INFLUENCE OF FORM AND PROPORTION OF LIME USED AND OF METHOD OF MIXING ON THE RESULTING BORDEAUX MIXTURE

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INTRODUCTION

Ever since Millardet (8, 9, 10, 13, p. 734) noted that a mixture of copper sulphate and lime prevented downy mildew on grapevines in 1882, and recommended its application as a fungicide, the "copper mixture of Gironde" (11) has undergone numerous modifications in copper content, ratio of lime to copper sulphate, and method of preparation in the hands of different investigators. Yet the influence of the form and the proportion of lime, and of the method of mixing on the resulting Bordeaux (bouillie bordelaise) is not clearly understood and merits additional study. Space does not permit an adequate review of the literature pertaining to this subject but attention will be called to some of the earlier investigations.

REVIEW OF LITERATURE

According to Millardet and Gayon (12) and most contemporary writers, calcium hydroxide reacts with copper sulphate to form cupric hydroxide and gypsum; but Pickering (1, p. 26, 27; 17, p. 1991, 1997, 2000; 18, p. 1852) has shown that limewater added to a solution of copper sulphate precipitates a blue basic sulphate increasing in basicity toward equal moles, converted by a large excess into what is termed a double sulphate and, by still more lime, into a double oxide. The variance between the two views is essentially a difference as to the point at which the sulphate radical disappears from the resulting copper precipitate. Whether the copper precipitates are chemical entities or mixtures is difficult to determine, owing to their instability and the presence of insoluble by-products but, in the last two instances at least, the compounds designated are empirical. The reaction in more concentrated mixtures such as Bordeaux is evidently somewhat depressed. Freshly prepared copper precipitates, with the exception of the tribasic sulphate, are usually gelatinous, of a high degree of hydration, and of excellent suspension. The gypsum and excess lime in suspension substantially increase the bulk of the precipitate and the portion in solution increases the viscosity of the serum.

Experiments made from 1885 to 1890 by Ferrand (3), Millardet and Gayon (14, p. 701; 15), Gaillot (4), Patrigeon (16, p. 701), Viala and Ferrouillat (19, p. 27), Mach (7), and many others, led to a reduction in the amount of copper sulphate and more or less change in the proportion of lime. Mixtures with a smaller percentage of copper sulphate were found effective and, with a lower ratio of lime, more active and adherent. Slightly alkaline, neutral, and even acid

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2 Reference is made by number (italic) to "Literature cited," p. 685.
mixtures received attention. In this country there has been a tendency recently to revert to a higher ratio of lime with a view of preventing foliage injury.

INFLUENCE OF THE FORM AND PROPORTION OF LIME USED

The two ingredients employed in preparing Bordeaux mixture are copper sulphate and lime (calcium hydroxide), although supplementary products are occasionally added. The aim is to secure the highest possible dispersion of the resulting precipitate, as the physical properties are of paramount consideration. The copper sulphate employed in the experiments reported was of good quality and substantially free from other metals. The solution was standardized as to copper content in most instances.

FORMS OF LIME USED

Four distinct forms of calcium hydroxide were employed, i.e.: Limewater, chemically precipitated calcium hydroxide, milk of lime, and commercial hydrated lime. The limewater was prepared from diluted milk of lime by filtration, thus assuring a fairly definite amount of active calcium hydroxide, although the low content limits the concentration of the resulting spray. In the Massachusetts laboratory quickly prepared solutions contained only 0.113 gm. of CaO in 100 c.c., as determined against n/10 hydrochloric acid, using phenolphthalein as indicator. This is probably due to incomplete saturation, partial carbonation, or selective absorption of the filter paper, and possibly to all three.

The chemically precipitated calcium hydroxide was prepared by the reaction of sodium hydroxide on calcium chloride and dialyzed free from chlorides, although any other modification that assures a homogeneous suspension of fine, active particles, free from impurities, might be employed. Such a product is nearly ideal for the preparation of Bordeaux mixture but too expensive for practical use.

The milk of lime was prepared by carefully slaking a high-grade granulated "fat" lime. The objective is complete hydration with a high degree of dispersion and the formation of a smooth, creamlike product having good suspension and adhesive properties. One of the writers (Dunbar), on a trial and error basis, obtained excellent results by adding 3 volumes of granulated lime to 5 of water, mixing vigorously and gradually introducing additional water. Subsequently, 1 part of lime added to 1.6 volumes of water and diluted with boiling water was found more satisfactory. Coarse particles of lime in the milk, whether due to poor stock or method of slaking, reduce the efficiency of the resulting Bordeaux, since they serve as nuclei for the formation of larger aggregates when the lime is mixed with the copper sulphate. Straining the milk of lime through double thickness of cheesecloth was adopted as preferable to screening, but this requires more time.

