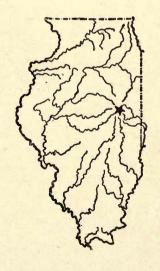


UNIVERSITY OF ILLINOIS Agricultural Experiment Station

BULLETIN No. 223

CARNATION STEM ROT AND ITS CONTROL

BY GEORGE L. PELTIER



URBANA, ILLINOIS, SEPTEMBER, 1919

Contents of Bulletin No. 223

		Page
IN	NTRODUCTION	579
	Stem Rot in Illinois	579
	Symptoms of the Disease	581
	Carnation Branch Rot	
	Infection	583
A	STUDY OF THE CONDITIONS INFLUENCING THE GROWTH OF PARASITE AN	ND
	Host	584
	The Fungus in Pure Culture	585
	Persistence of the Fungus in Soils	586
	Influence of Manures	
	Commercial Fertilizers	
	Acidity and Alkalinity of the Soil	588
	Replanting	
	Temperature	
	Soil Moisture	
Δ	ATTEMPTS TO CONTROL STEM ROT IN THE GREENHOUSE BY DISINFECTION AN	D
21	STERILIZATION OF THE SOIL	
	Disinfection of the Soil	
	Steam Sterilization	
~		
()	ONCLUSIONS AND RECOMMENDATIONS	606

CARNATION STEM ROT AND ITS CONTROL

By George L. Peltier, Associate in Floricultural Pathology¹

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

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

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

⁸A 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 earnation 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 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

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 ease 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 Rhizoetonia 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 Rhizoetonia 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

Sec- tion	Treatment	Number of diseased plants	Number of healthy plants	Percentage loss
113	Old soil	8	12	40.0
112		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

Sec- tion	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

Sec- tion	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	the state of the s		
	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			The part of
	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

¹Limestone 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 Rhizoetonia 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 sulfurie-

Table 5.—Effects of Acidity and Alkalinity on the Virulence of Stem Rot in the Greenhouse: 1912-13

Sec- tion	Treatment	Number of healthy plants	Number of diseased plants	Percentage loss
109	Sulfuric acid, 13 fluid ounce per square foot	7	13	65.0
110	Check	16	4	20.0
111 119	Limestone 5 pounds Sulfuric acid plus 5 pounds	19	1	5.0
Territori	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

Sec- tion	Treatment	Number of healthy plants	Number of diseased plants	Total diseased	Percentage loss
167	Inoculated. Acid treat- ment	5	20		
173	Inoculated. Acid treat- ment	1	24	44	88.0
168 174	Acid treatment. Inoculated	11	14		
174	lated	24	1	15	30.0
169 175	Acid treatment. Check Acid treatment. Check	25 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).	4	21		
177	Limestone (5 pounds). Inoculated	16	9	30	60.0
170		10		30	00.0
172	Limestone (5 pounds). Check	25	0		
178	Limestone (5 pounds). Check	25	0	0	0.0

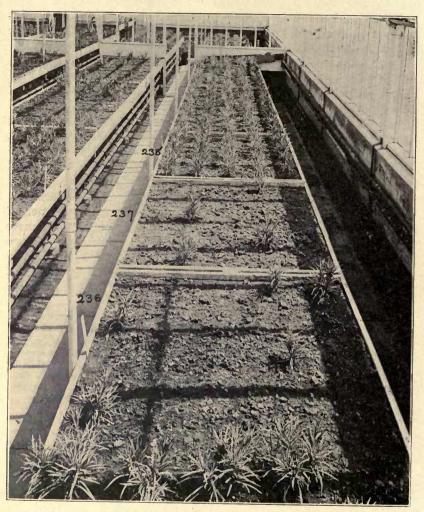


Fig. 2.—Virulence of Stem Rct in the Greenhouse in an Acid Soil (Photographed Sept. 20, 1914)

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

	1	INT	1NT 1 C	/D / 1	
Sec-	Treatment	healthy	Number of diseased	Total diseased	Percentage
tion	Treatment	plants	plants	aiscasca	loss
230	Inoculated. Acid treat-	6	19		
236	Inoculated. Acid treat- ment	4	21	40	80.0
231	Acid treatment. Inoculated	5	20		Waller of
237	Acid treatment. Inoculated	7	18	38	76.0
232 238	Acid treatment. Check Acid treatment. Check	25 25	0	0	0.0
233	Inoculated. Limestone	10	15		
239	(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).	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

