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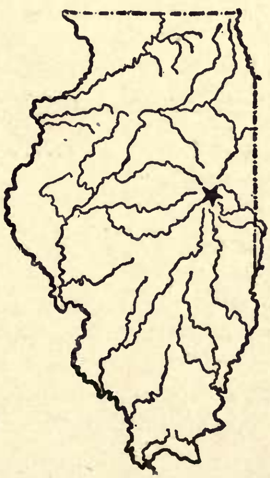
CARNATION STEM ROT AND ITS CONTROL

By GEORGE L. PELTIER



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Contents of Bulletin No. 223

CARNATION STEM ROT AND ITS CONTROL

By George L. Peltier, Associate in Floricultural Pathology[1]

INTRODUCTION

Carnation growing as a specialized industry in Illinois has assumed considerable proportions since its inception thirty years ago. It began in the vicinity of Chicago and the industry is still centered there. Other large establishments are scattered thruout the state, and no local florist is without a few benches of these plants. Accurate statistics are not available, tho it is a fair estimate to place the number of carnation plants grown in Illinois for the trade in a single year at five million in the field and three million under glass.[2] Allowing three-fourths of a square foot for each plant, the total number of plants under glass would represent an area of about two million square feet, which is approximately one-fifth the total area of glass in Illinois. It is thus evident that several millions of dollars are invested in the carnation industry in Illinois.

The carnation plant is attacked by a number of fungous diseases, several of which occasionally result in an appreciable loss to the grower. Perhaps the most serious of these is carnation stem rot. The following pages are devoted to a description of some experimental work undertaken by the author with the view of controlling this disease. A short discussion of the results, with recommendations, is given at the end of the bulletin.

Stem Rot in Illinois

Carnation stem rot is caused by the attacks of a soil fungus, *Rhizoctonia Solani* Kühn (*Corticium vagum* B. & C.).[3]

The disease is widely scattered thruout the state, in fact, it is present to some extent in every greenhouse where carnations are grown. The controlling influences in the occurrence of stem rot appear not to be due to unequal distribution of the fungus, but to be more closely related with climatic and edaphic conditions favorable to

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[1]Since September 1, 1916, Plant Pathologist, Ala. Agr. Exp. Sta., Auburn, Alabama.

[2]Based upon replies to a questionnaire sent in 1915 to all Illinois growers having 5,000 square feet of glass or more.

[3]A complete description of the general characters of this fungus, together with a historical account, its distribution, hosts, etc., will be found in Bulletin 189 of this station.

the spread and development of the fungus, together with the condition of the plant.

The losses from carnation stem rot are not often very great. However, under conditions favorable to the rapid development and spread of the fungus, it becomes a destructive parasite. Under such conditions, many cuttings may be destroyed in a short time and many plants also lost, both in the field and later in the benches. In isolated cases the loss may be as high as 50 percent of the cuttings. The percentage of loss may be equally high in the field and in benches. The average loss from season to season of course is much lower. From replies to questionnaires sent out by the writer to carnation growers in the state, it was learned that the percentage of loss varies from .1 percent to 20 percent, with an average of 2.2 percent in the greenhouse and 3.25 percent in the field. In two of the experimental houses at the Illinois Experiment Station the loss averaged nearly 2 percent a year for a period of five years (see Table 1).

TABLE 1.—LOSS FROM CARNATION STEM ROT IN THE EXPERIMENTAL HOUSES NOS. 1 AND 2, FOR A PERIOD OF FIVE YEARS

Season	Date of planting	No. of plants	Total loss	Percentage loss
1909–10	Sept. 9–13.	3200	33	1.03
1910–11	Sept. 9–12.	3200	27	.84
1911–12	Aug. 8–10.	3200	49	1.53
1912–13	Aug. 7–8.	3200	99	3.09
1913–14	Aug. 12–14.	3200	86	2.70

Practically all the soil used by the grower is inhabited to some extent by this fungus. The fungus is, in all probability, endemic, that is, it has not been introduced into the state with carnation plants but existed in the soils of Illinois before carnations were grown. This statement is supported by the fact that diseases due to the fungus are prevalent thruout the United States on many plants, and the fungus itself is found in many foreign countries.

The fungus may live purely as a saprophyte in the soil, getting its nourishment from dead organic materials, or it may be parasitic, that is, living on and getting its sustenance from growing plants. In a previous publication[1] the writer has shown that the fungus may attack a large group of plants, including vegetable and field crops, herbaceous plants, and weeds, besides many plants grown under glass.

The wide distribution, the many hosts, and the repeated reports of the destructiveness of the stem-rot organism prove very conclusively that it persists indefinitely under diverse conditions in arable

[1]Loc. cit.

soils. However, it is only when conditions are favorable for its development that it becomes an active parasite. Owing to this fact, it is not as serious as some of the Fusarium wilts, which once introduced into a locality, increase in severity each season until the growing of the crops attacked by them must be abandoned.

SYMPTOMS OF THE DISEASE

Stem rot may attack seedlings, cuttings, or mature plants. In all cases the symptoms are more or less alike. When seedlings become affected (a condition commonly known as ''damping-off''), lesions appearing as small brown spots are seen on the stem at the surface of the soil. The lesions increase in size, eventually almost girdling the stem and causing the collapse of the seedling. In severe cases the prostrate seedlings may later appear overgrown with a mat of brown strands made up of the mycelium of the fungus.

Cuttings are attacked several days after they have been placed in the sand. As in the case of seedlings, the cutting is attacked on the stem just above, or frequently just below, the surface of the sand. The leaves wilt, the cutting falls over, and a soft, wet, progressive rot may develop at the callus and extend to the surface of the sand, or lesions of various sizes may be formed at any point.

Stem rot occurs to some extent on the young plants in pots. The source of this infection is either in the use of diseased cuttings or of contaminated pots. On pulling up these plants it is found that stem rot usually starts from a small lesion which increases in size until the stem is girdled.

The symptoms shown by a mature plant attacked by the disease are very characteristic (Fig. 1). The fungus enters the stem at a point just below the surface of the soil. The foliage becomes pale, gradually losing the green color. In a few days or a longer period, depending upon the condition of the weather, this is accompanied by wilting. An examination of the stem at the surface of the soil reveals at this time a slimy, wet condition under the bark, which gives this rot its characteristic name. A slight twist is sufficient to slough off the bark and expose the harder tissues underneath. A plant at this stage may as well be pulled and removed, for it has been injured beyond recovery.

The fungus evidently enters the plant thru the cracks in the corky layer of the bark at a point near the surface of the soil. After passing thru the bark it attacks the growing layer of cells, the cambium. From this tissue the mycelium passes into the woody tissues and can be found even in the pith. It is at this time that wilting becomes evident. During later stages, sclerotia, which are small compact masses of mycelium, are formed on the center portions of the stem and these become quite evident to the unaided eye.

FIG. 1.—CARNATION PLANT SHOWING THE CHARACTERISTIC SYMPTOMS OF STEM ROT

CARNATION BRANCH ROT

There is but one carnation disease which may be mistaken for stem rot. To this disease the writer several years ago applied the term ''branch rot''. Before that time the two diseases were commonly known as wet stem rot and dry stem rot. In order to avoid confusion of these two terms, the term stem rot was adopted for the disease caused by Rhizoctonia and the name branch rot adopted to replace the term dry stem rot.