As the principal difficulty in preparing Bordeaux mixture with milk of lime is in the proper slaking of the lime, commercial hydrated lime was considered as a substitute. It has undoubtedly been used by others but to what extent is difficult to say. Of the hydrated limes on the market, agricultural lime is unsuitable, but some brands of plasterers' or finishers' lime are fairly soft, bulky, and substantially free from grit; and the so-called "chemical" hydrated lime is of greater
purity and better physical characteristics. The sample of plasterers' lime employed had a volume of 2.4 c. c. per gram, 99 per cent passing a 0.5 mm. sieve, and contained 42 per cent of active lime, calculated as oxide. As dry hydrated lime disperses slowly in water it was allowed to soak overnight before it was used to prepare Bordeaux, as the suspension of the latter is materially increased thereby. Several samples of "chemical" hydrated lime received recently had an average volume of 2.6 c. c. per gram and contained 67.3 per cent of active lime (theoretical for total CaO, 75.682 per cent). The manufacturers claim 96.5 to 99 per cent will pass a 200-mesh screen.

By active lime is meant that portion which can be readily determined by titration against standard acid to the initial disappearance of color, using thymolphthalein as indicator, thereby excluding coarse particles that are slow to react. The active portion of precipitated lime and milk of lime was determined in a similar manner and all tests were based on the active and not on the total lime present. Inert material is objectionable from the standpoint of both application and spray residue.

With precipitated lime, milk of lime, and hydrated lime, the fineness and uniformity of the particles seem to determine in large measure the physical properties of the resulting Bordeaux mixture. The degree of dispersion of the lime in the three forms evidently decreases in the order named.

PROCEDURE AND RESULTS

A series of experiments with 12 different ratios of lime to copper sulphate was instituted to determine the relative activity of the four forms of calcium hydroxide and the suspension of the Bordeaux mixtures prepared with them. The same concentration of copper sulphate, equivalent to that of ordinary Bordeaux, 4-4-50, was employed except in the case of limewater where a like strength was impossible, but the ratios of lime to copper sulphate were the same. Rubber-stoppered, glass museum jars of the following dimensions were employed for the purpose. Total height, 305.5 mm. (14 inches); length and outside diameter of the body, 303.0 by 63.5 mm. (13 by 3.5 inches); and capacity to the neck, 850 to 900 c. c. The jars were graduated to 780 c. c. and the length of the column determined for each jar. Suspension is expressed in percentage. The results at the end of 1, 2, and 3 hours are reported in Table 1.

Seven hundred and fifty cubic centimeters of the limewater were added to 30 c. c. of solution containing the required amount of copper sulphate for the different ratios. In most other cases, 663 c. c. of solution containing 7.49 gm. of copper sulphate were added to 117 c. c. of lime in suspension, containing the necessary amount of active lime for the different ratios. With precipitated lime and milk of lime the demands of the two highest ratios necessitated increasing their volume to 200 and 250 c. c., respectively, and reducing the volume of copper sulphate correspondingly. In American practice the composition of Bordeaux mixture is usually designated by figures such as 4-4-50, which signifies 4 pounds of copper sulphate and 4 of quick-lime in 50 gallons of mixture, and is substantially equivalent to 1 part (or 1 per cent) of each in 100. Some writers term such a mixture 1 per cent Bordeaux and indicate the proportion of lime by ratio 1:1. The former method is less confusing and is employed in the text. Owing to inability to control the reaction, considerable varia-
tion is inevitable in such tests. Average results therefore are reported, those tests that suffered appreciable decomposition being excluded, although by so doing a fictitious value is given those mixtures that were particularly susceptible.