Percentage	loss	100	100	89	68	100	75	95	100	100	95
	June	0	0	0	0	0	4	-	4	2	9
	May	1	0	ro	2	20	0	∞	_	1	7
	Apr.	0	1	9	0	-	0	2	_	4	0
ths	Mar.	0	0	0		0	0	0	0	0	0
s by mon	Feb.	0	0	0	0	0	0	0	0	0	0
Loss	Jan.	0	0	0	0	0	0	0	0	0	0
	Dec.	0	0	7	-	-1	0	2	0	0	-
	Nov.	2	20	2	00	∞		2	က	6	4
	Oct.	14	9	00	=	9	-	7	ro	⊷	2
Number	dead	17	12	26	22	21	9	20	14	17	18
Number	replanted	17	12	39	26	21	∞	21	14	17	19
	Section	152	153	157	158	163	167	170	171	173	176

Table 9.—Effect of Seasonal Temperatures on the Death Rate of Carnation Plants from Stem Rot:
Period of Five Years, in the Greenhouse

Dete of aleatin	No. of	Total				-	y sso.	y months	3			
Date of planting	plants	loss	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
t. 9-13	. 3200	33	0	15	2	-	5	7	0	3	0	0
t. 9–12	3200	27	0	13	5	∞	1	0	0	0	0	0
g. 8–10.	3200	49	13	23	2	9	2	0	0	0	0	0
7. 7-8	3200	66	48	30	0	12	2	0	7	0	0	0
g. 12–14	3200	98	0	44	9	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

Sec-	Date of	Experiment		ted plants		plants
tion	inoculation	discontinued	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	131	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

¹Ten 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

TEST	Saturated			No	mal		L	ow
Sec- tion	No. of plants dead	Percent	Sec- tion	No. of plants dead	Percent	Sec- tion	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	Section 4 Saturated		Section 3 Above normal		Section 2 Normal		Section 1 Low	
	of ending of	No. of plants dead		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 ease 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.

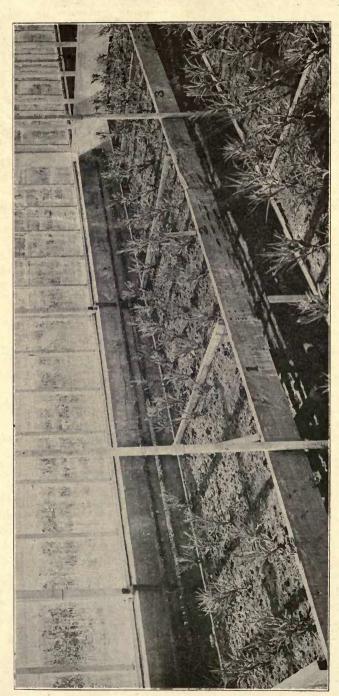


FIG. 4.—EFFECTS OF HIGH TEMPERATURE AND SOIL MOISTURE ON DEATH RATE OF CARNATION PLANTS FROM STEM ROT IN THE GREENHOUSE (Photographed Sept. 20, 1914)

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 tenfoot 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. Hartley¹ 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

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

²Another 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

Sec		Number of plants	Number dead	Percentage loss
106	Copper sulfate	32	13	40.6
107			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 scason 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

		Number	of plants	NT	Total	/D-4-1
Sec- tion	Treatment	Gloriosa	White Enchant- ress	Num- ber dead	Total number dead	Total percent loss
144	Inoculated. Formalin	25	25	3 12	15	
151	Inoculated. Formalin	25	25	0	9	24
147	Formalin. Inoculated	25	25	0	0	
152	Formalin. Inoculated	25	25	$\begin{array}{c} 5 \\ 25 \end{array}$	30	30
148	Inoculated	25	25	0	1	
153	Inoculated	25	25	$\begin{array}{c} 6 \\ 23 \end{array}$	29	30
149	Formalin	25	25	0	0	
154	Formalin	25	25	0	0	0
150	Check: no treatment	25	25	0 12	12	
155	Check: no treatment	25	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

