Station Bulletin 201 January, 1924

Oregon Agricultural College

Experiment Station

The Preparation of Spray Materials

By

R. H. Robinson, M.S.,
Associate Chemist

CORVALLIS, OREGON

FOREWORD

The successful production of orchard and certain farm crops depends, in a large measure, upon the quality of the spray materials used to control insect pests and fungous diseases.

The quality of the sprays depends upon the procedure followed and the care exercised in the preparation of the spray materials.

This bulletin outlines methods of procedure for the preparation of sprays, emphasizes precautions that should be taken in the selection of materials from which the sprays are prepared, and advises on safe mixtures that may be used in combination sprays.

Methods are given for the preparation of lime-sulfur solution, self-boiled lime-sulfur, Oregon cold-mix lime and sulfur, New Jersey dry-mix lime and sulfur, bordeaux mixture, "boiled" lubricating oil emulsion, and three different formulas for "cold" lubricating oil emulsions.

The Preparation of Spray Materials

By

R. H. ROBINSON

The introduction of new spray materials, the improvement of those in present use, and the prevalent custom of employing combination sprays, give rise continually to problems that must be solved in order to obtain best results in the orchard. Most of these troublesome problems are caused by chemical reactions that either reduce the efficiency of the spray material or form a by-product that causes foliage burn or other harmful effects. Observations of these chemical reactions under laboratory conditions have, in many instances, disclosed means of overcoming the difficulties.

The purpose of this bulletin, therefore, is to report the best methods by which our common spray materials may be prepared, what combinations are safe, and what precautions should be taken to insure best results. Comments, also, are made on certain commercial spray preparations.

ARSENATE OF LEAD

There are two forms of arsenate of lead that have been used as insecticides. They are known chemically as lead hydrogen or lead acid arsenate and basic or neutral lead arsenate. Investigations at the Oregon Experiment Station and in other states have shown that the lead hydrogen arsenate is more toxic to insect pests than basic lead arsenate, and consequently the production of the latter has been discontinued by most manufacturers. The basic lead arsenate, therefore, is rarely offered for sale in Oregon and if so it is plainly labeled to distinguish that form from the commonly used lead hydrogen arsenate.

High grade lead arsenate must be high in total arsenic for optimum killing efficiency, low in water-soluble arsenic in order that foliage burn may be reduced to a minimum, and free from foreign impurities. Since most manufacturers have perfected their processes for the production of lead arsenate, high grade material is the rule on the market. The chemical analyses of various brands of lead arsenate sampled in different parts of the state are given in Table I.

TABLE I. ANALYSES OF DIFFERENT COMMERCIAL BRANDS OF LEAD ARSENATE

Brand	Lead oxide (PbO)	Arsenic oxide (As_2O_5)	Water-soluble arsenic oxide (As_2O_5)
	%	%	%
A	63.82	31.80	0.06
B	63.96	32.53	Trace
C	63.19	31.64	0.04
D	64.14	32.19	Trace
E	64.41	31.27	0.06
F	63.87	32.36	Trace
G	65.71	30.46	Trace
H	64.86	30.75	0.12
I	63.93	32.07	0.17
J	63.74	32.94	0.07
K	64.41	31.84	Trace
L	63.74	31.04	0.16

The above results indicate that there are only slight differences in the composition of the various brands. The low water-soluble arsenic content of all samples further emphasizes the high degree of purity of the commercial brands that are now on the market. We can conclude, therefore, from these and numerous other analyses, that from the standpoint of their chemical composition all present brands of lead arsenate are high grade and safe for general use. Equally efficient results may be expected from any of them.

Recommended combinations. Lead arsenate may be combined with bordeaux mixture, nicotine sulfate, "cold prepared" oil emulsions, and either the self-boiled, cold-mix, or dry-mix lime and sulfur.

When combined with liquid lime-sulfur the latter should be diluted to spraying strength and one pound of hydrated lime or casein spreader to each 100 gallons added. Finally just before application the lead arsenate should be sifted into the spray.

LIME-SULFUR

Lime-sulfur is the most important of the sulfur sprays. It is an efficient contact poison for certain scale insects and an important fungicide for several fungous diseases.