Branch rot is caused by the fungus Fusarium. This disease affects the host plant much more slowly than does stem rot. There is no noticeably rapid wilting of the foliage of the entire plant. Infection does not, as a rule, take place at or near the surface of the soil but may take place at any point where the tissues have been broken. Branch rot is essentially a wound disease. Wherever a branch or leaf has been broken or removed, the disease may gain entrance. Infected parts turn yellow, wilt, and become dry. A single branch may thus be affected, while the rest of the plant appears healthy and normal. There is no soft and slimy area on the stem, as is found in stem rot, but instead the stem remains dry and tough. Occasionally both diseases occur on one and the same plant.

In the cutting bench the two diseases are not so easily distinguished. However, careful observations will show that in the case of branch rot the foliage is most often affected and very little rotting is evident at or below the surface of the soil. In the case of stem rot, on the other hand, the disease is noticeable on parts of the plant at or below the surface of the soil.

INFECTION

Mature Plants.—As said above, stem rot attacks seedlings, cuttings, and mature plants. Mature plants may become infected either in the field or in the greenhouse. From observations in the carnation field during four summers it has been found that, altho always present in the soil, the fungus attacks plants only under certain conditions. One of these conditions is the presence of wounds. Many counts in the field have brought to light the fact that plants with a single central stem, breaking one to two inches above the soil, are less frequently infected than are plants forking just at or slightly below the soil surface. The branches of the latter are easily broken during cultivation and many infections have been traced to such wounds.

Stem rot is more prevalent during a hot, sultry, wet season. Such a season produces large, bushy plants, with much soft growth. It is very probable that infection takes place more readily under such conditions.

Perhaps the most critical period of the mature plant is at the time when it is transferred from the field to the house. The growth of the plant at this time is more or less checked, and unless the weather is cool the temperatures of the house may be unfavorably high. It is at this time, or shortly after, that large losses due to Rhizoctonia occur. Losses at this time are unquestionably due to changed conditions, more or less abnormal until the plant has again become established, and to unavoidable injuries to the plant, such as breaking of branches, etc., during the process of transplanting.

Cuttings.—Cuttings in the sand succumb very rapidly to attacks of Rhizoctonia. The fungus may be introduced into the cutting bench by means of cuttings taken from plants already infected. Cuttings taken from the lower portions of the stock plant are most likely to harbor the fungus, especially when the leaves have been in contact with soil. Unclean sand also may be the means of infection. The source of sand used in the cutting bench is of much importance. Sand used previously for cuttings, unless disinfected, may harbor the fungus, which, when conditions are favorable, may become active and attack many cuttings.

After the rooted cuttings have been transferred to pots, losses are not frequent. Individual plants may be destroyed by the disease, but such infection cannot be carried readily to adjacent plants. If the rooted cuttings are transplanted into flats, the losses frequently are more extensive, for a single infection may readily be carried to a number of plants.

A STUDY OF THE CONDITIONS INFLUENCING THE GROWTH OF PARASITE AND HOST

In attempting to combat a fungous disease, such as stem rot of carnations, two possible courses are open; either the fungus must be eradicated from the soil or, if that is not possible, some method must be found to reduce its destructiveness to a minimum. Attempting the latter, two more or less clearly defined methods of procedure are possible; either the fungus must be placed in an environment which, being unfavorable, will greatly reduce its virulence but at the same time approximate rather closely the optimum conditions for the carnation plant, or carnation plants must be developed which are to a high degree immune from the attacks of the fungus.

A series of experiments was undertaken by the author with the view of ascertaining some of the conditions which influence the growth of the fungus; also the effect of these on its parasitism. Similar studies were made of possible methods of eradicating the fungus from soil in greenhouses.

THE FUNGUS IN PURE CULTURE

Temperature.—In pure culture in the laboratory it was found that the fungus grows slowly at relatively low temperatures. At higher temperatures growth is more rapid, the most rapid growth taking place at approximately 86 degrees Fahrenheit.

Moisture.—It was found also that the fungus responds in a similar way to moisture conditions. In relatively dry sand it makes good subsurface growth. In wet sand growth is on the surface of the sand. This is probably correlated with aeration, especially with the supply of oxygen. Practically all injury caused by Rhizoctonia occurs at or near the surface of the soil and rarely below three or four inches, except perhaps in seed beds in which sand is used. This fact has already been discussed in detail in Bulletin 189, already referred to.

The stem-rot organism is very resistant to unfavorable external conditions, such as low temperature and drying. An experiment was carried out by placing a set of flasks partially filled with sand which was inoculated with the fungus, in the open field. Another set of flasks containing some of the inoculated sand was placed in the greenhouse, while a third was kept in the laboratory. At different times during the winter months the flasks were weighed to determine the loss in water content. Cultures of the fungus also were made at the same time to determine whether it was still living. During the interim a minimum temperature of 12 degrees Fahrenheit below zero had been registered, and several flasks in the open field had been broken by the frost. In all cases the flasks had lost from 25 to 50 percent of their original weight. However, in every case the fungus survived and was able to make normal growth when transferred to more favorable conditions.

Cultures were made from flasks kept in the laboratory for two years and two months after they had been placed there, and the fungus was still alive. The sand at this time was dry and hard.

Thus, low temperatures and drying appear to have little or no effect on the vitality of the fungus.

Acidity and Alkalinity.—As a number of writers have recommended the use of lime for the control of stem rot, the effects of acidity and alkalinity on the growth of Rhizoctonia in pure culture were tested out in the laboratory. String-bean agar was made acid and alkaline to various degrees, inoculated, and measurements of the growth of the mycelium taken from day to day. The results showed that Rhizoctonia can grow on medium which is, within reasonable limits, either acid or alkaline in reaction.

PERSISTENCE OF THE FUNGUS IN SOILS

Fortunately most growers renew the soil in the benches each season. However, as some growers use the same soil during a second season, a knowledge of whether the stem-rot fungus will persist in the soil in the bench from one year to the next is of importance.

A five-foot section (No. 113) in the greenhouse was filled with soil taken from a bench in which carnations had been grown the previous season. The bench was planted to twenty Beacon carnation plants. A similar section (No. 112) was filled with fresh soil taken from a field that had been in sod for a number of years. This section was also planted to twenty Beacon plants. The two sections received similar treatment in the application of fertilizers and the cultural methods were uniform.

During the entire growing season one plant died of stem rot in the section containing fresh soil (No. 112). Eight plants were lost in the section in which old soil was used (No. 113). The results are tabulated in Table 2.

TABLE 2.—EFFECT OF PLANTING CARNATIONS IN OLD INFECTED SOIL USED THE PREVIOUS SEASON: 1912-13

Section	Treatment	Number of diseased plants	Number of healthy plants	Percentage loss
113	Old soil	8	12	40.0
112	New soil	1	19	5.0

The data show clearly that Rhizoctonia persists in the old soil of the benches from year to year. The evidence also seems to indicate that the disease becomes more virulent in the soil the second season.

INFLUENCE OF MANURES

To determine whether Rhizoctonia is introduced in the bench thru the use of manures, comprehensive experiments were carried on during the seasons 1912-13 and 1913-14, with negative results.

Since greenhouse soils receive, previous to the filling of the benches, heavy applications of manures, it is not improbable that such soils offer a good environment for the rapid growth of the fungus and present conditions conducive to its attack on the plant. A comparison in this respect was therefore made between soils containing no manure and soils receiving applications of different amounts of manures. Eight five-foot sections were filled with soil, manure was added to and incorporated with the soil of six of them, while two sections received no manure. Each section was inoculated with the fungus by mixing with the soil about a bushel of infected soil taken from benches in the experimental house where plants had previously succumbed to the disease. Twenty-five plants (variety Rosette) were planted in each section and uniform treatment given.