		Number	of plants	NT.	m i i	m-1-1
Sec- tion	Treatment	Gloriosa	White Enchant- ress	Num- ber dead	Total number dead	Total percent loss
202	Inoculated. Formalin	25	25	11 9	20	
207	Inoculated. Formalin	25	25	13 20	33	53
203	Formalin. Inoculated	25	25	17 23	40	
208	Formalin. Inoculated	25	25	19 25	44	84
204	Inoculated	25	25	17 18	35	
209	Inoculated	25	25	17 25	42	77
205	Formalin	25	25	0	0	
210	Formalin	25	25	0	0	0
206	Check: no treatment	25	25	0	0	
211	Check: no treatment	25	25	0 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 Johnson¹ 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 ½6 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

¹Johnson, 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)

Greenhouse 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

Sec- tion	Treatment	Number of plants	Number -dead	Percentage loss	
101 102	Inoculated. Sterilized	52 52	0 38	0 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

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

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

Sec- tion	Treatment		of plants White Enchant- tress	Num- ber dead	Total number dead	Total percent loss
216	Inoculated. Sterilized	25	25	0	0	
221	Inoculated. Sterilized	Water State	25	0	0	0
217	Sterilized. Inoculated	25	25	1 19	20	
222	Sterilized. Inoculated	25	25	10 24	34	54
218	Inoculated	25	25	18 21	. 39	
223	Inoculated	25	25	22 25	47	86
219	Sterilized	25	25	0	0	700
224	Sterilized	25	25	0	0	0
220	Check: no treatment	25	25	0	0	1
225	Check: no treatment	25	25	0 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									
160, 165	Sterilized Check Sterilized	No. 584 579 568	No. 562 565 552	percent 96.2 97.5 97.2	inches 2.79 2.76 2.76	inches 17.81 17.09 17.07	No. 470 259 396	percent 80.5 44.7 70.0	
White Enchantress									
160, 165	Sterilized Check Sterilized	863 773 819	706 713 660	81.2 92.2 81.8	3.11 3.12 3.11	14.74 14.76 14.64	758 643 637	87.8 83.8 77.7	

Table 20.—Effect of Steam-Sterilized Soil on Production and Quality of Carnation Flowers: 1914-15

Sections	Treatment	No. of flowers		erfect	Size	Stem	F	irsts
			Gl	oriosa				
220, 225	Sterilized Check Sterilized	No. 591 570 579	No. 577 533 563	percent 97.6 93.5 97.2	inches 2.87 2.83 2.86	inches 20.53 19.73 19.12	No. 508 479 475	percent 89.3 84.0 82.0
			White	Enchantre	ess			
220, 225	Sterilized Check Sterilized	721 705 762	679 674 689	94.1 95.6 90.4	3.18 3.16 3.09	18.83 18.69 19.00	701 674 737	97.2 95.7 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.

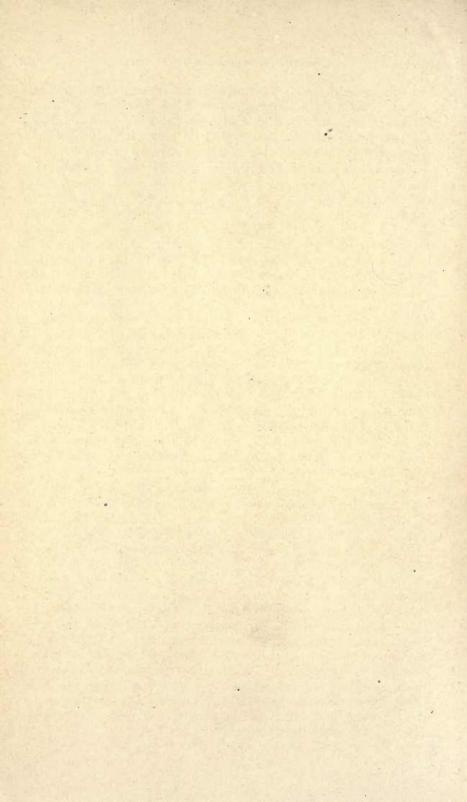
Soil Disinfectants of Little Value.—The results of these experiments indicate that the usual soil disinfectants, such as sulfuric acid, lime, Bordeaux, copper sulfate, and formalin, applied to the soil have but little effect on the fungus and that they are consequently of little value as a means of controlling 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 alkalics. 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 disearded.