The concentrated lime-sulfur solution having a Baumé test of 28° to 32° may be obtained usually from local dealers or association quarters. If not or where used in large quantities it may prove advantageous to prepare it at home. On account of the high cost of transportation the home-prepared or the association product has largely superseded the commercial product having a concentration of 33° Baumé.

Home preparation of lime-sulfur. Care should be exercised in the preparation of lime-sulfur in order to obtain as complete a reaction as possible between the lime and sulfur and to prevent the formation of excess sludge.

As a general rule the ingredients are used in the following proportions:

Sulfur (powdered)	2 pounds
Quicklime	1 pound
Water	1 gallon

Ordinarily 50 gallons or more, depending upon facilities, is prepared at one time. When the lime-sulfur is to be cooked over a fire the following procedure will be found most practicable. Place in a large kettle or feed-cooker 50 pounds of high-grade quicklime and add about 15 gallons of water. When the lime is slaking vigorously add 100 pounds of powdered sulfur and mix rapidly and thoroughly with the lime. Add water (preferably hot) gradually to prevent lime from drying out during the process of slaking. As soon as all the lime is well slaked and a uniform mixture of the slaked lime and sulfur has been obtained, add enough hot water to bring the total volume to 65 or 70 gallons. Continue boiling for 45 minutes, stirring occasionally and adding hot water at intervals to keep the volume at 65 to 70 gallons. Allow to cool and protect the solution from the air. (It is necessary to protect the lime-sulfur from the air since it is easily oxidized to a less toxic form. The best method is to pour enough lubricating or engine oil over the surface to form a thin film.)

If steam is available, quantities may be prepared limited only by the size of vessel used. For a 50- to 200-gallon outfit a circular, perforated

steam coil should be placed on the bottom of the vessel and a mechanical agitator with sweeping arms rotating on a shaft should be fitted at the bottom and in the center of the vessel. A half-inch-mesh wire screen cut to fit the vessel is supported by blocks 4 inches above the bottom. The agitator revolves between this screen and the bottom of the vessel.

To prepare 50 gallons proceed as follows: Place 50 pounds of the quicklime on the screen and add sufficient hot water to start the lime slaking rapidly. While the lime is slaking add 100 pounds of powdered sulfur and enough hot water to make a total of about 50 gallons. Turn on the steam, start agitator and cook about 30 minutes or until all of the free sulfur has disappeared. Add hot water occasionally if the original volume diminishes during the cooking process.

After the lime-sulfur has cooled and the sludge has settled completely, the clear liquid should be drawn off and the sludge discarded.

More detailed information pertaining to formulas, designs of large and small plants, storage, and other general information may be found in United States Department of Agriculture Farmer's Bulletin No. 1285.

Precautions. It is important to use fresh, high grade quicklime and pure powdered sulfur or flowers of sulfur. Since different brands of lime vary each year, in case of question the Chemistry department of the Experiment Station will be glad to give information and assistance.

If a low-grade or an impure quicklime is used, large amounts of sludge will be formed and sulfur will be wasted. Over-boiling or under-boiling also increases the amount of sludge. Strict adherence to the proper boiling period is therefore important.

Care should be taken to maintain the original volume advised, by the addition of more hot water. Too much water is better than not enough.

Dilution of stock lime-sulfur solution. Every horticulturist who makes his own lime-sulfur should secure from the druggist a Baumé hydrometer in order to test his stock solutions. Otherwise he will be unable to use the correct amount of water in diluting his spray for application. The commercial lime-sulfur solution usually has the strength marked upon the barrel.

When the Baumé reading has been ascertained, the lime-sulfur may be diluted according to Table II.

TABLE II. DILUTION TABLE FOR LIQUID LIME-SULFUR

—Strength of stock— solution		To make 100 gallons of dilute spray use the number of gallons of concentrated stock lime-sulfur indicated in the columns below and add water to make 100 gallons.				
Degrees Baumé	Specific gravity	1 Dormant strength for scale clean-up (12 to 100)	2 Dormant strength for blister-mite and twig-miner (8 to 100)	3 Early spring spray (3½ to 100)	4 Mid-spring spray (2½ to 100)	5 Late spring spray (2 to 100)
		gal.	*gal.*	*gal.*	*gal.*	*gal.*
34°	1.304	11 +	7½	3 +	2¼ +	1¾ +
32°	1.282	12	8	3¼	2½	2
30°	1.260	12¾ +	8½	3½	2¼ +	2 +
28°	1.239	14 —	9¼	3¾	2¾ +	2¼ +
26°	1.218	15	10	4	3	2½
24°	1.198	16½ —	11	4½ —	3¼ +	2¾
22°	1.179	18½ +	12¼	4¾ +	3¾ —	3 +
20°	1.160	20¾ +	13⅝	5½ —	4¼ —	3½

