compounds to take up large amounts of oxygen and to give off free sulfur in very finely divided particles.

³Geo. M. List—The sulfide sulfur content as a basis for diluting lime-sulfur for spraying.—Colo. Agr. Exp. Sta. Bul. No. 352.

Protection from the psyllids comes in three ways. 1.—Lethal effect thru contact with their bodies at the time of application. 2.—Repellent effect upon the egg-laying adults. 3.—Residual effect upon the scale-like nymphs that locate upon a sprayed surface.

Indications of injury to tomatoes and possibly also to potatoes from the use of lime-sulfur have been noted. The strength of the stock material of lime-sulfur should be known and directions for dilution strictly followed. The liquid and dry proprietary lime-sulfur compounds on the market are discussed. They should be evaluated on the basis of the sulfide sulfur content. The commercial liquid lime-sulfur is sufficiently standardized that the recommendation of 1 part to 40 parts of water for potatoes, and 1 part to 45 or 50 parts for tomatoes, can be followed. It takes approximately 5 pounds of dry lime-sulfur to supply the amount of sulfide sulfur in 1 gallon of the commercial liquid concentrate. The dry should therefore be used at the rate of 1 pound to 8 gallons of water for potatoes and 1 pound to 9 or 10 gallons for tomatoes.

Concentrated lime-sulfur may be made at home. Formula and directions are given. Each cooking must be tested and diluted according to test shown. A dilution table for potato spraying is given.

Since the above was written, Dr. Dwight M. DeLong, Ohio State University, in Bulletin No. 44, Crop Protection Institute, "Experiments with Sulphur and Pyrethrum," has advanced the theory that the residual effect of sulfur sprays may come thru the production of abnormal quantities of certain chemical substances within the plant cells due to the presence of the material on the surface of the leaf. He states:

"The exact effect of sulphur upon the insect or the plant or both, and the method of its action, are not known but experimental data would indicate strongly that it works in some way through the plant. In ordinary use the toxicity of sulphur to insects has been attributed to volatile products, but the residual effect could scarcely be correlated with a volatile product, especially since the effectiveness may last for a period of several days. . . .

"Some detailed experiments were performed to determine the general effect of sulphur on leafhoppers and it was found in some series of tests that when the plant was treated and leafhoppers placed on the leaves a week, two weeks, or even three weeks later, these insects would die in four or five days after being placed on these treated plants."