LATE BLIGHT AND ROT OF POTATOES

CAUSED BY THE

FUNGUS *PHYTOPHTHORA INFESTANS* (MONT.) DE BARY

BY

R. R. HURST
ASSISTANT PLANT PATHOLOGIST
DOMINION LABORATORY OF PLANT PATHOLOGY
CHARLOTTETOWN, P.E.I.

DIVISION OF BOTANY
H. T. GÜSSOW, Dominion Botanist

DOMINION EXPERIMENTAL FARMS
E. S. ARCHIBALD, Director

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Late Blight on Potato Leaves

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Caused by the fungus *Phytophthora infestans* (Mont.) de Bary

BY

R. R. HURST,

Assistant Plant Pathologist,

Dominion Laboratory of Plant Pathology,

Charlottetown, P.E.I.

INTRODUCTION

Late blight is unquestionably the most widely spread and oftentimes the most destructive disease affecting the potato. It is capable of destroying, with remarkable rapidity, the entire growth of the potato plant, and also of causing a very prominent tuber rot. It occurs in practically all potato growing sections of the world and, under favourable circumstances, has caused serious losses.

ECONOMIC IMPORTANCE

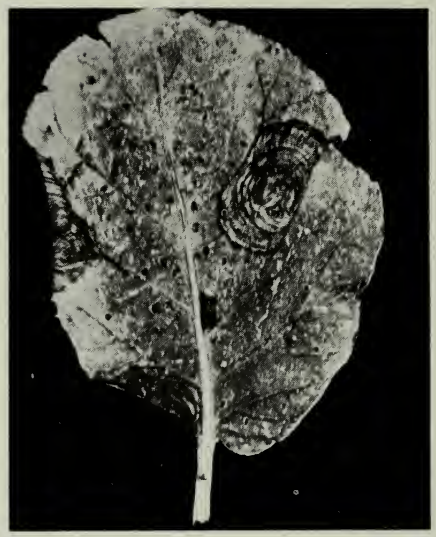
The average yield per acre of potatoes in Canada is approximately half what it should be. While this deficiency is due to several causes, late blight is often an important factor both because of the premature destruction of the tops and the rotting of tubers.

It has been shown* that, in unsprayed potato fields in Prince Edward Island, late blight was chiefly responsible for a reduction in yield to the extent of 130½ bushels per acre during a five year period of investigation. It is impossible to estimate the actual loss to growers, as enormous quantities of rotted tubers are graded out in the field, yet it happens commonly that, in localities where blight is a factor, as high as fifty per cent of the crop is rendered unmarketable by the action of blight. It is significant to note that, in the United States during the period of years from 1918 to 1921 inclusive, late blight accounted for a loss of seventy-five million bushels of potatoes. It is equally striking that, in regions where the disease is common, its control resulted in increased yields aggregating from 40 to 233 bushels per acre.

HISTORICAL SKETCH

This disease is known as the oldest potato malady. It attacks the wild forms in South America, the native home of the potato. Doubtless it has been a factor since potatoes were introduced into Europe in the sixteenth century. Early records show that in 1840 it was prevalent in France and Germany, while in 1844, it was particularly severe in Nova Scotia and New Brunswick. In 1845 the historical outbreak took place in Western Europe and the United States. In Ireland, where potatoes were so extensively grown, the resulting failure of the crop caused a famine and it was then that the disease became known as "Irish Potato Blight."

*Bulletin No. 44, page 7; Division of Botany.



A

B

FIG. 1.—(A) Early blight spot on potato leaflet showing the concentric rings. (B) Late blight on potato leaf. Concentric rings are never present. Note the lighter area showing the path of the invading organism. (Photo by S. G. Peppin).

OCCURRENCE AND SYMPTOMS

Late blight was so named because it is generally most active late in the growing season, and usually appears later than the leaf spot disease known as early blight. (See figure 1A). It may, however, do serious damage as early as July. In Canada it seldom develops until after the plants have produced flowers. This does not mean to say that the plant is not liable to attack before then, for, in countries where two crops are grown each season, the young second crop may contract the disease from the unharvested first crop.