Note: Where the + sign is used, employ a little over the number of gallons indicated. Where the — sign appears use scant measure.

Recommended combinations. Lime-sulfur may be combined with nicotine sulfate and with lead arsenate when directions are followed as given under lead arsenate.

Self-boiled Lime-sulfur

The self-boiled lime-sulfur often used as a special spray for peaches or other tender foliage is mainly a mechanical mixture of lime and sulfur. The addition of sulfur to hot slaking lime reacts chemically to a slight degree and tends further to disintegrate the sulfur particle, giving a mixture of milk of lime containing a suspension of very fine sulfur.

A satisfactory product may be prepared if ordinary care is exercised and if fresh, high-grade quicklime and finely ground sulfur or flowers of sulfur are used. The following proportions are used for each 50 gallons:

Quicklime	8 pounds
Sulfur	8 pounds
Water	50 gallons

The lime is placed in a suitable vessel and about 2 gallons of cold water is added. As soon as the lime begins to slake actively, add the sulfur and mix quickly with the lime. While stirring the mixture constantly, add more water as needed, to maintain a thick pasty consistency. When the boiling has stopped, immediately add enough cold water to cool the mixture. If the mixture is not cooled immediately, chemical reactions occur that may cause the spray to be unsafe for use on peach or other tender foliage. Strain through a burlap strainer into spray tank and dilute to 50 gallons. The spray is now ready for application. Since the spray is a suspension of sulfur in milk of lime, the agitator should be kept going constantly while spraying is in process.

Oregon Cold-mix Lime and Sulfur

It is often inconvenient to prepare self-boiled lime-sulfur since the process involves care and, especially if large quantities are needed, takes considerable time.

A more simplified procedure has been worked out by the writer at the Oregon Experiment Station that may be substituted for the method outlined above for the self-boiled lime-sulfur or the dry-mix types of sulfur sprays. For making 50 gallons the following ingredients and amounts are recommended:

Sulfur (superfine flour)	8 pounds
Hydrated lime	4 pounds
Skim milk	2 quarts

Preparation. Weigh out the proper amounts of sulfur and hydrated lime and mix them together. It is unnecessary to mix them thoroughly.

Take 2 quarts of sweet skim milk and add an equal amount of water. Pour this onto the sulfur and lime, stirring until a smooth paste is formed, adding more water if the paste becomes too thick.

Finally add several gallons of water and pour through strainer into the spray tank. Fill tank with the required amount of water and the spray is ready for application.

Precautions. Less care, perhaps, is required to prepare the above substitute for self-boiled lime-sulfur than for any other spray. If the hydrated lime is not fresh it will not decrease the effectiveness of the

spray. The sulfur, however, should be ground superfine. If skim milk is not available whole milk may be used with equal effectiveness. If the milk is only slightly sour it may be used. If information regarding means of preserving milk is desired write to the Chemistry department of the Oregon Experiment Station.

The method is simple and convenient and the cost of materials is the lowest for this type of sprays. It is therefore felt to be worthy of immediate practical tests by growers in comparison with other types of sulfur sprays for summer use.

Dry-mix lime and sulfur

The New Jersey Experiment Station also has developed an excellent substitute for self-boiled lime-sulfur that has given good results in field experiments. The mixture is composed of the dry materials which may be prepared at any time and used when necessary. The formula used for making 50 gallons of spray is as follows:

Sulfur	8 pounds
Hydrated lime	4 pounds
Calcium caseinate	½ pound

The above amounts may be proportionately increased or decreased, depending upon the quantity desired.

Preparation. Weigh out the proper amounts of sulfur, hydrated lime, and calcium caseinate.

If necessary, sift both sulfur and lime through a small-mesh sieve in order to remove any lumps.