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

PAGE	PAGE
Bull, Sleeter, Grindley, H. S.,	Mosier, J. G. Climate of Illi-
Mumford, H. W., and Em-	nois
mett, A. D. Fertilizing Con-	Mumford, H. W., Grindley, H. S.,
stituents Excreted by Two-	Emmett, A. D., and Bull,
year-old Steers127-162	
	Sleeter, Fertilizing Constitu-
Burlison, W. L., and Stark, R. W.	ents Excreted by Two-year-
Spring Wheat for Illinois. 313-320	old Steers
Crandall, Charles S. Apple-Bud	Pearson, F. A. The Cost of Milk
Selection: Apple Seedlings	Production Computed on the
from Selected Trees179-264	Year Basis341–364
Emmett, A. D., Grindley, H. S.,	Peltier, George L. Carnation
Mumford, H. W., and Bull,	Stem Rot and its Control. 577-608
Sleeter. Fertilizing Constit-	
uents Exercted by Two-year-	Peltier, George L. Snapdragon
old Steers127–162	Rust
	Rusk, H. P., and Grindley, H. S.
Fahrnkopf, H. F. T., Hopkins,	Field Investigations of For-
Cyril G., Garrett, F. W.,	age Poisoning in Cattle and
and Whitchurch, J. E. Illi-	Horses
nois Crop Yields from Ex-	Stark, R. W., and Burlison, W. L.
periment Fields397–504	Spring Wheat for Illinois.313-320
Garrett, F. W., Hopkins, Cyril G.,	
Whitehurch, J. E., and	Stevens, Frank Lincoln. An Ap-
Fahrnkopf, H. F. T. Illinois	ple Canker Due to Cyto-
Crop Yields from Experi-	spora
ment Fields397-504	Stevens, Frank Lincoln. Two Illi-
Grindley, H. S., Mumford, H. W.,	nois Rhubarb Diseases297-312
Emmett, A. D., and Bull,	Stevens, Frank Lincoln, and True,
Sleeter. Fertilizing Constit-	Esther Young. Black Spot
uents Excreted by Two-year-	of Onion Sets505-532
old Steers127-162	Stewart, Robert, and Wyatt, F.
	A. Limestone Action on Acid
Grindley, H. S., and Rusk, H. P.	Soils
Field Investigations of For-	
age Poisoning in Cattle and	True, Esther Young, and Stevens,
Horses	Frank Lincoln. Black Spot
Gunderson, A. J. Field Experi-	of Onion Sets505-532
ments in Spraying Apple	Whitehurch, J. E., Hopkins, Cyril
Orehards for the Control of	G., Garrett, F. W., and
Apple Blotch549-576	Fahrnkopf, H. F. T. Illi- nois Crop Yields from Ex-
Gunderson, A. J. The Pruning	nois Crop Yields from Ex-
of Winter-Injured Peach	periment Fields397-504
Trees	Wyatt, F. A., and Stewart,
	Robert. Limestone Action on
Hopkins, Cyril G., Garrett, F. W.,	Acid Soils265–296
Whitehurch, J. E., and	
Fahrnkopf, H. F. T. Illinois	Yapp, W. W. A Study of the
Crop Yields from Soil Ex-	Relative Reliability of Offi-
periment Fields	cial Tests of Dairy Cows 321-340

INDEX

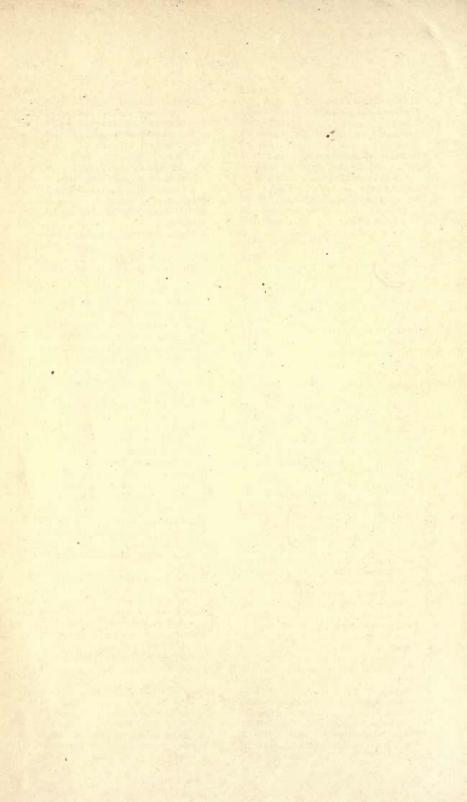
(The headings in capitals are subjects of entire bulletins)