### Table 1.—Ratio of volume of suspended Bordeaux to total volume of liquid, when different forms and proportions of calcium hydroxide were used

<table>
<thead>
<tr>
<th>No.</th>
<th>Bordeaux mixture</th>
<th>Limewater</th>
<th>Precipitated lime</th>
<th>Milk of lime</th>
<th>Hydrated lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-0.672-50</td>
<td>73.8</td>
<td>39.8</td>
<td>32.3</td>
<td>87.0</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>78.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>71.7</td>
</tr>
<tr>
<td>2</td>
<td>4-0.720-50</td>
<td>65.3</td>
<td>36.1</td>
<td>28.2</td>
<td>80.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62.3</td>
</tr>
<tr>
<td>3</td>
<td>Neutral:</td>
<td>95.6</td>
<td>91.0</td>
<td>86.1</td>
<td>96.6</td>
</tr>
<tr>
<td></td>
<td>4-0.808-50</td>
<td></td>
<td></td>
<td></td>
<td>93.2</td>
</tr>
<tr>
<td></td>
<td>Alkaline:</td>
<td></td>
<td></td>
<td></td>
<td>90.1</td>
</tr>
<tr>
<td>4</td>
<td>4-1.000-50</td>
<td>92.2</td>
<td>84.6</td>
<td>71.1</td>
<td>97.2</td>
</tr>
<tr>
<td>5</td>
<td>4-1.500-50</td>
<td>78.8</td>
<td>63.3</td>
<td>46.6</td>
<td>97.6</td>
</tr>
<tr>
<td>6</td>
<td>4-2.000-50</td>
<td>34.0</td>
<td>23.9</td>
<td>18.9</td>
<td>97.3</td>
</tr>
<tr>
<td>7</td>
<td>4-2.250-50</td>
<td>29.3</td>
<td>20.6</td>
<td>16.3</td>
<td>97.2</td>
</tr>
<tr>
<td>8</td>
<td>4-2.500-50</td>
<td>27.0</td>
<td>19.0</td>
<td>15.0</td>
<td>97.1</td>
</tr>
<tr>
<td>9</td>
<td>4-3.000-50</td>
<td>22.4</td>
<td>15.0</td>
<td>11.9</td>
<td>97.1</td>
</tr>
<tr>
<td>10</td>
<td>4-4.000-50</td>
<td>16.8</td>
<td>11.3</td>
<td>8.2</td>
<td>96.6</td>
</tr>
<tr>
<td>11</td>
<td>4-6.000-50</td>
<td>12.5</td>
<td>8.0</td>
<td>6.2</td>
<td>92.1</td>
</tr>
<tr>
<td>12</td>
<td>4-8.000-50</td>
<td>9.4</td>
<td>6.6</td>
<td>4.9</td>
<td>89.1</td>
</tr>
</tbody>
</table>

With limewater the concentration of copper sulphate varied from 0.647 gm. in 100 c. c. in No. 1 to 0.054 gm. in 100 c. c. in No. 12. No. 1 gave a light blue, flocculent precipitate; No. 2 a fairly gelatinous, blue precipitate, and No. 3 a full blue, gelatinous precipitate with the highest suspension. In Nos. 4 to 12 the color and suspension gradually decreased. None of these mixtures decomposed within three hours.

With chemically precipitated calcium hydroxide the mixture 4-0.672-50 (No. 1) yielded a light blue, flocculent precipitate, increasing to a full blue, gelatinous precipitate in the mixtures 4-1-50 (No. 4) and 4-1.5-50 (No. 5). No. 5 showed a slightly higher suspension. In Nos. 6 to 12 the color and suspension gradually decreased, although the difference in suspension between the mixtures 4-0.808-50 No. 3) and 4-4-50 (No. 10) was negligible, evidently on account of the high dispersion of the lime. None of the mixtures of this series suffered decomposition within three hours.

With milk of lime the mixture 4-0.672-50 (No. 1) gave a light blue, coarse, flocculent precipitate, increasing to a full blue, gelatinous precipitate in the mixture 4-1.5-50 (No. 4) and 4-1.5-50 (No. 5). The higher suspension was generally obtained with a 4-2-50 mixture (No. 6) or occasionally with a 4-2.5-50 mixture (No. 7). In Nos. 8 to 12 the color and suspension gradually decreased, although the difference in suspension between the mixtures 4-0.808-50 (No. 3) and 4-4-50 (No. 10) was inappreciable when the lime was properly prepared. On warm days decomposition sometimes occurred in the third hour with a 4-3-50 mixture (No. 9) and more frequently in the second or third hour with the mixtures 4-4-50 (No. 10), 4-6-50 (No. 11), and 4-8-50 (No. 12). On the average, milk of lime proved nearly as satisfactory as precipitated lime but judging from the color and suspension, was less active, far more variable, and in some instances, even erratic.
With dry, hydrated lime the full blue precipitate and the highest suspension were obtained with the mixture 4–2–50 (No. 6). The product was less efficient than milk of lime, but the mixtures 4–1–50 (No. 4) to 4–2.5–50 (No. 8) gave satisfactory results, considering the quality of the hydrate employed. Occasionally a test broke down in the second or third hour.

