

A COPPER EMULSION AS A FUNGICIDE.

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(With Plate XI.)

IN the report of the Agricultural and Horticultural Research Station, Long Ashton, for 1917, A. H. Lees described methods of preparing an emulsion containing copper by mixing a solution of copper sulphate with soap solutions.

In conjunction with other experiments, a very similar emulsion was made and used at Wye early in 1917. Since the observations made at Wye as to the nature of this emulsion corroborate those of Mr Lees, and since additionally the fungicidal properties of this emulsion have been examined, it seems desirable to record the work so far done, although further experiments must be carried out before an emulsion of this kind can be recommended as a practical spray fluid.

The emulsion prepared at Wye contained rather more copper than that made by Mr Lees. It contained the equivalent of 0.4 per cent. copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) and 2 per cent. of soft soap¹ and was made by pouring slowly a 0.8 per cent. solution of copper sulphate into an equal volume of 4 per cent. soft soap solution, stirring well all the time. The emulsion made in this way did not settle, even on standing for several weeks; it could not be filtered and turned chocolate colour on addition of potassium ferrocyanide. When the soap solution was added to the copper solution a quite different result was obtained, and instead of an emulsion (probably of copper stearate in part) green sticky masses having a putty-like consistency were formed.

In order to determine whether the emulsion made as above described possessed fungicidal properties, the following experiment was carried out on August 8, 1917.

Fresh potato shoots were brought into the laboratory, cut under water and placed with ends in water in flasks the mouths of which were under water. On each of two shoots, three leaves at successive nodes were

¹ The soap used throughout these experiments is that sold under the name of "Chiswick Soft Soap."

selected; the uppermost and lowest leaves were sprayed with freshly made copper emulsion by means of an atomiser and the middle leaf left unsprayed. When the sprayed leaves were dry, drops of distilled water containing motile zoospores of *Phytophthora infestans* were placed on all three leaves by means of a platinum loop, two drops being placed on each side of the midrib of the lower side of the terminal leaflet and the second pair of leaflets in each case. The zoospores were obtained by placing affected leaves with ends in water under a bell jar on the previous day and leaving overnight. From one to two hours before the zoospores were required, the portions of the leaves bearing sporangiophores were brought in contact with a few drops of distilled water in a watch glass; numerous sporangia became free in the water and zoospores were liberated within an hour.

Three days later, on August 11, there were black spots on both unsprayed leaves but none on any of the sprayed leaves. On August 13, one of the sprayed inoculated leaves had fallen off so the observations were not continued.

On August 15, a second experiment was carried out on growing potato plants in the garden. Three healthy leaves were selected on successive nodes; two of these, the uppermost and lowest, were sprayed with freshly made emulsion and the other left unsprayed. About two hours after the leaves had been sprayed, there was a heavy thunderstorm lasting about ten minutes, so the leaves were not inoculated until the next morning. These were inoculated in the way described in the previous experiment.

On August 20, the unsprayed leaf showed seven distinct diseased spots though there were no spots on either of the sprayed leaves and on September 11, when the whole of the unsprayed leaf was destroyed, the whole of one of the sprayed leaves was quite uninjured; on the other sprayed leaf, one leaflet, though not one of those inoculated, was withered but otherwise the leaf was quite green and uninjured. On this date, the shoot was removed from the plant and photographed (see figure).

The two lowest leaves shown in the photograph had become naturally infected; the two healthy leaves seen on the right had been sprayed with the emulsion and then inoculated, and the diseased leaf occurring between the two healthy ones had been left unsprayed but had been inoculated.

The accompanying table shows in detail the observations made on the inoculated leaflets.

Detailed observations of Experiment II.

Inoculated August 16		August 20	August 23	August 28	Sept. 11
Leaf a sprayed	terminal leaflet	no diseased spots	no diseased spots	no diseased spots	} Whole leaf uninjured
	left "	do. do.	do. do.	do. do.	
	right "	do. do.	do. do.	do. do.	
Leaf b unsprayed	terminal "	1 distinct spot of blight	1 spot 1 cm., another 0.3 cm. diam.	} All three leaflets destroyed	} Whole leaf destroyed
	left "	2 distinct spots of blight	The two spots have coalesced		
	right "	4 distinct spots of blight	Whole leaflet blackened and withered		
Leaf c sprayed	terminal "	no diseased spots	no diseased spots	no spots	no spots
	left "	do. do.	do. do.	do.	do.
	right "	do. do.	do. do.	do.	do.

On the same date as the last experiment, a plant with many badly diseased leaves was sprayed with the emulsion but the disease extended in all the affected leaflets.

From these experiments, it is evident that the emulsion acted as a preventive against infection by zoospores of *Phytophthora infestans* and justified trials on a larger scale.