FAGE	FAGE
Acidity of soil, influence on car-	Bloomington experiment field,
nation stem rot588-92	Crop yields in soil experi-
Aledo experiment field, Crop	ments
yields in soil experiments. 405, 407	Blotch, Apple, see Apple blotch
Alfalfa, germination at various	Calves, Tests to determine feeds
temperatures 25	responsible for unthriftiness
Alkalinity of soil, effect on car-	of
nation stem rot588–92	Carlinville experiment field, crop
Anthracnose, on onion sets 507	yields in soil experi-
Rhubarb	ments
Anticyclones, Weather changes	CARNATION STEM ROT AND
produced by 5, 9	ITS CONTROL 577-607
Antioch experiment field, Crop	Carnations
yields in soil experiments. 406, 407	Branch rot 583
Antirrhinum majus535, 540,548	Stem rot
Apple blotch	Conditions influencing growth
Recommendations for control	of parasite and host584-97
of	Control of
Spraying for control of 549-75	Conclusions and recommen-
Weather conditions affecting 553	dations
Apple-bud selection	Fungus
Comparative value of buds	Carthage experiment field, Crop
from different locations on	yields in soil experiments. 411, 413
shoot	Cattle, Feeding tests for forage
from different locations on	poisoning of163-69
tree	See also Dairy cows, Steers
Comparative value of robust	Chicago, Cost of milk production
and slender scions250-52	for
Conclusions	Clayton experiment field, Crop
Effect of vigor of stock on	yields in soil experiments. 412, 413
growth	Cleistothecopsis circinans507, 530
Influence of care in grafting. 252-53	CLIMATE OF ILLINOIS1-125
Test of size183–202	Clover, Red, germination at var-
Varietal and individual differ-	
	- I
ences	Colletotrichum erumpens299-308
APPLE-BUD SELECTION: AP-	Colletotrichum, Falcate-spored
PLE SEEDLINGS FROM	forms of
SELECTED TREES179-264	Corn
APPLE CANKER DUE TO	Days required for germination
CYTOSPORA, AN365-79	at various temperatures 25
Bibliography	Effect of rainfall on yield28-30
Description	Temperature for growth 27
Fungus	Corn silage, see Silage
APPLE ORCHARDS, FIELD	Corticium vagum 579
EXPERIMENTS IN	Cows, see Cattle, Dairy cows
SPRAYING, FOR CON-	Cutler experiment field, Crop
TROL OF APPLE	yields in soil experiments. 414-16
BLOTCH 549–75	Cyclones, Weather changes pro-
Apple seedlings, tests with, from	duced by 5,9
selected trees254–64	Cytosporas
	Bibliography
Black spot of onion sets505-32	on Rosaceous hosts374-75
See also Onion sets	On Mosaccous nosts