TABLE 3.—RELATION OF VARYING AMOUNTS OF MANURE IN THE SOIL TO THE VIRULENCE OF STEM ROT: 1914–15

Section	Treatment	Number of healthy plants	Number of diseased plants	Percentage loss
254	Check: no fertilizer or manure	22	3	12.0
255	20 pounds of manure	20	5	20.0
256	40 pounds of manure	25	0	0.0
257	80 pounds of manure	21	4	16.0
258	160 pounds of manure	18	7	28.0
259	Check: no fertilizer or manure	21	4	16.0
260	40 pounds of manure	25	0	0.0
261	80 pounds of manure	8	17	68.0

The data shown in Table 3 are somewhat contradictory. On the whole it seems that manure added to soil has little influence on the growth and parasitism of the fungus.

COMMERCIAL FERTILIZERS

Table 4 contains data of plants growing in soils treated with commercial fertilizers. The sections in the experiment were inoculated with the fungus by adding to each a pint of a mixture of sand and corn meal in which the fungus was growing. Twenty-five Rosette carnations were planted in each section.

TABLE 4.—RELATION OF EXCESSIVE AMOUNTS OF COMMERCIAL FERTILIZERS TO THE VIRULENCE OF STEM ROT IN THE GREENHOUSE: 1914–15

Section	Treatment	Number of healthy plants	Number of diseased plants	Percentage loss
246	Check: no fertilizer...........	8	17	68.0
247	Dried blood 1 pound per week..	7	18	72.0
248	Potassium sulfate 1 pound per week.....................	18	7	28.0
249	Dried blood 1 pound per week and 4 pounds limestone[1]	10	15	60.0
250	Potassium sulfate 1 pound per week and 4 pounds limestone[1]	9	16	64.0
251	Ammonium sulfate 1 pound[1] ...	14	11	44.0
252	Ammonium sulfate 2 pounds[1] ..	9	16	64.0
253	Ammonium sulfate 4 pounds[1] ..	6	19	76.0

[1]Limestone and ammonium sulfate turned into soil before setting plants.

The data do not show any close relation between the use of commercial fertilizers and infection. In most cases the commercial fertilizers were used in excessive amounts. This in all probability had an influence on infection as a whole, for excessive amounts added to soil lower the vitality of the carnation plant. This was noticeable in the sections to which potassium sulfate was added, the plants showing the usual symptoms of overfeeding with potassium. The plants of Sections 252 and 253 also showed clearly the effects of the large amounts of ammonium sulfate used. The large application of dried blood in Section 247 showed its effects on the physical structure of the soil and the plants did not make normal growth. The high percentage of infection in these sections is in all probability correlated with the weakened condition of the plants. Nevertheless, the percentage of loss in the untreated soils of the check sections was high, so that no definite conclusions can be drawn from the results.

ACIDITY AND ALKALINITY OF THE SOIL

In 1912 limestone was tested out next to a section in which sulfuric acid was used as a possible control measure. Both of these methods failing as far as control was concerned, the experiments were carried out thru two more seasons to test out the effects of alkalinity and acidity of the soil and its relation to stem rot.

A solution of sulfuric acid was prepared and applied to soil of a five-foot section at the rate of three-sixteenths fluid ounce per square foot. One day previous, the soil was inoculated with Rhizoctonia by mixing with it a pint of infected soil. Two days after the acid treatment, the section was planted to twenty carnation plants (variety Beacon).

A second section was inoculated and planted the same as the first, while a third was inoculated and five pounds of crushed limestone (applied at the rate of five tons to the acre) was thoroly mixed with the soil two days later. A combination of the acid-limestone treatment was applied to a fourth section. The soil in this section also was inoculated and allowed to stand for a day. The sulfuric-

TABLE 5.—EFFECTS OF ACIDITY AND ALKALINITY ON THE VIRULENCE OF STEM ROT IN THE GREENHOUSE: 1912–13

Section	Treatment	Number of healthy plants	Number of diseased plants	Percentage loss
109	Sulfuric acid, $\frac{3}{16}$ fluid ounce per square foot	7	13	65.0
110	Check	16	4	20.0
111	Limestone 5 pounds	19	1	5.0
119	Sulfuric acid plus 5 pounds limestone	15	5	25.0

acid solution was then applied, and on the second day after five pounds of crushed limestone was mixed with the soil.

The results shown in Table 5 indicate that the acid solution did not control the amount of stem rot. Tests made frequently during the course of the season gave good acid reactions. The addition of crushed limestone, however, appears to have checked stem rot.

The above experiment, with some modifications, was repeated during the seasons 1913-14 and 1914-15. For the first season the same amounts of acid and limestone were used, while for the second season, these amounts were doubled. The experiment was divided into six treatments, two five-foot sections being devoted to each treatment. Each section was planted to twenty-five plants (variety White Enchantress) and all given the same conditions thruout the season. Before planting, the sections were treated as follows:

Two sections were inoculated with a soil culture of Rhizoctonia, allowed to stand for several days, and then given an application of sulfuric acid at the rate of three-sixteenths fluid ounce per square foot. In 1914-15 this rate was doubled. Two other sections were given an application of sulfuric acid at the above rate, allowed to stand for three days, and then inoculated with a soil culture of Rhizoctonia. The rate of application was doubled in 1914-15. To

TABLE 6.—EFFECTS OF ACIDITY AND ALKALINITY ON THE VIRULENCE OF STEM ROT IN THE GREENHOUSE: 1913–14

Section	Treatment	Number of healthy plants	Number of diseased plants	Total diseased	Percentage loss
167	Inoculated. Acid treatment	5	20		
173	Inoculated. Acid treatment	1	24	44	88.0
168	Acid treatment. Inoculated	11	14		
174	Acid treatment. Inoculated	24	1	15	30.0
169	Acid treatment. Check	25	0		
175	Acid treatment. Check	25	0	0	0.0
170	Inoculated. Limestone (5 pounds)	1	24		
176	Inoculated. Limestone (5 pounds)	0	25	49	98.0
171	Limestone (5 pounds). Inoculated	4	21		
177	Limestone (5 pounds). Inoculated	16	9	30	60.0
172	Limestone (5 pounds). Check	25	0		
178	Limestone (5 pounds). Check	25	0	0	0.0