Late blight may be recognized in its early stages by the appearance of dark brown dead or dying areas on the leaves (figure 1B). These areas commonly occur near the edge or tip of the leaf and spread inwards, the rate of advance depending upon weather conditions. The leaf stalk or even the main stem of the plant may be attacked. The immediate margin of the infected areas appears to be water-soaked, readily noticeable when the leaf is held against the light. This zone results from the actual permeation of the leaf substance by the invading fungus, the active progress of which is further indicated by a characteristic light green zoning which surrounds each blotch. On a dewy morning or during showery weather a careful study of the affected areas reveals a very delicate mildew or mould growing generally on the lower surface of the leaves. If moist weather continues after infection the disease soon involves the entire plant which rapidly decays, giving off the odour so characteristic of dying potato tops. At first very insignificant and affecting a leaf here and there, the danger is, therefore, not immediately realized, with the usual result that fields apparently healthy may totally succumb to the blight within twenty-four hours. According to the severity of blight present in a field a corresponding quantity of tubers become affected by a dry rot which is the tuber stage of late blight, and which actually appears in small purplish or brown discolorations of the skin. Immediately below the skin, a rusty spotting of the flesh is noticeable which later extends to one-half an inch in depth or so.

The affected parts of the tuber die and shrink causing irregular, depressed areas all over the surface (figure 2A). Upon cutting into such tubers the typical late blight rot is easily recognized (figure 2B). Late blight rot is essentially a hard rot and remains so, but wet soils and wet weather soon encourage other rot-causing microbes or moulds to invade the late blight infected areas and secondary, often very destructive rots result. In dry weather the disease progresses rather slowly and, when the crop is harvested, slightly infected tubers escape notice; but all of these are exposed to subsequent rots under unfavourable storage conditions, particularly to the types of so called dry or storage rots (figure 2C). Perfectly sound potatoes placed in proper storage rarely suffer from any of these rots.

THE CAUSE OF LATE BLIGHT

Late blight is caused by a microscopically minute, parasitic fungus. A fungus of this kind is simply a low form of plant life, more properly known as mould, which is unable to manufacture its own food and, consequently, has to rely upon its more fortunate, self-sustaining relations for support, whence the term, parasite. This mode of life on the part of the parasite results in a diseased condition of the plant hosts.