With all four forms of calcium hydroxide, No. 1 precipitate was of a light or greenish-blue color, and of a flocculent rather than a gelatinous character. The presence of any soluble copper was accompanied by reduced suspension. No. 2 was slightly darker in color and somewhat flocculent. Nos. 1 and 2 were rather inferior for spraying purposes. Lime in excess of the mixture 4–2–50 tends to drag down the precipitate, especially when coarse particles are present. With limewater, No. 3 was preferable, probably on account of the greater dilution.

The foregoing results conform essentially to the relative activity of the different forms of calcium hydroxide employed. Limewater is the most active, as the material is entirely soluble and partly ionized. Precipitated lime, a resultant of chemical precipitation, is finely divided and uniform and approaches limewater in activity. The activity of milk of lime varies with the quality of the quicklime and the thoroughness of slaking. The particles are naturally larger than those of precipitated lime. Commercial hydrated lime is extremely variable, both in composition and in the size and character of the particles, but it is reasonable to suppose that a high-grade product would approach freshly slaked lime in activity and assure even more uniform results in general use.

INFLUENCE OF METHOD OF MIXING

The effect of the method of mixing is important and must also be considered. There are 12 or more methods with innumerable modifications, for mixing solutions of copper sulphate and lime in suspension. At least three concentrations, i.e., concentrated, equal volume, and dilute, are feasible without subsequent dilution for each procedure, copper into lime, and lime into copper.

PROCEDURE AND RESULTS

The methods of mixing are as follows:

<table>
<thead>
<tr>
<th>Method</th>
<th>Volume per cent</th>
<th>Volume c.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Concentrated copper into dilute lime</td>
<td>15 : 85</td>
<td>117 : 663</td>
</tr>
<tr>
<td>2. Equal volume of copper into lime</td>
<td>50 : 50</td>
<td>390 : 390</td>
</tr>
<tr>
<td>3. Dilute copper into concentrated lime</td>
<td>85 : 15</td>
<td>663 : 117</td>
</tr>
<tr>
<td>4. Concentrated lime into dilute copper</td>
<td>15 : 85</td>
<td>117 : 663</td>
</tr>
<tr>
<td>5. Equal volume of lime into copper</td>
<td>50 : 50</td>
<td>390 : 390</td>
</tr>
<tr>
<td>6. Dilute lime into concentrated copper</td>
<td>85 : 15</td>
<td>663 : 117</td>
</tr>
<tr>
<td>7. Concentrated copper and dilute lime poured simultaneously into a third receptacle</td>
<td>15 : 85</td>
<td>117 : 663</td>
</tr>
<tr>
<td>8. Equal volumes of copper and lime poured simultaneously into a third receptacle</td>
<td>50 : 50</td>
<td>390 : 390</td>
</tr>
<tr>
<td>9. Dilute copper and concentrated lime poured simultaneously into a third receptacle</td>
<td>85 : 15</td>
<td>663 : 117</td>
</tr>
<tr>
<td>10. Concentrated copper into concentrated lime and diluted</td>
<td>30 : 30 : 40</td>
<td>234 : 234 : 312</td>
</tr>
<tr>
<td>11. Concentrated lime into concentrated copper and diluted</td>
<td>30 : 30 : 40</td>
<td>234 : 234 : 312</td>
</tr>
<tr>
<td>12. Concentrated copper and concentrated lime poured simultaneously into a third receptacle and diluted</td>
<td>30 : 30 : 40</td>
<td>234 : 234 : 312</td>
</tr>
</tbody>
</table>
The volume ratios, 15 : 85 and 30 : 30 : 40, etc., are purely arbitrary, but serve to illustrate the principle involved. As in the previous experiment, rubber-stoppered museum jars were used in making the tests. The Bordeaux mixture was prepared with milk of lime from carefully slaked lime and the mixture 4-4-50 was generally employed as the basis for comparison since the mixture 4-2-50 proved less discriminating. The other forms of calcium hydroxide might also have been included, but were not considered necessary.