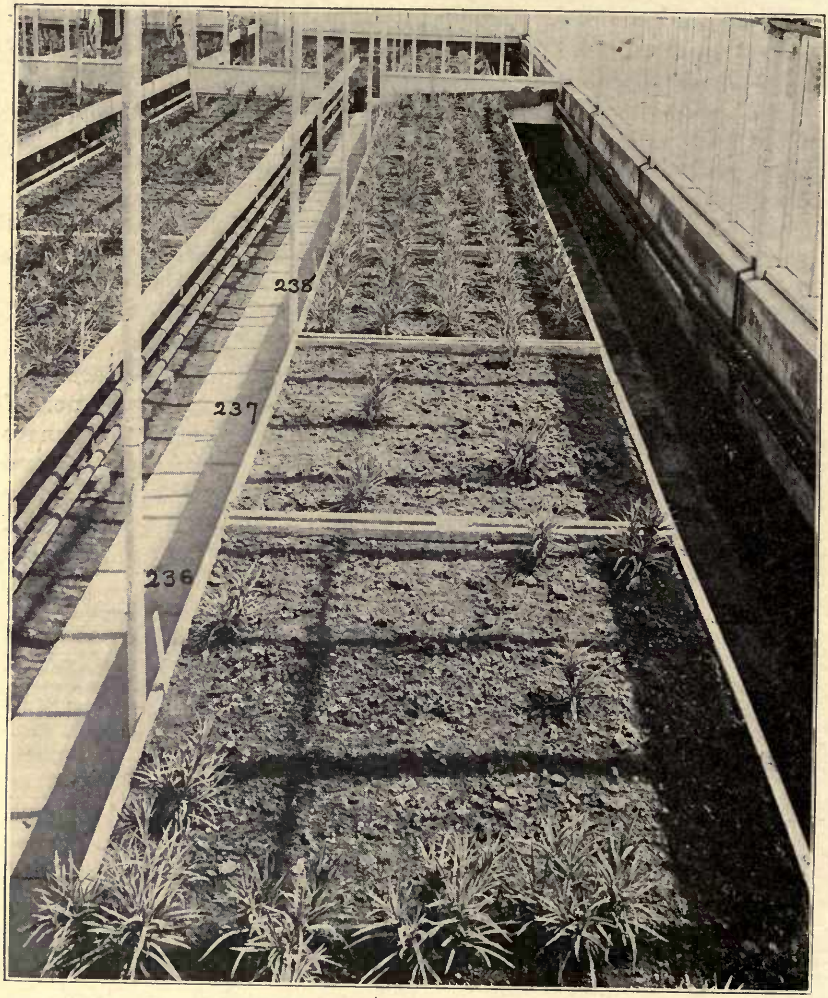

FIG. 2.—VIRULENCE OF STEM ROT IN THE GREENHOUSE IN AN ACID SOIL
(*Photographed Sept. 20, 1914*)
Section 236—Inoculated. Acid Treatment
Section 237—Acid Treatment. Inoculated
Section 238—Acid Treatment. Check

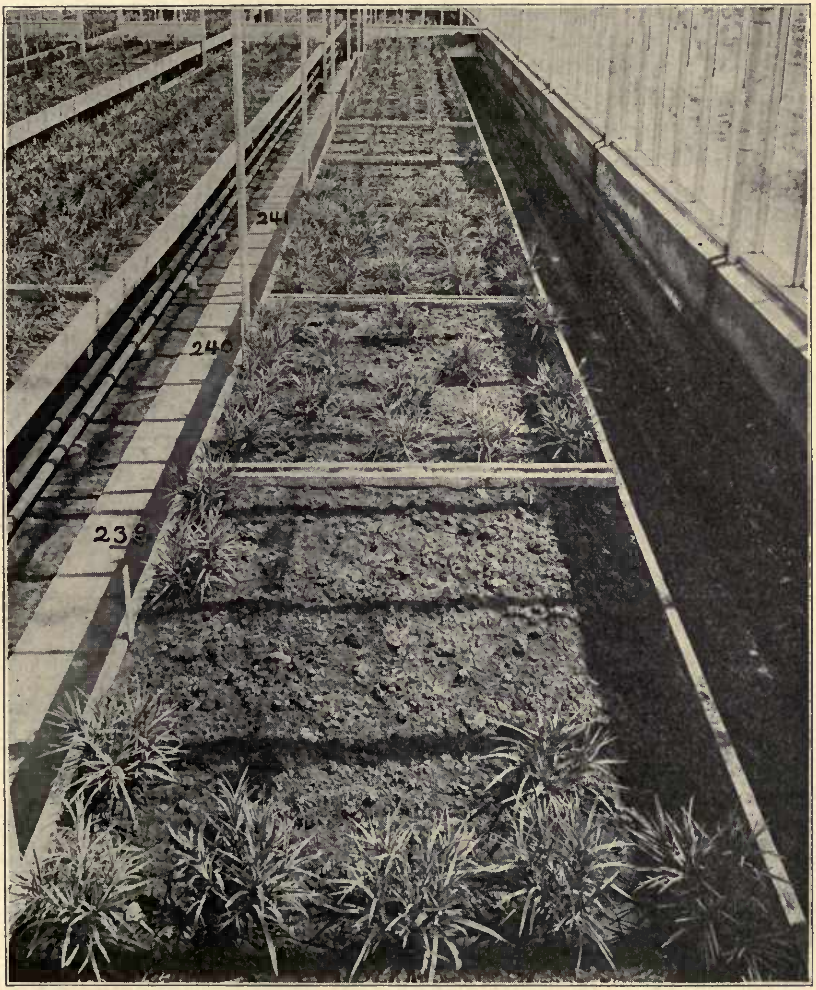

FIG. 3.—AN ALKALINE SOIL INEFFECTIVE IN CONTROLLING THE VIRULENCE OF STEM ROT IN THE GREENHOUSE (*Photographed Sept. 20, 1914*)

Section 239—Inoculated. Limestone
Section 240—Limestone. Inoculated
Section 241—Limestone. Check

two other sections sulfuric acid was applied at the same rate as above and allowed to stand several days. Six additional sections were treated in the same way as the six sections above, except that the acid treatment was in each case replaced by 5 pounds of crushed limestone. In the 1914-15 experiments 10 pounds of crushed limestone was used instead of 5 pounds. The results of these experiments are summarized in Tables 6 and 7 (see also Figs. 2 and 3).

Under the conditions of the above experiments, neither sulfuric acid nor lime had a controlling effect on stem rot. The fungus seemed to thrive equally well in an acid soil and in an alkaline soil. This result has been corroborated by growing the fungus in the laboratory on culture media of definite, known acidity and alkalinity; within certain limits the fungus showed but little preference for either substratum.

TABLE 7.—EFFECTS OF ACIDITY AND ALKALINITY ON THE VIRULENCE OF STEM ROT IN THE GREENHOUSE: 1914–15

Section	Treatment	Number of healthy plants	Number of diseased plants	Total diseased	Percentage loss
230	Inoculated. Acid treatment	6	19		
236	Inoculated. Acid treatment	4	21	40	80.0
231	Acid treatment. Inoculated	5	20		
237	Acid treatment. Inoculated	7	18	38	76.0
232	Acid treatment. Check	25	0		
238	Acid treatment. Check	25	0	0	0.0
233	Inoculated. Limestone (10 pounds)	10	15		
239	Inoculated. Limestone (10 pounds)	4	21	36	72.0
234	Limestone (10 pounds). Inoculated	6	19		
240	Limestone (10 pounds). Inoculated	0	25	44	88.0
235	Limestone (10 pounds). Check	25	0		
241	Limestone (10 pounds). Check	25	0	0	0.0

REPLANTING

Experiments were carried on for two seasons to determine what percentage of the plants survived when replanted under ordinary greenhouse conditions. After a large number of plants had been taken out of the different sections in a diseased condition, they were replaced by new plants. As can be seen from Table 8, 68 to 100 percent of the replants were killed by stem rot. An average of 92 percent for all sections was lost. From these results we can conclude that the mortality of the replants is extremely high and in a few cases only will they survive thru a growing season.

TEMPERATURE

Cultures of Rhizoctonia in the laboratory have shown that the fungus grows best at a relatively high temperature. The optimum temperature for the growth of the fungus is from 86 to 88 degrees Fahrenheit. This is much higher than the optimum temperature for the growth of the carnation plant. Carnations in the greenhouse are grown, when possible, at 50 to 53 degrees F. at night and 60 to 62 degrees F. during the day. Altho the stem-rot fungus will grow at the latter temperatures, its growth is slow. These facts indicate that there may be a temperature relation between the growth of the parasite and host infection, and that possibly temperature is the controlling factor in infection. Carnation growers probably are aware of the fact that losses due to stem rot are greater at certain periods of the year than at others. The following data, collected during a period of five years, show that this is true. The data also tend to confirm the existence of a more or less definite relation between temperature and loss by stem rot.