Mix together the three ingredients thoroughly in order to secure a uniform mixture.

Dilution. The New Jersey Experiment Station recommends that the dry-mix material be used at the rate of 12½ pounds to 50 gallons of water. Any of the following methods may be used for diluting with water.

Method 1. Place the proper amount of material in a barrel, or other container which will hold water. Add water slowly, stirring the mixture until the grains of sulfur are wet and a thin solution is obtained that will pass readily through a strainer into the spray tank. Strain the material into the spray tank after filling it at least one-half full of water. This method is recommended particularly for use with hand outfits or where it is not convenient to have the agitator running when the tank is being filled.

Method 2. Wash the proper amount of dry-mix lime and sulfur through the strainer into the spray tank with the agitator running. This method can be used to advantage only where a strong flow of water from an overhead pipe or hose is available. The strainer used should not have more than 12 to 14 meshes to the inch.

Method 3. Put the proper amount of dry-mix directly into the spray tank after filling it at least one-half full of water. As in Method 2, the agitator should be running when the dry material is added in order to insure a thorough mixture with a minimum amount of settling. Open up the nozzle or spray-gun and drive a stream of the liquid that is being forced through the hose directly into the dry material as it falls upon the surface of the water in the tank.

Precautions. The same care should be exercised in the use of fresh hydrated lime and very fine flowers of sulfur or dusting sulfur as for the other lime and sulfur combinations.

Casein is one of the ingredients of skim milk, and after drying, grinding, and mixing with lime it is sold on the market as calcium caseinate spreader. This may be obtained in Oregon under several trade names such as Spreado, Hood River Spray Co. Spreader, and Kayso.

Sufficient systematic field experiments have not yet been carried out in Oregon to show definitely the fungicidal properties of the substitutes for self-boiled lime-sulfur. It is generally recognized, however, that sulfur is the active ingredient in this class of sprays and satisfactory results should be obtained. The New Jersey Experiment Station, however, reports the dry-mix lime-sulfur as superior to Sulfur Dust, Atomic Sulfur, or self-boiled lime-sulfur. The Oregon cold-mix lime and sulfur should prove equally effective.

Recommended combinations. Self-boiled, cold-mix, or dry-mix lime and sulfur may be combined safely with lead arsenate, nicotine sulfate, cold oil emulsions, or bordeaux mixture.

Other Sulfur Sprays

Besides the lime-sulfur solutions, there are several commercial products in more or less common use. Among them may be mentioned dry lime-sulfur, barium-tetra-sulfid (B.T.S.), and soluble sulfur.

Barium-tetra-sulfid has been shown to be a fairly effective contact poison, but it possesses no distinct advantage over the lime-sulfur solution except that it is in powder form and convenient to handle. Its cost, however, is prohibitive, and consequently it has not been used to any extent in the Northwest.

Soluble sulfur is similar to lime-sulfur except that lye is used instead of lime in its preparation. As a dormant spray it has been found satisfactory, but it has no superiority over the lime-sulfur. It cannot be used as a summer spray or later than the dormant spray since it causes very severe foliage burn.

Dry lime-sulfur is the product obtained in the dehydration of the concentrated lime-sulfur solution. Apparently there is partial decomposition of the polysulfides during the process of manufacture since the percentage of both free sulfur and thiosulfate sulfur is higher and the polysulfide sulfur is lower than the amounts found in the concentrated lime-sulfur solution calculated on a dry basis. The most recent guaranteed composition of dry lime-sulfur at this writing is as follows:

	Percent
Calcium polysulfid	70.0
Calcium thiosulfate	5.0
Free sulfur	10.0
Inert ingredients	15.0

It may be considered therefore that 85 percent of dry lime-sulfur consists of active ingredients and 15 percent of inert materials that are of no value as a spray.

An average analysis for lime-sulfur solution 33° Baumé is as follows:

	Percent
Calcium polysulfid	30.5
Calcium thiosulfate	1.5
Water	68.0

A gallon of lime-sulfur 33° Baumé weighs about 10.7 pounds. Calculating the amount of active ingredients from these figures we find that there are 3.47 pounds per gallon.