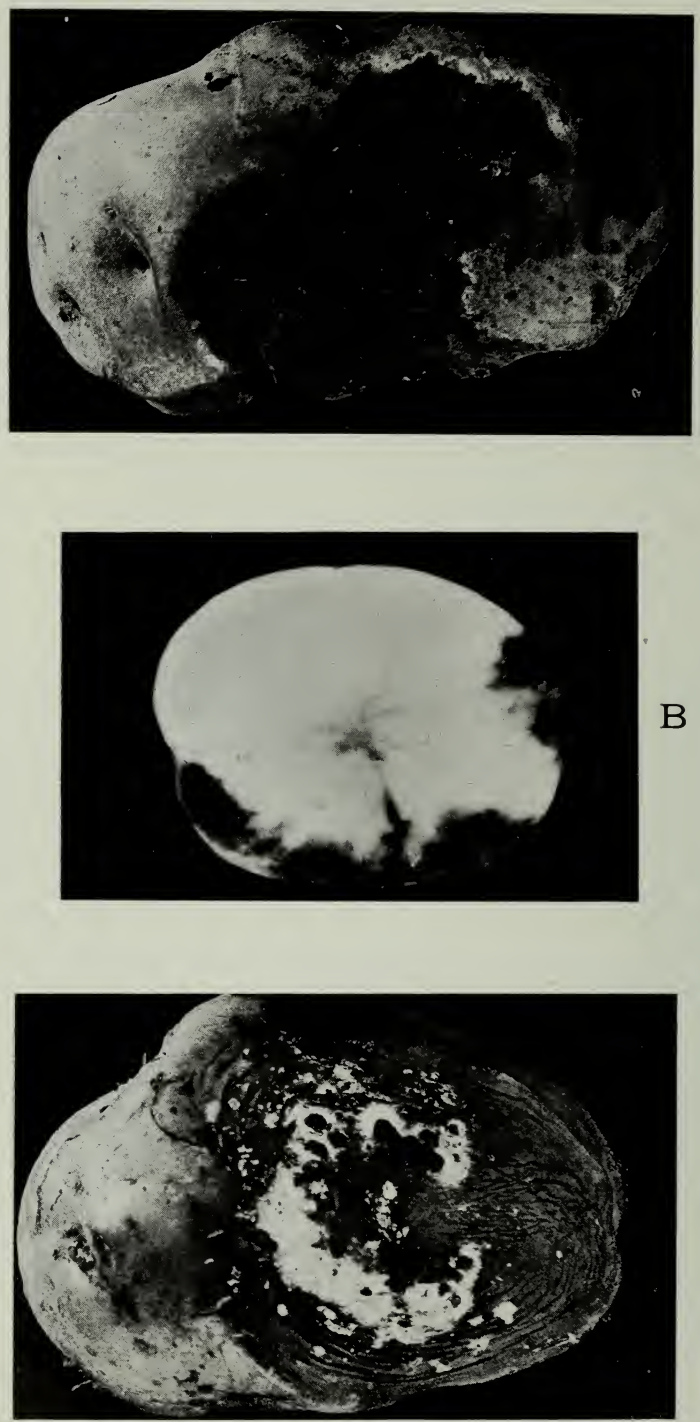


FIG. 2.—(A) Late blight tuber rot. (B) Cross-section of tuber showing discoloration caused by late blight. (C) Fusarium storage rot which frequently follows late blight rot. Note the wrinkles and mildew.

LIFE HISTORY OF THE CAUSAL ORGANISM

The fungus causing late blight enters and ramifies within the plant tissues where it obtains food. Eventually it again grows on to the surface from within, reappearing as a fine, cotton-like down, at the branched tips of which develop specialized egg-shaped spores (conidia) (figure 3). Although these spores and the stalks upon which they develop are exceedingly minute, they are so abundant that they are visible to the unaided eye in the form of the white mildew. Each of these spores contains several reproductive organs (zoospores) which, once free from the parent receptacle, swim about in drops of rain or dew on the leaves. In a very brief time they settle down and send out germ tubes which penetrate the leaves through the breathing pores on the lower surface. Once inside, these slender threads multiply rapidly and, by feeding upon the interior leaf tissues totally destroy these, causing the blight areas. When the supply of moisture is limited the spores may not produce zoospores but germinate directly and enter the leaves. In dry weather the spores die since they have no power to resist adverse conditions. Under moist conditions countless numbers are produced on a single leaf. It will be realized, therefore, how easily they will be carried to other plants by even the slightest wind, to start up with surprising rapidity new centers of infection throughout the field.

In addition to spreading the disease among the plants countless spores are washed into the soil by the rain, and, coming into contact with tubers, penetrate the skin and late blight rot results. The fungus then spends the winter in a semi-dormant stage within the infected tubers.

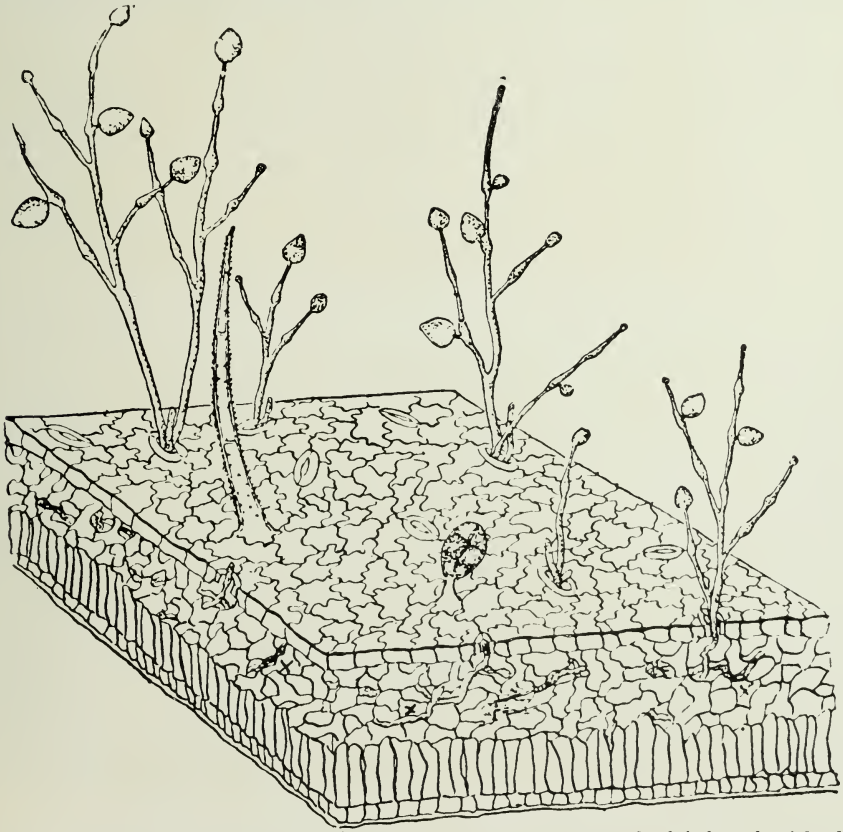


FIG. 3.—Diagramatic appearance of a section through a potato leaf infected with the late blight fungus. Note the fruiting strands emerging through the breathing pores. The egg-shaped bodies are the spores. The feeding strands of the fungus are marked "X".