In Table 9 is given the data of the benching of carnation plants for five years and the subsequent losses of plants by months.

For two seasons the plants were benched during September; the following three seasons they were benched in August. From the data presented it is seen that the greater losses occur during the month following that of benching. When benching was done in September, no loss occurred during that month, but the greater loss occurred during October. When benching was done in August, the greater loss occurred in September, and the total loss was much larger than among the plantings benched in September. It also is seen from the data that loss gradually decreases from the first month after benching to the beginning of the warmer months of the following season. In Table 8, also, the monthly loss is tabulated, with the same results. During August, September, and October, in the state of Illinois, the outdoor temperature is high and the temperature in the

TABLE 8.—EFFECT OF REPLANTING IN THE GREENHOUSE: 1913–14

Section	Number replanted	Number dead	Loss by months									Percentage loss
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
152	17	17	14	2	0	0	0	0	0	1	0	100
153	12	12	6	5	0	0	0	0	1	0	0	100
157	39	26	8	5	2	0	0	0	6	5	0	68
158	26	22	11	8	1	0	0	0	0	2	0	89
163	21	21	6	8	1	0	0	0	1	5	0	100
167	8	6	1	1	0	0	0	0	0	0	4	75
170	21	20	2	5	2	0	0	0	2	8	1	95
171	14	14	5	3	0	0	0	0	1	1	4	100
173	17	17	1	9	0	0	0	0	4	1	2	100
176	19	18	5	4	1	0	0	0	0	2	6	95

TABLE 9.—EFFECT OF SEASONAL TEMPERATURES ON THE DEATH RATE OF CARNATION PLANTS FROM STEM ROT: PERIOD OF FIVE YEARS, IN THE GREENHOUSE

Season	Date of planting	No. of plants	Total loss	Loss by months									
				Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1909–10	Sept. 9–13	3200	33	0	15	2	1	5	7	0	3	0	0
1910–11	Sept. 9–12	3200	27	0	13	5	8	1	0	0	0	0	0
1911–12	Aug. 8–10	3200	49	13	23	5	6	2	0	0	0	0	0
1912–13	Aug. 7–8	3200	99	48	30	0	12	2	0	7	0	0	0
1913–14	Aug. 12–14	3200	86	0	44	6	4	0	0	0	4	0	28

greenhouses correspondingly high. Beginning with November, lower temperatures prevail out of doors and the temperature indoors is correspondingly lower. With these lower temperatures there results a gradual falling off in plant losses due to stem rot.

During the season 1913-14 a number of sections containing carnations were reserved in the greenhouse and one section inoculated at the first of each month, with Rhizoctonia. Each section contained twenty plants, sixteen of which were inoculated by placing infected bean plugs at the base of the stem. The remaining four plants served as checks.

TABLE 10.—EFFECT OF SEASONAL TEMPERATURES ON THE DEATH RATE OF CARNATION PLANTS FROM STEM ROT IN THE GREENHOUSE: 1913-14

Section	Date of inoculation	Experiment discontinued	Inoculated plants		Check plants	
			Healthy	Diseased	Healthy	Diseased
143	Sept. 1, 1913	Oct. 1, 1913	1	15	4	0
140	Oct. 1, 1913	Nov. 1, 1913	3	13	4	0
139	Nov. 1, 1913	Jan. 1, 1914	10	6	4	0
138	Dec. 1, 1913	Feb. 1, 1914	8	8	4	0
137	Jan. 1, 1914	Mar. 1, 1914	14	2	4	0
134	Feb. 1, 1914	Apr. 1, 1914	3	13[1]	4	0
133	Mar. 1, 1914	May 1, 1914	12	4	4	0
132	Apr. 1, 1914	June 1, 1914	9	7	4	0
131	May 1, 1914	July 1, 1914	0	16	4	0
130	June 1, 1914	July 1, 1914	2	14	4	0
128	July 1, 1914	July 23, 1914	6	10	4	0

[1]Ten plants found infected April 1; only three plants died during the months of February and March.

As can be seen from Table 10, the death rate of the plants inoculated the first two months was high. This rate diminished markedly thru the colder months, increasing in the spring, until in May it had again reached a maximum. During the remaining two months this same condition prevailed, showing very noticeably the influence of temperature on mortality.

SOIL MOISTURE

In 1913 the soil in eight sections was inoculated with a soil culture of Rhizoctonia and each section planted to twenty-five plants (variety Gloriosa). The plants were grown at the usual temperatures of carnations in greenhouses (53-55 degrees F. by night and 65-70 degrees F. by day). In order to determine the influence of soil moisture on death rate due to stem rot, the various sections were given different applications of water. The soil of two sections (Nos. 135 and 136) was kept uniformly moist, the soil moisture being approximately that which carnation growers attempt to maintain for the growth of commercial plants. The soil of three sections (Nos. 126, 144, and 185) was kept almost saturated by applying water frequently. The soil of the three remaining sections (Nos. 127, 145, and 166) was kept dry. (The term dry does not imply that no water was applied, but it means that less water was given the plants than growers ordinarily use in growing carnations.) As nearly as it was possible to do so, the soil moisture of each section was kept uniform and constant thruout the season.

Records of losses of each section are tabulated in Table 11. The average losses for the saturated, the "normal," and the dry sections were 36, 22, and 21 percent respectively. These figures seem to indicate that a high degree of soil moisture, at the temperatures of a carnation house, is favorable to infection by stem rot.

TABLE 11.—EFFECT OF SOIL MOISTURE ON VIRULENCE OF STEM ROT IN THE GREENHOUSE: 1913-14

Section	Saturated		Section	Normal		Section	Low	
	No. of plants dead	Percent loss		No. of plants dead	Percent loss		No. of plants dead	Percent loss
126	5	20	135	7	28	127	2	8
144	9	36	136	4	16	145	10	40
185	13	52	...	.	..	166	3	14

In 1914 the experiment was repeated, with some modifications. Instead of growing the plants at the usual carnation temperatures, a high soil temperature was maintained in the benches. The underlying reason for this procedure was to determine whether the same percentages of loss from stem rot would occur thruout the season and whether the moisture relation might be of value in an effective control of stem rot. If high temperature—that is, a temperature above that best suited for carnation growing—is instrumental in provoking infection (as the data of Tables 8, 9, and 10 would lead one to believe), then possibly the soil-moisture factor might be successfully employed to counteract the influence of high temperatures. High temperatures of course are often unavoidable, especially at seasons of the year when the outdoor temperature is high.

Four twenty-foot benches were divided each into four five-foot sections and each section planted to twenty-five plants (variety Gloriosa). The soil of the different sections was inoculated at different times of the year, as shown in Table 12. During the early part of the season the air temperature was high, so that no effort was made to control the soil temperature in Bench 1. Later the soil temperature was controlled by inclosing, by means of boards, the area under three benches (Nos. 2, 3, and 4). Previously an extra steam pipe, also, was added to the regular number of heating pipes, and by means of this increased radiating surface the temperature of the soil in the benches could be raised several degrees over that of the temperature of the house. No soil thermograph being available, frequent readings were made from a soil thermometer set from three to four inches into the soil. Thruout the winter the soil temperature of Benches 2, 3, and 4 was several degrees higher than was the air temperature of the house.