**Table 2.** Ratio of volume of suspended Bordeaux to total volume of liquid, when different methods of preparation were used

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Bordeaux mixture, 4-4-50, first series</th>
<th>Bordeaux mixture, 4-4-50, second series</th>
<th>Bordeaux mixture, 4-2-50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All tests</td>
<td>Excluding tests that decomposed within 3 hours</td>
<td>All tests</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>2 hours</td>
<td>3 hours</td>
</tr>
<tr>
<td>1</td>
<td>88.2</td>
<td>57.9</td>
<td>50.3</td>
</tr>
<tr>
<td>2</td>
<td>96.5</td>
<td>58.6</td>
<td>78.0</td>
</tr>
<tr>
<td>3</td>
<td>97.2</td>
<td>89.3</td>
<td>91.5</td>
</tr>
<tr>
<td>4</td>
<td>96.6</td>
<td>84.5</td>
<td>75.1</td>
</tr>
<tr>
<td>5</td>
<td>95.9</td>
<td>81.3</td>
<td>72.1</td>
</tr>
<tr>
<td>6</td>
<td>74.4</td>
<td>50.8</td>
<td>44.5</td>
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<td>7</td>
<td>96.4</td>
<td>90.2</td>
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<td>8</td>
<td>95.8</td>
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<td>70.5</td>
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<td>96.9</td>
<td>93.6</td>
<td>90.4</td>
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<tr>
<td>10</td>
<td>95.2</td>
<td>85.6</td>
<td>76.5</td>
</tr>
<tr>
<td>11</td>
<td>95.8</td>
<td>77.9</td>
<td>70.5</td>
</tr>
<tr>
<td>12</td>
<td>95.1</td>
<td>74.8</td>
<td>62.9</td>
</tr>
</tbody>
</table>

*a Blanks in this column indicate no decomposition. Results are as in “all tests.”

In the first series reported the milk of lime was not as carefully screened in every case nor the mixtures as thoroughly agitated as in later practice. As a result the differences between the several members of the series are increased. Apparently all tests below 60 per cent suspension must have suffered more or less decomposition, but none of them were excluded from the average in this series. Of the nine methods tested, dilute copper into concentrated lime (No. 3) gave the best suspension, and dilute lime into concentrated copper (No. 6) the poorest; an equal volume of copper into lime (method No. 2) was preferable to an equal volume of lime into copper (No. 5); and concentrated copper into concentrated lime and diluted (method No. 10) was better than concentrated lime into concentrated copper and diluted (No.11); but concentrated copper into dilute lime (method No. 1) was much inferior to concentrated lime into dilute copper (No. 4). From the above results it follows that suspension varied inversely with the amount of lime in solution when mixed. Copper into lime (methods Nos. 1, 2, 3, and 10) proved superior to the reverse procedure (methods Nos. 4, 5, 6, and 11), except in the case of concentrated copper into dilute lime (method No. 1), previously noted. Whether a small quantity of lime in solution favors the formation of a lower basic sulphate in the primary reaction or a basic sulphate of
a higher hydration, or whether the degree of fineness of the lime particles is the deciding factor by controlling the speed of reaction, or by reducing the drag on the precipitate when added to the copper solution, is uncertain; but the resulting gelatinous precipitate was more bulky and settled more slowly. Considering the data as a whole, method No. 3 gave the best suspension, with little choice between methods Nos. 2, 10, and 4 or between Nos. 5 and 8, while methods Nos. 11, 1, and 6 were the poorest. Method No. 3, requiring the addition of cold, sufficiently dilute copper sulphate to cold, concentrated milk of lime to make the required volume, and thorough agitation, was the most dependable, and as simple and practical a procedure as any.

With the elimination of coarse particles from the milk of lime (see p. 678), immediate and thorough agitation after mixing, and a tolerance of 1 per cent in rating, substantially uniform, average suspensions were obtained in the second 4–4–50 mixture series from dilute copper into concentrated lime (method No. 3), dilute copper and concentrated lime into a third receptacle (method No. 9), concentrated lime into dilute copper (method No. 4), equal volume of copper into lime (method No. 2), equal volume of copper and lime into a third receptacle (method No. 8), and equal volume of lime into copper (method No. 5); but inferior and more or less unstable mixtures were secured from concentrated copper and dilute lime into a third receptacle (method No. 7), concentrated copper into dilute lime (method No. 1), and dilute lime into concentrated copper (method No. 6), increasing in the order named; also, concentrated copper into concentrated lime and diluted (method No. 10), concentrated lime into concentrated copper and diluted (method No. 11), and concentrated copper and lime into a third receptacle and diluted (method No. 12), increasing in the order named. Dilute copper (methods Nos. 3 and 9) proved slightly superior to an equal volume (methods Nos. 2 and 8) and decidedly more efficient than concentrated copper (methods Nos. 1 and 7) whether poured directly into the lime or simultaneously into a third receptacle. Copper and lime poured simultaneously into a third receptacle (methods Nos. 7, 8, 9, and 12) was slightly more efficient than copper into lime (methods Nos. 1, 2, 3, and 10) except in the case of concentrated copper into concentrated lime and diluted, and concentrated copper and concentrated lime poured into a third receptacle and diluted (methods Nos. 10 and 12).