OVERWINTERING OF THE FUNGUS

The facts concerning primary infection are not well established, but the theory is propounded that the fungus may live over in the soil and draw sustenance from decaying tubers or plants. There is, however, no conclusive evidence to support this view. Others believe that diseased sets contaminate the soil in which they are planted, the fungus later attacking the growing sprouts and ultimately producing infection of the plant. Opposed to this again is the view that the fungus present in diseased sets attacks the growing sprouts and, growing up within the plant, produces the spores responsible for the first outbreak. Striking evidence bearing upon this point was observed in 1928 at Charlottetown. A field seeded with Bliss Triumph stock showed a very poor stand in the early growing season. Upon examination it was demonstrated conclusively that the sets under the plants were, without exception, infected with the late blight organism. Many of them had rotted away, while others eventually decayed without even producing sprouts. Furthermore, late blight spots were observed upon stunted plants during the first week in July, thus associating the infection symptoms with the diseased sets from which the plants developed. It is a much debated question whether the fungus grows within the plant or develops in the surrounding soil to produce spots upon the surface. If the former theory were correct all plants from infected sets would contract the disease, but this did not appear to be the case.

Another theory occupying the attention of eminent investigators is the possible development of underground resting spores (oospores), which resist the winter conditions and reproduce the fungus the following season.

Apart from these considerations it is apparent that the organism responsible for this disease spends the greater part of its existence within the plant tissues, and is thus reasonably safe from harm. To be successfully combated, remedial methods must be preventive rather than curative, and upon this principle are based the control measures here recommended.

CONTROL

SPRAYING

The application of Bordeaux mixture* during the growing season will control late blight, for, if the vines are kept free from the disease, the tubers will not rot. It has been the regrettable experience of many potato growers that late blight causes more than a fifty per cent loss of the crop; and this loss spraying would have prevented (figure 4). Spraying is most effective when sufficient applications are made to keep the new growth covered. For this reason it is of utmost importance to make the first application when the plants are about six inches high, and again every ten days throughout the growing season. While the frequency of applications is determined largely by weather conditions, the only safe way, in districts subject to the blight, is to spray often and until late in the season. The plants may be injured by the machine and horses but losses from these are insignificant when compared with losses from blight. Spraying will not check the growth of the blight once infection takes place, hence the object in view is to prevent infection by making the first application before blight develops and by keeping the entire plant thoroughly covered with the chemical throughout the growing season.

If the best results are to be obtained, spraying must be done thoroughly and, in cloudy or rainy weather, it is advisable to spray oftener than every ten days, since infection and spread are favoured by these conditions. It is better to apply the Bordeaux spray before rain than after, as, once dried on the leaves, it does not wash off so readily.

*Directions for the preparation of Bordeaux are given at the end of this bulletin.

FIG. 4.—A field of unsprayed potatoes showing the effect of late blight on the plants. Note especially the areas in the foreground and in the upper right half of the field. Careful spraying with Bordeaux would have prevented this. (Photo by S. G. Peppin.)

FIG. 5.—Spraying potatoes on a 30-acre field. This type of traction machine is well suited for spraying large acreages. Note the fog-like spray and convenient boom. (Photo by courtesy of D. J. MacLeod, Fredericton, N.B.)

The first requisite is an efficient spraying machine. Where large areas are to be sprayed the most satisfactory results are obtained by the use of horse-power sprayers capable of maintaining an even air pressure of at least 150 to 200 pounds. This type is illustrated in figure 5. Such a machine sprays four rows and should have three nozzles for each row, one pointing downwards while the other two direct the spray upwards between the rows. The best nozzles emit a fog-like spray with considerable force and do not clog easily. Besides having convenient adjustments the boom should handle easily and not catch on gates or posts.

Spraying is done most efficiently when the rows are not less than thirty inches apart. When the plants are small 100 pounds pressure is sufficient, but as they grow the pressure should be increased, and eighty to one hundred gallons of Bordeaux applied to the acre.

Machines have a tendency to lose pressure at the ends of the rows, so that the plants in these areas are not properly sprayed. This may be remedied by skipping every four rows going one way and spraying these on the return trip. In this manner the sprayer covers a sufficient distance on the turn to maintain the pressure.