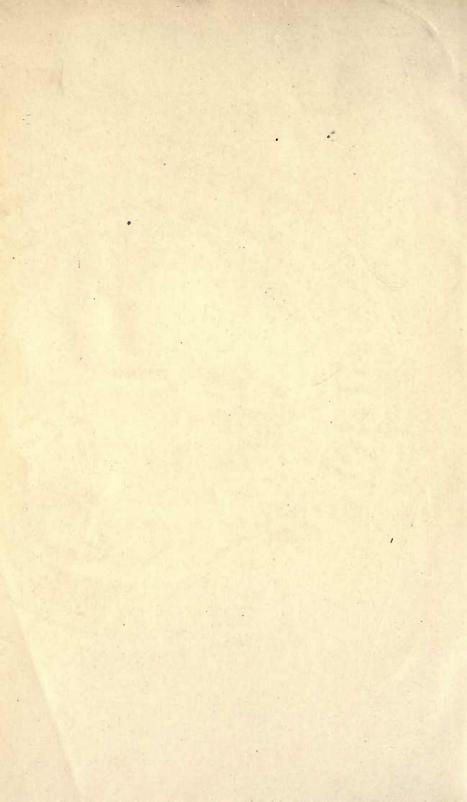
PAGE	PAG:
DAIRY COWS, A STUDY OF	Manures, Influence on carna-
THE RELATIVE RELIA-	tion stem rot of586-8
BILITY OF OFFICIAL	Commercial value of 155-59, 35-
TESTS OF321-39	FERTILIZING CONSTITU-
Dairy cows	ENTS EXCRETED BY
Official tests	TWO-YEAR-OLD
Comparison of seven-day test	STEERS
and seven-day test eight	Flax, germination at various
months after ealving 334-36	temperatures 2
Comparison of seven-and	
thirty-day tests333-34	Flora, Ill., Spraying experiments
Conclusions	
Correlation between semioffi-	FORAGE POISONING IN CAT-
eial and337–38	TLE AND HORSES, FIELD
Explanation of323-24	INVESTIGATIONS OF 163-70
Plan of investigation 325	Serum developed
	Serum treatment171-72, 174, 175
Records	Friend spray gun57
Relation of fat percentage	Frost, Time of, in Illinois46-4
to test period327–28	Fungicides, Experiments for con-
Variability in percentage of	trol of snapdragon rust541-4
fat	See also Sprays
Semiofficial tests	Galesburg experiment field, Crop
Accuracy	yields in soil experiments. 431-34
Correlation between seven-	Grafting, Influence of care in .252-53
day and	Grain system of farming on ex-
Explanation of324	poriment fields 401-09
Relation of fat percentage	periment fields
to test period328-30	Harristown, Ill., Feeding test
Variability in percentage of	with suspected silage at 168-69
fat	Hartsburg experiment field, Crop
Used in tests 323	yields in soil experiments. 435-36
Dairying, see Milk production	Holstein-Friesian dairy eattle
DeKalb experiment field, Crop	used in tests323
yields in soil experiments417-19	Horses, Forage poisoning investi-
Variety tests of spring	gations
wheat	Serum treatment 171-72, 174, 176
Dixon experiment field, Crop	Illinois, Climate1-124 ILLINOIS CROP YIELDS
yields in soil experiments. 420-22	ILLINOIS CROP YIELDS
Drainage, Effect upon loss of	FROM SOIL EXPERI-
limestone from soil272-73, 293	MENT FIELDS397-503
Dubois experiment field, Crop	Joliet experiment field, Crop
yields in soil experiments. 423-24	yields in soil experiments. 437-38
	Kewanee experiment field, Crop
Dusting apple trees for control of	yields in soil experiments43
apple blotch551, 552	I ille experiment field Crep
Compared with liquid spray-	Lamoille experiment field, Crop
ing	yields in soil experiments. 440-4
Edgewood experiment field, Lime-	Lebanon experiment field, Crop
stone on	yields in soil experiments. 442-4-
Enfield experiment field, Crop	LIMESTONE ACTION ON
yields in soil experiments.425, 427	ACID SOILS265-90
Experiment fields, see Soil experi-	Results from Newton field268-83
ment fields, names of particu-	Results from Odin field286-9
lar fields	Limestone
Ewing experiment field, Crop	Comparative effect of light and
yields in soil experiments. 426, 427	heavy applications. 286, 288, 29
Fairfield experiment field, Crop	Comparative value of high-cal-
yields in soil experiments428-30	cium and dolomitic274-8
Fertilizers	Effect of degree of fineness280-8
Commercial, Influence on ear-	Effect of drainage upon loss
nation stem rot of587-88	of 272 29