When dry lime-sulfur is used either for the dormant spray or for the summer sprays it should be applied in amounts equivalent to the liquid lime-sulfur in order to obtain equivalent protection. Since each gallon of lime-sulfur solution contains 3.4 pounds of active ingredients it would take 4.0 pounds of a dry lime-sulfur having 85 percent active ingredients to be equivalent to one gallon of liquid lime-sulfur. Therefore, in making dilutions for the various sprays 4.0 pounds of the dry lime-sulfur should be used for each gallon of liquid lime-sulfur, Baumé 33°, necessary. While this amount is much higher than is recommended by the manufacturer, field experiments carried on in different parts of the country have indicated conclusively the need of using larger amounts than the manufacturers have recommended in the past, particularly when weather conditions favor the development of serious disease epidemics.

BORDEAUX MIXTURE

Bordeaux mixture was for a long time the most widely used material for controlling fungous diseases of plants. It has been supplanted to a large extent by sulfur sprays and other materials; yet for certain diseases such as apple-tree anthracnose, peach-leaf curl, peach blight, potato late blight, celery blight, etc., bordeaux is still the most efficient and safest preventive known.

The effectiveness of most protective sprays depends to a large extent upon the spreading and adhering properties of the materials. When bordeaux mixture is properly made it adheres well and has excellent spreading properties.

Laboratory experiments substantiated by field tests have demonstrated the superiority of the carefully prepared home-made bordeaux over all commercial brands. Most commercial brands, both paste and powder forms, do not adhere sufficiently well to warrant advising their use for those fungous diseases that require the toxic ingredient to adhere for several weeks for effective control. The commercial product is inferior owing to the fact that in the manufacturing process the gelatinous, colloidal properties, peculiar to a good bordeaux mixture, are destroyed.

Bordeaux mixture is produced when dissolved copper sulfate (bluestone) and milk of lime are poured together. A chemical reaction takes place between them which results in the formation of a voluminous precipitate.

Formulas are generally designated by the proportion of materials used. For example:

4-4-50 formula

Copper sulfate (bluestone)	4 pounds
Calcium oxide (stone or quicklime)	4 pounds
Water	50 gallons

Other formulas frequently advised for specific purposes are 3-3-50; 3-6-50; 6-6-50; 6-8-50, etc.

In recent years high-grade hydrated lime has been offered on the market, and if properly used it may be substituted for the quicklime.

When the hydrated lime is used about one-third more by weight than quicklime should be taken. The 4-4-50 formula then is as follows:

Copper sulfate (bluestone)	4 pounds
Hydrated lime	5⅓ pounds
Water	50 gallons

Other formulas likewise require ⅓ more of hydrated lime than quicklime.

Stock solutions. If large quantities of bordeaux are to be used it is best to prepare concentrated stock solutions. A convenient concentration is one pound of lime or one pound of copper sulfate in each gallon of water.

(a) The copper sulfate when in lump form may be dissolved easily by taking a 50-gallon barrel of water and suspending near the surface of the water 50 pounds of the bluestone in a burlap sack. It will dissolve completely after standing about ten hours or over night.

(b) To prepare the milk of lime, slake 50 pounds of quicklime in a barrel by the addition, with constant stirring, of enough water to prevent "burning" or drying of the lime. When thoroughly slaked add water to make 50 gallons.

The stock solutions (a) and (b) each will contain 1 pound of material to 1 gallon of water. If covered to prevent evaporation these will keep indefinitely.

When hydrated lime is used instead of quicklime, weigh out 66 pounds and add enough water to make 50 gallons. This will contain the equivalent of 1 pound of quicklime to 1 gallon of water.

Copper sulfate also may be obtained in powder form. When the powder is used it is unnecessary to prepare a stock solution since any desired amount may be dissolved quickly by sifting and stirring into the quantity of water to be used in making the bordeaux mixture.

Methods of preparation. Bordeaux mixture may be made in a satisfactory manner by several different methods, but it is very important to have both the copper sulfate and milk of lime as dilute as possible before combining. The stock solution must never be mixed without first diluting with water. The following methods will give good results using the stock solutions described above. The quantities given below are for 50 gallons of the 4-4-50 formula. If another formula is desired vary the proportions accordingly.