A small hand-pump, or a horse-drawn barrel sprayer holding forty gallons is suitable for small areas. A good pump capable of maintaining high pressure should be the first consideration. For garden lots hand-barrow pumps holding approximately fifteen gallons are very suitable.

Spraying is a matter of cheap insurance. Half-way measures bring poor results and mean waste of time, labour, and material. Thorough spraying promotes higher yields and disease control. This being so the farmer can devote a smaller acreage to the production of potatoes and with the consequent economy of time, labour, and material, the production costs will be less per bushel and the profit greater.

DUSTING

Copper-lime dust has lately been used to control blight instead of the liquid Bordeaux. Advocates of this method draw attention to the decreased labour cost, reduced depreciation on machinery, ease and timeliness of operation and application, as well as the control of blight and insects.

We are all anxious to see the burden lightened and will welcome any advances in the present well-established practices to control blight. Investigations at Charlottetown have demonstrated that dusting compares favourably with liquid spraying except in bad blight years. On these occasions dust has not proved satisfactory. At Fredericton in 1928 the results were in favour of Bordeaux spray as will be seen by an examination of table 1.

In using dust for blight control certain hints are of value, as follows:—

1. Insure the maximum discharge by preventing the dust from "caking" in the bottom of the hopper or in the entrance to the delivery pipe.
2. A cloth curtain attached to the rear of the dusting machine and trailing over and behind the nozzles, helps to confine the dust to the plants.
3. Applications should be made after sun-down, or early in the morning, before the dew dries off the plants.
4. In driving, turn away from the dust. Begin on the side of the field away from the wind and at the end of each row turn out of the cloud of dust which has just been discharged. This precaution will add greatly to the comfort of the operator and team.

Twenty to twenty-five pounds of dust is the usual application though the amount will vary with the product available. Remember that dusting operations must be as carefully performed as those for spraying. The human element has much to do with success or failure.

TABLE I* DUSTING VS. SPRAYING

(Comparison)

Fungicide spray or dust	Percentage late blight on vines			Percentage late blight on tubers	
	Slight	Moderate	Severe	Weight	Number
	%	%	%	%	%
Copper-lime dust (20-80)	2·6	9·6	68·4	2·9	3·4
Bordeaux spray (4 : 4 : 40)	5·2	13·7	46·6	1·3	1·4
Check (poison only)	0·0	3·8	96·2	3·6	3·4

* Data supplied by D. J. MacLeod, Plant Pathologist, Fredericton, N.B.

DUSTING VS. SPRAYING

(Application and yield)

TABLE II

Spray or dust	Number of applications	Total metallic copper per acre	Yield per acre
		lb.	bush.
Copper-lime (20 : 80)	6	13·63	294·1
Bordeaux spray (4 : 4 : 40)	6	14·71	304·8
Check (poison dust)	2	.....	131·0

While spraying with Bordeaux mixture is the most effective means of preventing losses from blight, there are other very beneficial measures to be taken:—

1. DELAY IN DIGGING.—It is known that the summer spores are short-lived but may remain alive in the soil for a period of at least ten days. Furthermore, much of the tuber infection appearing in storage takes place at digging time, especially where the tops are badly diseased. Therefore, digging operations should be delayed for ten days, or as long as is consistent with weather conditions. By this time most of the loose spores will have died and tubers already infected will have advanced to the stage where they may readily be seen and discarded. Tubers not infected at this time are likely to remain sound.

2. DESTRUCTION OF DISEASED TOPS.—Destruction of blighted tops at the end of the growing season is to be recommended. If the plants have not received applications of Bordeaux they may be killed by spraying with bluestone at the rate of 10 pounds to 40 gallons of water. Where Bordeaux has been applied the amount of bluestone should be increased.

3. STORAGE.—Late blight rot does not commonly spread from tuber to tuber in storage. However, under poor storage conditions, this injury paves the way for organisms producing other rots that do spread in storage and cause heavy losses (figure 2C). Dry, cool storage, not higher than 40° F., is necessary to retard the development of blight rot.

Before placing in storage the crop should be allowed to sweat in a pile for a few days when any infected tubers may be detected and discarded.

In such localities as Thunder Bay and Rainy River, where potatoes are pitted for at least a short period in the autumn, it is a common practice to cover the tubers with potato tops. This practice is to be discouraged, because the healthy tubers will contract blight from the diseased tops.

4. Selection of Seed.—Care should be used in selecting sound seed. It is important to discard tubers showing late blight infection, and thus to prevent the disease being carried to the field.