Later in the year, two small plots of potatoes, each measuring approximately 120 sq. yds, were sprayed with the emulsion and on this occasion when tap water was used instead of distilled water hitherto employed in these experiments, a little difficulty was experienced in spraying the fluid owing to the accumulation in the nozzles of the sprayer of the green sticky substance referred to already.

At the time the crop was lifted the leaves of the sprayed plots were certainly much greener and showed far less damage by blight than those of the unsprayed control plot, but owing to the lateness of the appearance of the blight, all three plots had approximately the same low percentage of diseased tubers although the two sprayed plots showed a slightly greater total yield than the control plot.

In 1918, these trials were repeated and two more small plots, each approximately 36 sq. yds in area, were sprayed, the control plot of the same size being between them. On Plot I, the emulsion described (*i.e.* containing the equivalent of 0.4 per cent. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and 2 per cent. soft soap) was sprayed. On Plot III, an emulsion containing twice as much copper and twice as much soap was used. The plots were sprayed on August 7. Each plot received six gallons, applied by means

of a knapsack sprayer, and both emulsions were made with rain water and were applied in the usual way by a man accustomed to the work, but no unusual care was taken to effect complete treatment of the plot.

To make six gallons of emulsion for Plot I, three gallons of soap solution containing 1.2 lbs. (544.3 gms.) of soap were put in a perfectly clean wooden pail; 0.24 lb. (108.9 gms.) of copper sulphate was dissolved in three gallons of water and this solution was added slowly to the soap solution, which was stirred well all the time.

On August 19, both plots were sprayed again, each receiving six gallons as before. On this occasion both emulsions were made with tap water and Plot I was actually sprayed with emulsion made from tap water though a small amount of a putty-like substance was formed; this remained in the strainer and the whole of the spray went on satisfactorily. In the case of the stronger emulsion, a mass of green "putty" was formed, clogging up the tube and nozzles of the sprayer, even after straining, which was a very long process; this was therefore rejected, the sprayer thoroughly cleaned and the emulsion made again with rain water. Although some "putty" was formed, the emulsion which was put on Plot III contained considerably more copper than that put on Plot I.

The green putty-like substance has strongly adhesive properties and some method has yet to be found for retaining all the copper in the emulsified condition.

The effect of the spray on the leaves was most striking. The control plot began to blacken about three weeks before the sprayed plot showed any signs of being affected and on September 25, when the sprayed plots were still fairly green and healthy, not one green leaf could be seen on the control plot.

From the results given, it will be seen that the sprayed plots gave an appreciably higher yield than the unsprayed and the percentage of diseased tubers was much higher in the unsprayed plot than in either of the sprayed plots.

Plot I. Sprayed twice with an emulsion containing approximately the equivalent of 0.4 per cent. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

		%
Ware	63 lbs.	70.8
Chats	18½ „	20.8
Blight	7½ „	8.4
Total	89 „	

Plot II. Unsprayed.

		%
Ware	34 lbs.	61.8
Chats	13 „	23.6
Blight	8 „	14.5
Total	55 „	

Plot III. Sprayed twice with emulsion containing approximately the equivalent of 0.8 per cent. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

		%
Ware	72½ lbs.	81.9
Chats	13 „	14.7
Blight	3 „	3.4
Total	88½ „	

From these experiments, it would appear that the copper emulsion at the lower strength (containing the equivalent of 0.4 per cent. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and 2 per cent. soft soap) is an efficient preventive against blight when used on potato foliage, and when carefully prepared with rain water it can be applied without difficulty. Further experiments, however, are necessary, particularly with respect to its preparation when only hard water is available, before it can be generally recommended as a practical spray fluid. Although this fluid was originally prepared and examined from another point of view, on account of the small amount of copper used in its preparation and of its fungicidal value, it is worth while trying to overcome the difficulty experienced in making the emulsion under practical conditions. From an economic point of view, the large amount of soap required is partly compensated for by the small amount of copper necessary and the property of spreading over the foliage which soap gives to the fluid.

The fungicidal value of the emulsion, which contains much less copper than Burgundy or Bordeaux mixtures as commonly used, is probably due, in part, to the fact that the particles, owing to their extreme fineness, must come in intimate contact with the leaf surface and to the adhesive nature of the copper compound which it contains.

Summary. An emulsion containing the equivalent of 0.4 per cent. copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) can be made by mixing solutions of copper sulphate and soft soap, and this exhibits preventive action against the attacks of the potato blight fungus.



In conclusion, we should like to thank Dr Eyre, who indicated the possibility of preparing an emulsion by the method adopted, and at whose suggestion the above experiments were carried out.

DESCRIPTION OF PLATE XI

Photograph of potato shoot described on p. 201. The two healthy leaves seen on the right had been sprayed with copper emulsion and then inoculated with zoospores of *Phytophthora infestans*; the diseased leaf occurring between these had been left unsprayed and had been inoculated. The remaining leaves on the shoot had become naturally infected.