The soil of Section 1 of each bench was kept dry, being watered thoroly only when absolutely needed. Section 2 received a "normal" supply of water; Section 3, above normal; and Section 4 was continually saturated. Table 12 gives the results of the experiment.

TABLE 12.—EFFECT OF HIGH TEMPERATURE AND SOIL MOISTURE ON THE DEATH RATE OF CARNATION PLANTS FROM STEM ROT IN THE GREENHOUSE: 1914–15

Bench	Dates of inoculation and of ending of experiment	Section 4 Saturated		Section 3 Above normal		Section 2 Normal		Section 1 Low	
		No. of plants dead	Per-cent loss	No. of plants dead	Per-cent loss	No. of plants dead	Per-cent loss	No. of plants dead	Per-cent loss
1	Aug. 7–Nov. 1...	15	60	12	48	6	24	14	56
2	Dec. 1–Feb. 1...	7	28	7	28	5	20	12	48
3	Feb. 1–Apr. 1...	16	64	15	60	12	48	19	76
4	May 1–July 1...	21	84	19	76	13	52	14	56

The data again show that the percentage of loss was higher in the sections in which the soil moisture was high. However, the percentage of loss was equally high in the sections with the dry soil. In the latter case the plants suffered severely from lack of water, as was quite evident by their appearance, and this weak condition of the plants no doubt accounts for the high percentage of infection (Fig. 4). The important fact brought out by the data is that in all cases the percentage of loss from stem rot was high in all sections thruout the year, showing quite conclusively that soil temperature is the limiting condition in the control of stem rot.

The data also show in a striking way the double relation of moisture and temperature to infection. A high soil moisture is favorable to infection; a high temperature also is favorable to infection. Under conditions of both a high temperature and a high percentage of soil moisture, the loss exceeds that of either alone. In other words, soil moisture and soil temperature each have an important bearing on the loss of carnations by stem rot. With either condition prevailing or both conditions present, we have conditions very favorable for the fungus infection.

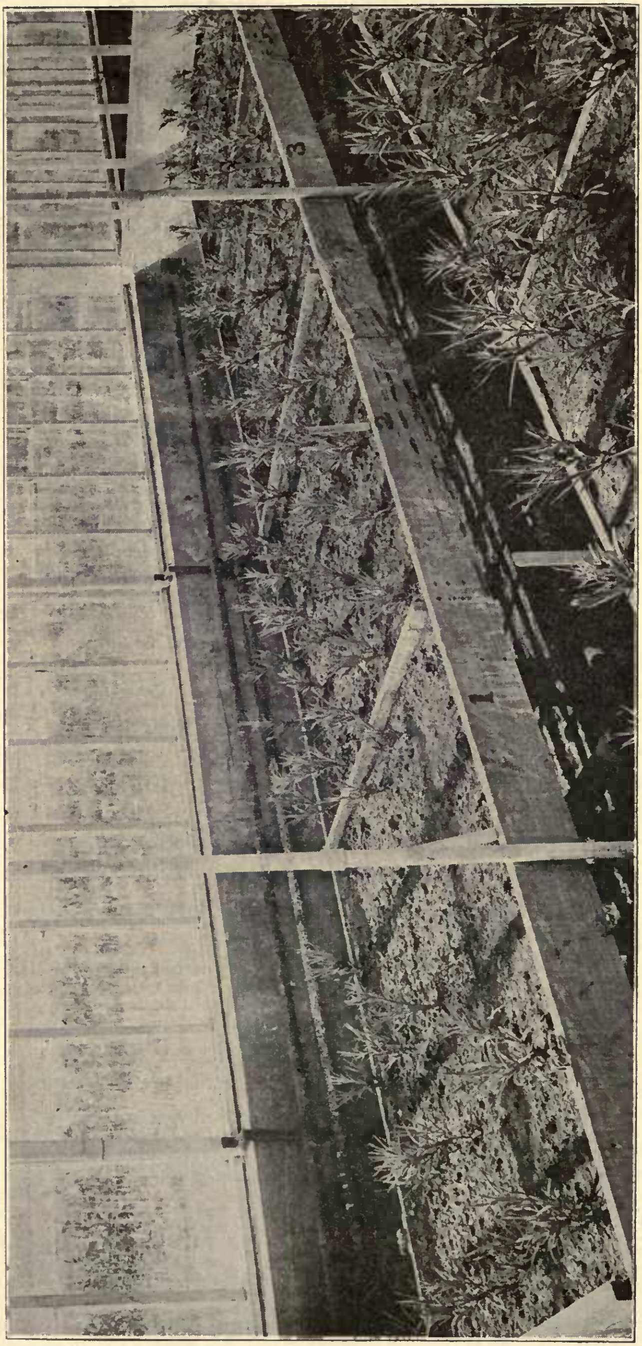

FIG. 4.—EFFECTS OF HIGH TEMPERATURE AND SOIL MOISTURE ON DEATH RATE OF CARNATION PLANTS FROM STEM ROT IN THE GREENHOUSE (*Photographed Sept. 20, 1914*)

Section 1—Soil Kept Dry
Section 2—Soil Normal
Section 3—Soil Above Normal
Section 4—Soil Saturated

ATTEMPTS TO CONTROL STEM ROT IN THE GREENHOUSE BY DISINFECTION AND STERILIZATION OF THE SOIL

In all the experiments discussed in the foregoing pages and under this heading the treatment of the soil in the house was the same as described in Bulletin 176 of this station. Unless otherwise stated in the experiment, all the sections were given the same treatment.

All infected sections were inoculated with a two-week-old soil culture of Rhizoctonia figured and described in Bulletin 189. For the five-foot sections a one-pint culture jar was used, and for the ten-foot sections, a one-quart culture.

DISINFECTION OF THE SOIL

Various soil disinfectants have been recommended and employed in the treatment of soil in order either to eliminate the parasite or to so weaken its activities that infection is greatly reduced. Hartley[1] recommends the use of sulfuric acid in soils to prevent damping-off of pine seedlings in Western nurseries, by Rhizoctonia and other fungi. In his experimental work he found an application of the acid in aqueous solution, made at the rate of three-sixteenths fluid ounce per square foot of soil, to be effective. Aqueous solutions of formalin have been recommended and are frequently used to rid soils and plant structures, such as tubers and seeds, of destructive fungi. It is a common practice of carnation growers in replacing dead plants to mix with the soil of the replant a small quantity of lime to ward off, presumably, the attack of the fungus. Various other so-called disinfectants have been employed from time to time and various recommendations may be found in the literature. The results of different investigations often are contradictory, probably due to the difference in soils employed and in the control of conditions during the investigation.[2]

Sulfuric Acid and Lime.—Under the heading of acidity and alkalinity of the soil (page 588) are given the results of the use of sulfuric acid and lime in a carnation soil. As a control method it failed absolutely in the three seasons it was carried on. As can be seen from Tables 6 and 7, a loss of 84 percent occurred in the infected sections treated with sulfuric acid, and 85 percent of the plants were lost in the corresponding lime sections during the two seasons 1913-14 and 1914-15.

Bordeaux and Copper Sulfate.—The soil in three sixteen-foot sections was inoculated with Rhizoctonia, watered, and allowed to stand

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[1]Hartley, Carl. The Use of Fungicides to Prevent Damping-Off. Phytopath. 2, 99. 1912.

[2]Another important factor, not yet thoroly understood, is the effect of the disinfectant on the life and activity of the soil organisms.