5. Resistant Varieties.—Certain varieties of potatoes are known to be resistant to blight, some being practically immune. This is particularly true of some European varieties; while the Canadian varieties are mostly very susceptible. At the Charlottetown Laboratory, foreign and Canadian varieties, along with a number of seedlings, are being investigated with a view to obtaining a desirable commercial blight-resistant type.

PREPARATION OF BORDEAUX MIXTURE

Bordeaux mixture is made by combining solutions of bluestone and milk of lime in dilute proportions, according to the following formula:—

Bluestone (copper sulphate)	4 pounds
Quick lime (stone lime)	4 pounds
Water	40 gallons

High grade hydrated lime may be substituted for quick lime, though on account of variations in the grades on the market it is sometimes difficult to know the amount to use. The logical plan is to insist upon the best grade and use 6 pounds to 40 gallons. It should be left to stand several hours in the form of a thin paste before using.

A valuable aid to the preparation of Bordeaux is a platform for supporting the vats containing lime and bluestone solutions. It should be constructed near the water supply, and be of sufficient height to necessitate little effort when filling the sprayer. Everything going into the spray tank should be most carefully strained, for, if this precaution is neglected, clogging of the nozzles is certain to follow. Bluestone or Bordeaux should never be stored in iron containers.

In preparing Bordeaux it is advisable to make a " Stock Solution " of Bluestone in this manner:—

Forty pounds of bluestone are dissolved in a 40 gallon cask of water. It dissolves more readily if suspended in a sack near the surface of the water. A gallon of the liquid will contain one pound of bluestone. Place a cover on the cask to keep out rain and to prevent evaporation.

A Stock Lime Solution is then made, by placing 40 pounds of the best grade of stone lime in a cask and slaking it. Add water very gradually when slaking in order not to " drown " the lime; the slower the action the better will be the final product. After the lime is completely powdered water is added to make up 40 gallons. One gallon of this will contain one pound of lime. Cover this cask also.

In making the mixture *never mix the stock solutions of lime and bluestone and dilute afterwards.* Either of the following methods may be adopted with satisfactory results:

A. To prepare 80 gallons of mixture pour 64 gallons of water into the spray tank. Then stir the stock solutions thoroughly. Now add 8 gallons of the stock solution of bluestone, and stir in 8 gallons of the stock milk of lime. *As specified previously, strain everything that goes into the tank.* If smaller quantities are required simply take one-half of the above amounts to make 40 gallons of spray. For 10 gallons mix one gallon of the bluestone solution and one gallon of milk lime in the manner just outlined.

B. While the method just described is satisfactory the following is even more desirable.

Late Blight Tuber Rot

To make 80 gallons of Bordeaux stir the stock solutions and pour 8 gallons of the bluestone solution into a 40 gallon cask and fill it up with water. Then put a like amount of milk of lime into another 40 gallon cask and fill it with water. The solutions are now ready to mix. This is done most conveniently if the casks containing the stock and diluted solutions are placed upon an elevated platform. The casks containing the diluted solutions are fitted previously with a hose. The operation is completed when the contents of both are poured simultaneously into the spray tank. A convenient way to do this is illustrated in figure 6.

FIG. 6.—A convenient and reliable method of mixing Bordeaux. Bluestone and lime in the proper proportions and dilutions are poured through a cloth strainer simultaneously into the spray tank. (Photo by S. G. Peppin.)

For very small plots smaller amounts may be made as follows:

Dissolve a quarter of a pound of bluestone in 5 quarts of water. Slake a quarter of a pound of stone lime and make up to 5 quarts with water. When ready to spray pour these two solutions at one time into the spray container.

Strengthening Bordeaux by using more bluestone than the specified amount is not recommended. If greater efficiency is desired increase the pressure and go back over the field from the opposite direction.

TEST FOR BORDEAUX

If the lime is not of a good grade, or too much bluestone is used, the mixture may be " too strong " in which case the foliage will scorch after being sprayed. For this reason a solution for testing the lime requirements of Bordeaux is prepared by dissolving half an ounce of potassium ferrocyanide in half a pint of water. The test consists of adding a few drops of this liquid to the mixture. If a distinctly brown colour appears, more lime is prepared to prevent burning of the plants.

Bordeaux mixture loses its strength if kept overnight. The stock solutions will keep indefinitely.

Insect poison may be added to the spray as required. One pound of Paris green along with four pounds of arsenate of lime in 80 gallons will control the Colorado potato beetle or bug. Bordeaux mixture controls flea beetles by its repelling action rather than as a poison.

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