1. Stir up the stock copper sulfate solution thoroughly, take 4 gallons and add 21 gallons of water. (If powdered copper sulfate is used, sift slowly 4 pounds into 25 gallons of water, stirring meanwhile.)
2. Stir up the stock solution of milk of lime thoroughly, take 4 gallons and add 21 gallons of water.
3. Finally pour the diluted copper sulfate *into* the diluted milk of lime, stirring vigorously.

It is preferable to prepare the bordeaux by mixing directly in the spray tank. For a 50-gallon tank and the 4-4-50 formula proceed as follows:

1. Fill the spray tank about half full of water and start the agitator.
2. Pour 4 gallons of the stock milk of lime solution through a 20-mesh strainer into the spray tank.
3. Take 4 gallons of the stock copper sulfate solution, add 21 gallons of water, and pour into the spray tank while the agitator is running.

Precautions. 1. Use fresh quicklime or hydrated lime of highest purity. The Chemistry department of the Experiment Station will give information regarding lime.

2. Dilute the stock solution of copper sulfate and milk of lime before combining them and use water as cold as convenient.

3. Follow closely the procedure as outlined above.

4. Do not fail to pass the prepared bordeaux or the milk of lime through a 20-mesh copper wire strainer before using.

5. Bordeaux mixture will attack iron; always use brass or bronze spray rods or connections and copper strainers. Rinse out spray tank, hose, and rod or gun with clean water immediately after using.

Preservative for bordeaux mixture. Bordeaux mixture must be applied immediately after preparation. If it is not possible to use all in the tank within three hours after it was made the bordeaux may be preserved by the addition of a very small amount of ordinary sugar. The sugar retards the breaking down of the gelatinous precipitate that is so essential in the formation of a membrane that causes adherence to the surface sprayed.

The tests of the Oregon Experiment Station indicate that $\frac{1}{8}$ oz. of sugar should be used for each pound of copper sulfate in the spray. For example, in a 100 gallon tank filled with 4-4-50 bordeaux mixture there were 8 lbs. of copper sulfate used. Therefore, $8 \times \frac{1}{8}$ oz. or 1 oz. (1 heaped tablespoonful) of sugar should be used. The required amount of sugar is added after first dissolving in a little water.

Combination with other sprays. Bordeaux mixture may be combined safely with lead arsenate, calcium arsenate, paris green, certain mineral oil emulsions, and nicotine sulfate preparations.

When preparing the combination spray always add any of the above materials to the bordeaux mixture after starting the agitator and just before application.

Mineral oil emulsion should be mixed with two times its volume of water before adding *slowly* to the bordeaux mixture.

BURGUNDY MIXTURE

This spray is sometimes used in place of bordeaux in sprays for small fruits shortly before picking because it does not leave the objectionable deposit on the fruit which comes from applying bordeaux at such a time. Like bordeaux, the active principle is copper but it does not adhere as well as in the case of bordeaux.

Preparation. Burgundy mixture may be prepared in the same manner as bordeaux except that sodium carbonate is substituted for quicklime. The following formula is commonly used:

Copper sulfate (bluestone)	2 pounds
Sodium carbonate (sal soda)	3 pounds
Water	100 gallons

COMMERCIAL BORDEAUX

There are on the market numerous commercial brands of paste and powder bordeaux mixtures the copper content of which ranges between 10 and 25 percent. As stated previously a favorable recommendation

cannot be made for this class of spray materials especially where the spray must adhere for several weeks to obtain effective results.

There are, however, the "two powder" commercial preparations that, if combined according to directions, will give an excellent bordeaux mixture. These should be used in preference to the other type if it is not convenient to prepare the home-made bordeaux.

MINERAL OR LUBRICATING OIL EMULSIONS

The use of oil emulsions such as miscible oils or mineral oil emulsions was limited until very recently. The Experiment Station has not advised the home preparation of this spray, because more than ordinary care should be exercised in its preparation. On account of its wider use and the comparative high cost in some localities of the commercial product it seems opportune to describe in detail the methods by which oil emulsions may be home prepared by the horticulturist.

It is generally known that oil and water alone will not mix. In order to break up the oil globules an "emulsion" is made with the help of a third substance. The emulsion then may be added to the spray tank and dispersed in a suitable quantity of water in a manner similar to lead arsenate or other diluted spray. The importance of a good emulsion, therefore, is obvious. Recent laboratory experiments have shown that numerous materials can be used as the third substance but only those that are practical will be considered.