TABLE 13.—RESULTS OF BORDEAUX AND COPPER-SULFATE TREATMENTS ON CONTROL OF STEM ROT IN THE GREENHOUSE: 1912–13

Section	Treatment	Number of plants	Number dead	Percentage loss
106	Copper sulfate................	32	13	40.6
107	Check........................	32	3	9.4
108	Bordeaux....................	32	11	34.4

for several days. One section then was drenched with Bordeaux (4-4-50), applied at the rate of two gallons to ten square feet. Each section was planted to thirty-two Beacon plants. At the end of the season no favorable results were evident. Stem rot appeared in each section; the data (Table 13) show even a greater percentage of loss in the treated section than in the untreated section. Whether the copper had an unfavorable influence on the carnation plants was not determined.

Formalin.—Formalin as a soil disinfectant for stem rot was tested during three successive seasons. In August, 1912, two ten-foot sections were inoculated with soil cultures, watered, and allowed to stand for several days. To one section a formalin solution (1-200) was applied at the rate of one gallon per square foot, with a sprinkler.

TABLE 14.—RESULTS OF FORMALIN TREATMENT IN THE CONTROL OF CARNATION STEM ROT IN THE GREENHOUSE: 1913–14

Section	Treatment	Number of plants		Number dead	Total number dead	Total percent loss
		Gloriosa	White Enchantress			
144	Inoculated. Formalin....	25		3		
			25	12	15	
151	Inoculated. Formalin....	25		0		
			25	9	9	24
147	Formalin. Inoculated....	25		0		
			25	0	0	
152	Formalin. Inoculated....	25		5		
			25	25	30	30
148	Inoculated.............	25		0		
			25	1	1	
153	Inoculated.............	25		6		
			25	23	29	30
149	Formalin...............	25		0		
			25	0	0	
154	Formalin...............	25		0		
			25	0	0	0
150	Check: no treatment.....	25		0		
			25	12	12	
155	Check: no treatment.....	25		0		
			25	0	0	12

The soil would not take up all the solution at one time, so three applications had to be made during the day. The bench was then covered with a tarpaulin for a few days to prevent a rapid loss of the fumes. The soil was allowed to dry. On August 17 both sections were planted to fifty plants (variety Beacon). During the season, one plant died in the treated section and two in the check. No conclusions can be drawn from this experiment because of the low percentage of loss occurring in both sections.

In 1913 ten ten-foot sections were prepared for the formalin experiment, and divided into five treatments of two sections each. The first set was inoculated with soil cultures of Rhizoctonia, watered, and allowed to stand several days. A solution of formalin (1-120) was then applied at the rate of one gallon per square foot. In the second set the soil was treated with a like solution of formalin, allowed to dry, and then inoculated. The third set of sections was inoculated and allowed to stand. The soil in the fourth set was treated with formalin as in the first set, while the last two sections were given no treatment and served as checks.

Each section was planted to twenty-five Gloriosa and twenty-five White Enchantress, on August 25, 1913.

TABLE 15.—RESULTS OF FORMALIN TREATMENT IN THE CONTROL OF CARNATION STEM ROT IN THE GREENHOUSE: 1914–15

Section	Treatment	Number of plants		Number dead	Total number dead	Total percent loss
		Gloriosa	White Enchantress			
202	Inoculated. Formalin....	25		11		
			25	9	20	
207	Inoculated. Formalin....	25		13		
			25	20	33	53
203	Formalin. Inoculated....	25		17		
			25	23	40	
208	Formalin. Inoculated...	25		19		
			25	25	44	84
204	Inoculated..............	25		17		
			25	18	35	
209	Inoculated..............	25		17		
			25	25	42	77
205	Formalin................	25		0		
			25	0	0	
210	Formalin................	25		0		
			25	0	0	0
206	Check: no treatment.....	25		0		
			25	0	0	
211	Check: no treatment.....	25		0		
			25	0	0	0

This same experiment was repeated in 1914, except that formalin (1-50) was applied at the rate of one-half gallon per square foot, as had been recommended by Johnson[1] for controlling damping-off.

The results presented in Tables 14 and 15 show that the use of formalin as a soil disinfectant for two years was but a partial success. The loss, even after the application of the formalin, varied from 24 to 53 percent (see Fig. 5). In the sections in which the soil was not artificially inoculated prior to the application of the formalin, no losses are recorded. This may be due, however, to the possibility that the organism was not present in the soil, for in the check sections of the last series no stem rot occurred.

STEAM STERILIZATION

A sterilizing box measuring 4 feet by 16 feet by 20 inches was constructed of two-inch boards. It was divided into two equal compartments for the simultaneous sterilization of soil artifically inoculated and of soil not inoculated. Another sterilizing box, 4 feet by 8 feet by 10 inches, was built for the purpose of sterilizing manure.

The large box was fitted with four perforated steam pipes, running lengthwise, 12 inches apart and about 6 inches from the bottom. The perforations in the pipes were 1/16 inch in diameter and 12 inches apart, alternating in position on two adjacent pipes. By means of T's and L's the pipes in the box were connected, thru a valve, with a pipe leading directly to the boiler. The latter contained, at a point beyond this connection, another valve by means of which all water and wet steam could be released prior to forcing the steam into the soil box. A lid of boards completed the sterilizing apparatus.

The smaller box contained three steam pipes connected in a similar way with the pipe leading to the boiler. After filling the compartment with soil, dry steam was forced thru the pipes at forty pounds pressure for one hour.

In case the soil was to be inoculated, the amount necessary to fill a section of bench was calculated, a soil culture of Rhizoctonia added, the whole thoroly mixed, watered, covered, and allowed to stand several days before sterilization.

After the sterilization was complete, the lid was removed and the soil allowed to cool. It was then taken into the greenhouse in disinfected wheelbarrows.

The experiment was begun in 1912 by using two sections of bench, each ten feet long. The soil of one section was inoculated with the fungus, and after several days was steam sterilized; the soil of the second section was inoculated but not sterilized. Each section was

[1]Johnson, J. The Control of Damping-off Disease in Plant Beds. Wis. Agr. Exp. Sta. Res. Bul. 31, 29-61. 1914.

FIG. 5.—COMPARISON OF THE FORMALIN AND STEAM STERILIZATION TREATMENTS FOR THE CONTROL OF STEM ROT IN THE GREENHOUSE (*Photographed Sept. 20, 1914*)

Section 207—Inoculated. Formalin
Section 208—Formalin. Inoculated
Section 209—Formalin. Check

Section 221—Inoculated. Sterilized
Section 222—Sterilized. Inoculated
Section 223—Sterilized. Check

TABLE 16.—RESULTS OF STEAM STERILIZATION IN THE CONTROL OF STEM ROT IN THE GREENHOUSE: 1912–13

Section	Treatment	Number of plants	Number dead	Percentage loss
101	Inoculated. Sterilized........	52	0	0
102	Inoculated. Check...........	52	38	73

planted (August 9) to fifty-two plants of Beacon carnations. The losses are tabulated in Table 16. No loss of plants occurred in the sterilized soil; in the unsterilized soil 73 percent of the plants were lost by the disease.

During the season of 1913-14 and 1914-15 the experiment was repeated on a larger scale. Five ten-foot sections were used, each in duplicate. The soil of the first set was inoculated and sterilized; that of the second set was sterilized and then inoculated; the soil of the third set was inoculated only; that of the fourth set was sterilized only. The soil of the fifth set received no treatment and served as a general check.