From the above it will be seen that the line of demarcation between dilute copper and an equal volume of copper and between concentrated lime and an equal volume of lime, from copper into lime or lime into copper, or both into a third receptacle, is not significant; but that the demarcation is apparent between an equal volume of copper and concentrated copper, and between an equal volume of lime and dilute lime by all three procedures, and also between copper into lime and lime into copper. The limiting factors noted in the first series of Bordeaux mixture, 4–4–50, probably prevail in the second, but with a more uniform and highly dispersed milk of lime their influence is more difficult to perceive. Possibly with a more highly dispersed milk of lime, if such could be prepared, these differences might in turn become even less perceptible. The rapidity with which the several mixtures decomposed is an additional characteristic to be
noted. A part of the tests by methods Nos. 10 and 11 broke down in the third hour, by No. 12 in the second or third hour, and by No. 1 in the second hour; and all the tests by method No. 6 in the first or second hour.

The results with 4–2–50 Bordeaux are higher and less discriminating than with 4–4–50, second series, except in methods Nos. 11 and 12, but otherwise serve to substantiate what has been said. A part of the tests by methods Nos. 11 and 12 decomposed in the second hour. The decomposition of Bordeaux mixture is manifested by a gradual loss of gelatinous character, more rapid settling, spurting of the mixture and the slow acquisition of a purplish color. The final dense aggregates are said to be sphaerocrystals. Decomposition increases with copper content, ratio of lime to copper sulphate, mixing of concentrated copper and dilute lime or of concentrated copper and concentrated lime and diluting, and with temperature, as previously shown.

RESULTS OBTAINED BY OTHER INVESTIGATORS WITH DIFFERENT METHODS OF MIXING

Other investigators (Table 3) have noted the effect of different methods of preparation on the suspension of Bordeaux mixture, and some of their results are cited although not strictly comparable. Butler (2, p. 161) found that a concentrated milk of lime (low amount of lime in solution) favored suspension but was not in agreement as to the relative efficiency of the several methods. Pickering (1, p. 53) showed that copper into lime was preferable to lime into copper. For some reason not apparent the writers obtained far better results on mixing concentrated solutions and diluting than Butler, Jones (6, p. 91), Pickering, and Warren and Voorhees (20, p. 233).

<table>
<thead>
<tr>
<th>Table 3.—Ratio of volume of suspended Bordeaux to total volume of liquid by other investigators when different methods of preparation were used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
</tr>
<tr>
<td>Per cent</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
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<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

* For specific reference to the work of these investigators see "Literature cited," p. 685.

While the fungicidal activity of Bordeaux mixture is said to be inversely proportional to the amount of lime in excess of that required for complete precipitation of the copper, its efficiency as a whole is largely dependent on the degree of dispersion and other physical characteristics as determined by suspension, which is undoubtedly the simplest and most practical method of evaluation.
SUMMARY

Four forms of lime (limewater, chemically precipitated lime, milk of lime, and commercial hydrated lime) were employed in preparing Bordeaux and allied mixtures. The activity varies directly as the degree of dispersion and decreases in the order named.

The best ratios of active lime in the several forms to copper sulphate, as judged by suspension, are as follows:

- **Limewater**: 0.538 gm.-0.109 gm.-100 c. c.
- **Precipitated lime**: 4 pounds-1.50 pounds-50 gallons.
- **Milk of lime**: 4 pounds-2.00 or 2.25 pounds-50 gallons.
- **Hydrated lime**: 4 pounds-2.00 pounds-50 gallons.

The best method of mixing, similarly judged, is by pouring dilute copper into concentrated lime or the two simultaneously into a third receptacle.

Some of the better grades of hydrated lime are promising substitutes for milk of lime but require soaking before being used.

LITERATURE CITED

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