Among the first substances commonly used for preparing mineral or lubricating engine oil emulsion is potash fish-oil soap. The formula advised is as follows:

Mineral oil	2 gallons
Water (soft)	1 gallon
Caustic potash fish-oil soap	2 pounds

Preparation. Dissolve the potash soap in the water by heating in a kettle or other suitable vessel that will stand fire. Add the oil and heat to the boiling point. Remove kettle from fire and while still hot pump the mixture into another vessel with a bucket pump or through a spray pump at a pressure of about 60 pounds and then pump it back again. The emulsion, after cooling, is ready for diluting and should mix well with water. If it does not mix well with water repump it.

Remarks. The mineral oil may be any of the medium-grade engine oils, but on account of the cost the commonly called red engine oil medium grade is advised. Black fuel oil or similar oils should not be used until experimental studies indicate that no harmful effects will result.

When pumping from one vessel to another the nozzle should be closed to form a fine spray.

"Cold Oil" Emulsions

The oil emulsion described above may be referred to as a "boiled" emulsion to distinguish from the "cold" emulsions that are prepared without the aid of heat. The latter, *if properly made*, is preferable to the boiled emulsion and does not require as much labor in its preparation. Furthermore, the cold emulsion does not break down easily in hard water.

Several formulas have proved to be successful and slight variations do not seem to influence the quality of the product. Three formulas follow:

Formula 1		
Mineral oil	4	gallons
Copper sulfate (bluestone)	½	lb. in 1 gal. water
Calcium oxide (quicklime)	½	lb. in 1 gal. water
Formula 2		
Mineral oil	4	gallons
Water	1	gallon
Skim milk	1½	quarts
Hydrated lime	1	teaspoonful
Formula 3		
Mineral oil	4	gallons
Water	1½	gallons
Casein spreader	½	pound

Stock solutions for Formula 1. Stock solutions of both copper sulfate and lime facilitate the preparation of the oil emulsion especially if several 200-gallon tanks of a 2 percent, or higher, oil spray are to be used in a day. The stock solution of copper sulfate is prepared as directed under bordeaux mixture; that is, 1 pound is dissolved in 1 gallon of water. The calcium oxide likewise is slaked and water added until in the proportion of 1 pound to 1 gallon of water.

Preparation of Formula 1. Put 4 gallons of the mineral oil in a half barrel or other convenient vessel.

Take 2 quarts of the stock solution of copper sulfate and add 2 quarts of water. Pour this into 2 quarts of the milk of lime that also has been diluted with 2 quarts of water.

Pour immediately this freshly prepared bordeaux into the oil and pump the mixture back into itself, using a coarse spray of a bucket pump or spray pump. After pumping for a minute or two reduce the opening of the nozzle until a fine spray is obtained and pump into another container. Then pump it back again. This should give a good emulsion; if not, repump it.

Preparation of Formula 2. Put 4 gallons of the mineral oil in a half barrel or other convenient vessel. Add the skim milk to a gallon of water and stir in the teaspoonful of hydrated lime or equivalent of slaked quicklime. Pour this mixture into the oil and pump it back into itself as described above. Then reduce the opening of the nozzle until a fine spray is obtained and pump into another container. Then pump it back again. The emulsion should now be ready for final dilution and spraying.

Preparation of Formula 3. Make a smooth paste out of the casein by slowly adding water and stirring. Continue adding water until 1½ gallons have been added. Put the oil in a suitable container, add the casein mixture, and pump through spray pump as described above.

Precautions. The above emulsions are concentrated material and must be diluted with water before using. To dilute, take the required amount of oil and add an equal amount of water. Stir thoroughly and pour slowly into the spray tank which has the required amount of water for final dilution. The agitator should be started before the emulsion is added.

The emulsions may break down after standing for several hours and consequently should be applied as soon after preparation as possible. The solution may be reemulsified by pumping again, although sometimes it is necessary to add more of the emulsifying agent—bordeaux, milk, or casein depending upon the formula used. An emulsion that has broken down or does not mix well with water must not be used.