The results are brought together in Tables 17 and 18. In all cases where steam sterilization was used no loss of plants occurred. In all

TABLE 17.—RESULTS OF STEAM STERILIZATION IN THE CONTROL OF STEM ROT IN THE GREENHOUSE: 1913–14

Section	Treatment	Number of plants: Gloriosa	Number of plants: White Enchantress	Number dead	Total number dead	Total percent loss
156	Inoculated. Sterilized....	25		0		
			25	0	0	
161	Inoculated. Sterilized....	25		0		
			25	0	0	0
157	Sterilized. Inoculated....	25		21		
			25	25	46	
162	Sterilized. Inoculated....	25		1		
			25	2	3	49
158	Inoculated..............	25		9		
			25	23	32	
163.	Inoculated..............	25		8		
			25	25	33	65
159	Sterilized...............	25		0		
			25	0	0	
164	Sterilized...............	25		0		
			25	0	0	0
160	Check: no treatment.....	25		0		
			25	0	0	
165	Check: no treatment.....	25		0		
			25	0	0	0

TABLE 18.—RESULTS OF STEAM STERILIZATION IN THE CONTROL OF STEM ROT IN THE GREENHOUSE: 1914–15

Section	Treatment	Number of plants		Number dead	Total number dead	Total percent loss
		Gloriosa	White Enchantress			
216	Inoculated. Sterilized....	25		0		
			25	0	0	
221	Inoculated. Sterilized....	25		0		
			25	0	0	0
217	Sterilized. Inoculated....	25		1		
			25	19	20	
222	Sterilized. Inoculated....	25		10		
			25	24	34	54
218	Inoculated..............	25		18		
			25	21	39	
223	Inoculated..............	25		22		
			25	25	47	86
219	Sterilized...............	25		0		
			25	0	0	
224	Sterilized...............	25		0		
			25	0	0	0
220	Check: no treatment.....	25		0		
			25	0	0	
225	Check: no treatment.....	25		0		
			25	0	0	0

sections in which the fungus was introduced and not sterilized, the losses ranged from 49 to 86 percent (see Fig. 5). Why no losses occurred in the untreated sections is difficult to explain, unless it may be inferred that the fungus was not present in the soil.

Records were kept of the production of flowers by the plants in the various sections. These records are given in Tables 19 and 20. In no case was production affected by the soil sterilization process.

TABLE 19.—EFFECT OF STEAM-STERILIZED SOIL ON PRODUCTION AND QUALITY OF CARNATION FLOWERS: 1913-14

Sections	Treatment	No. of flowers	Perfect		Size	Stem length	Firsts	
				Gloriosa				
		No.	*No.*	*percent*	*inches*	*inches*	*No.*	*percent*
156, 161	Sterilized.....	584	562	96.2	2.79	17.81	470	80.5
160, 165	Check........	579	565	97.5	2.76	17.09	259	44.7
159, 164	Sterilized.....	568	552	97.2	2.76	17.07	396	70.0
				White Enchantress				
156, 161	Sterilized.....	863	706	81.2	3.11	14.74	758	87.8
160, 165	Check........	773	713	92.2	3.12	14.76	643	83.8
158, 164	Sterilized.....	819	660	81.8	3.11	14.64	637	77.7

TABLE 20.—EFFECT OF STEAM-STERILIZED SOIL ON PRODUCTION AND QUALITY OF CARNATION FLOWERS: 1914-15

Sections	Treatment	No. of flowers	Perfect		Size	Stem length	Firsts	
Gloriosa								
		No.	*No.*	*percent*	*inches*	*inches*	*No.*	*percent*
216, 221	Sterilized.....	591	577	97.6	2.87	20.53	508	89.3
220, 225	Check........	570	533	93.5	2.83	19.73	479	84.0
219, 224	Sterilized.....	579	563	97.2	2.86	19.12	475	82.0
White Enchantress								
216, 221	Sterilized.....	721	679	94.1	3.18	18.83	701	97.2
220, 225	Check........	705	674	95.6	3.16	18.69	674	95.7
219, 224	Sterilized.....	762	689	90.4	3.09	19.00	737	96.7

CONCLUSIONS AND RECOMMENDATIONS

From the data and experimental evidence presented in this bulletin it seems clear that the control of stem rot of carnations lies along the line of careful control of growing conditions of the carnation plant and in the use of a clean soil. The disease is a soil disease. The organism lives in the soil, under ordinary conditions as a saprophyte, but under more favorable conditions attacking the carnation plant and causing its destruction. The conditions influencing its spread and development are high soil temperature and soil moisture.

Soil Disinfectants of Little Value.—The results of these experiments indicate that the usual soil disinfectants, such as sulfuric acid, lime, Bordeaux, copper sulfate, and formalin, applied to the soil have but little effect on the fungus and that they are consequently of little value as a means of controlling the disease. No chemical solution was found which, when applied to the soil in quantities not harmful to the plant, eradicated the fungus. The fungus is very resistant in soil to weak solutions of acids and alkalies. It is also resistant to low temperatures and drying. Evidence is presented that it lives in soils for years, resisting all the rigorous conditions of a cold winter and a hot summer.

Steam Sterilization Effective.—In order completely to eradicate the fungus from the soil, steam sterilization alone seems to be effective. Dry steam forced thru the soil at forty pounds pressure for one hour will destroy the fungus. There is no indication that such sterilization of soil is accompanied by evil effects on the growth or the production of carnation plants. Sterilized soil grows equally good carnation plants as unsterilized soil. However, aside from the labor and expense involved in sterilization, unless the plants brought in from the field are free from the disease organism the disease may again be introduced into the soil of the benches. There is of course but little assurance that the fungus is not present in the field. In order to prevent the introduction of the disease from the field into the benches, only healthy and uninjured plants should be used. Every plant should be carefully examined at the crown for evidences of the disease and any plant showing symptoms should be discarded.

Importance of Low Temperature and Minimum of Moisture.—The first month the plant is in the bench is the most critical point in the life of the plant, especially if the transplanting is done early. The temperature of the greenhouse is high at this time, and, still more important, owing to the large amount and the frequent use of water concomitant with transplanting, the humidity of both soil and air is high. Experiments have shown that high temperature and high water content of soil, especially when existing simultaneously, offer a most favorable environment to the fungus. High temperatures in the cutting bench and in the carnation house give Rhizoctonia a twofold advantage; they lower the vitality of the cuttings and plants and give the fungus optimum conditions under which to develop. In other words, when normal temperature for the best development of the plant is furnished, no stem rot occurs; while if high temperatures are maintained, the vitality of the plant is lowered, thus making it more susceptible to stem rot. At the same time, high temperatures favor the growth of the fungus, increasing its virulence. A careful watch, therefore, of the growing conditions of the plants is necessary at this time. The temperature should be kept as low as possible and no more water applied to the soil than is absolutely necessary for a healthy growth of the plant.

Seedlings and Cuttings.—These statements apply also to the growing of seedlings and cuttings. Steam sterilization of soil and sand is recommended whenever it is possible. The cutting bench offers a most favorable environment for the growth of the fungus if it is present in the sand. A relatively high temperature and high percentage of moisture of the sand, as well as the high humidity of the air resulting from artificial shading, are characteristic of the cutting bench. Under such conditions it is extremely difficult to control damping-off if it is present in the sand. It is therefore recommended that the sand be sterilized with steam and careful attention given later to the moisture and temperature conditions. A relatively high temperature of soil together with a high percentage of moisture is conducive to infection. It is important, therefore, that the temperature be kept as low as possible for a good healthy growth of the carnation plant. This temperature, since it is lower than that of the optimum temperature of the fungus, will prove an important factor in the control of infection.

AUTHOR INDEX

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(*The headings in capitals are subjects of entire bulletins*)