Sufficient experimental data are not available to advise definitely regarding the type or grades of oil that will give best control of scale, red spider, or other pest against which oil has shown promise. Thus far the red engine oil has given best results and is recommended at this time.

While pumping, a pressure of at least 60 pounds should be maintained.

In Formula 1, hydrated lime may be substituted for the quicklime. It is important that the quicklime or hydrated lime should be fresh and a high-grade product. When hydrated lime is used one-fourth more by weight should be taken.

Any casein spreader such as sold under the trade names Spreado, Hood River Spray Co. Spreader, or Kayso may be used in Formula 3.

Recommended formula. Any one of the formulas may be used, but it is more economical to use certain ones for certain purposes. If a bordeaux oil combination spray is to be applied Formula 1 should be used. For other purposes Formula 2 is advised. If skim milk or whole milk is not available then Formula 3 may be used.

Combination with other sprays. Cold prepared mineral oil emulsion may be combined safely with bordeaux mixture, lead arsenate, and tobacco or nicotine preparation. No other combinations are recommended until further experimental observations have been made. Boiled emulsion should not be used with lead arsenate.

The cold emulsion may be used with hard water without breaking down. The boiled soap emulsion, however, is ruined by hard water or small amounts of lime-sulfur.

COMBINATION SPRAYS

It is economically important to combine two or more sprays for the effective control of insect pests and fungous diseases. Oftentimes it is necessary to apply at a crucial time a combination of a stomach poison, a contact insecticide and a fungicide. Such a combination is a saving in labor and the high cost of spraying is materially diminished. When certain combinations are made, however, chemical reactions take place and may result harmfully in one or more of the following ways:

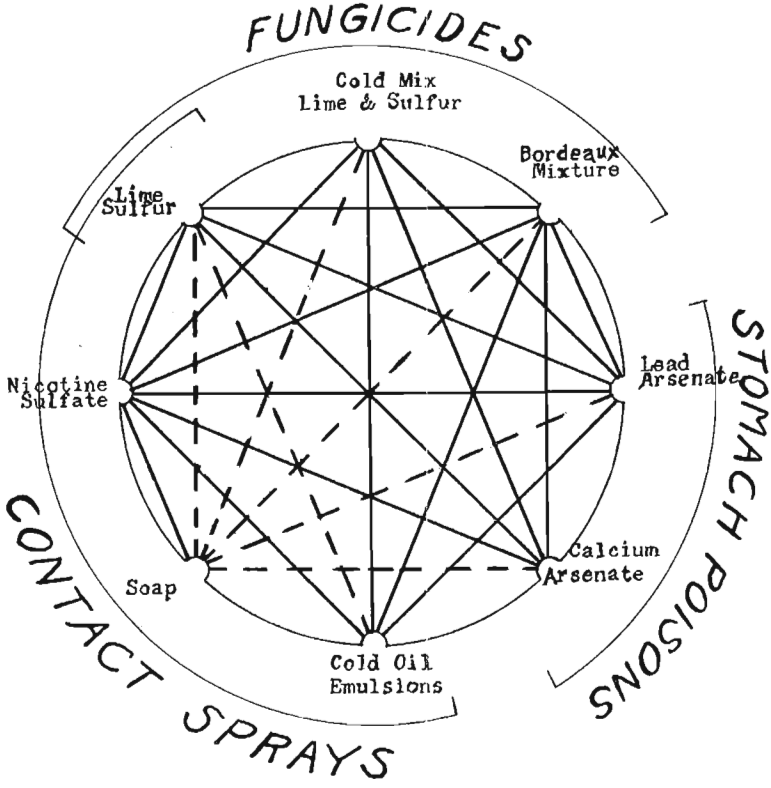
1. Formation of a soluble substance that will cause burning of the foliage or other injury.

2. Complete or partial destruction of the toxic properties the sprays combined.

3. Decrease of the natural spreading and adhering properties of the sprays.

It is very important, therefore, to combine compatible insecticides and fungicides as given under recommended combinations.

The compatibilities of various spray materials are graphically represented in the diagram on page 15.



——— RECOMMENDED COMBINATIONS

— — — — DANGEROUS COMBINATIONS

Adapted from Cal.Sta.Cir. #195.
By Geo. P. Gray.