PAGE	PAGE
Effect on surface soil 270	Oquawka experiment field, Crop
Influence on subsurface and	yields in soil experiment462-63
subsoil 273-74, 282-85, 291-93	Ottawa, Ill., Forage poisoning in-
Live-stock farming on experiment	vestigations at169-76
fields 401	Pana experiment field, Crop yields
McNabb experiment field, Crop	in soil experiments463-65
yield in soil experiments. 445, 447	in soil experiments463-65 PEACH TREES, THE PRUN-
Manure, see Fertilizers	ING OF WINTER-IN-
Meteriological summary, Ill. Exp.	JURED
Sta. (1889-1916)	Phosphorus excreted by steers. 150-55
Sta. (1889-1916)55-64 MILK PRODUCTION, COST	Phyllosticta straminella308-312
OF	Poff Orchard, experiments at 387-93
Bases of calculation344-45	Pumpkin seed, germination at
Conclusions	various temperatures 25
Cow as unit in determining.357-64	1 To
Expenses	Rainfall in Illinois
Net cow cost	
Returns	Raleigh experiment field, Crop
Dairy herd as unit in determin-	yields in soil experiments. 466-67
ing	Rhizoctonia, Temperature best for
Expenses	growth of culture593
Net herd cost354–56	Rhizoctonia Solani579
Returns	Rhubarb Anthracnose299-308
Farm as unit in determining 345-46	Fungus
Source of data	RHUBARB DISEASES, TWO
See also Dairy cows	ILLINOIS
Minonk experiment field, Crop	Rhubarb leaf spot308-12
yields in soil experiments . 446, 447	Fungus
Mold on onion sets 507	Rockford experiment field, Crop yields in soil experiments. 468-72
Morrow plots 401	
Crop yields in soil experi-	Rosaceous twigs, Fungi on372-75
ments 486–87	Rye, germination at various tem-
Mt. Morris experiment field, Crop	peratures 25
yields in soil experiments. 448-49	Seedlings, Experiments with ap-
Neck rot of onion sets 507	ple
Neoga, Ill., Experiments with	Sidell experiment field, Crop
winter-injured peach trees.386-87	yields in soil experiments. 473-74
Newton experiment field, Crop	Silage, Feeding tests with sus-
yields in soil experiments450-54	pected
Limestone experiment on268-85	Smudge on onion sets507
Nitrogen excreted by steers143-50	SNAPDRAGON RUST533-48
Oats, germination at various tem-	Control
peratures 25	Fungus, Description of538
Oblong experiment field, Crop	History and distribution535-36
yields in soil experiments455-56	Host relationship and resis-
Odin experiment field, Crop yields	tance
in soil experiments457-61	In the field 547
Limestone experiments on286-95	Prevention and control541-47
Olney, Ill., Experiment with win-	Recommendations 548
ter-injured peach trees387-93	Seed not carriers of 546-47
ONION SETS, BLACK SPOT	Summary 548
OF	Symptoms
Bibliography	Snowfall in Illinois22-24
Causal fungus	Soil
Control of	Disinfection of599-602
Morphology	Limestone action on acid265-96
Perithecium	Moisture affecting carnation
Taxonomic position of asciger-	stem rot
ous stage	Steam sterilization602-06
Type of disease508-09	Temperature of 42, 43, 44, 45, 46
1) pc 01 discuse	10mportuture 011.11.12, 12, 11, 10, 1

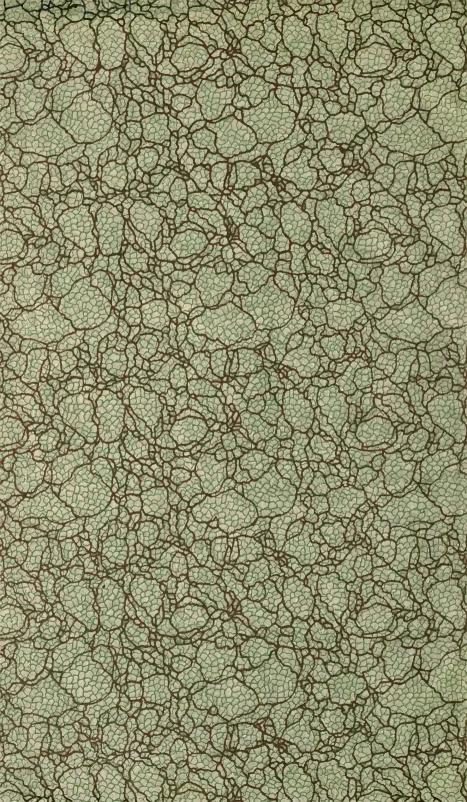
PAGE	PAGI
Soil experiment fields	Organic matter
Illinois crop yields from397-503	consumed
List of	exereted138-40, 141, 145
Materials for soil treatment . 402-03	Phosphorus excreted150-53
Rotations	Summary
Systems of forming 401-02	
Systems of farming401-02	Urine
Sparta experiment field, Crop	Amounts
yields in soil experiments 475-76	Collection and sampling 13:
Spraying experiments	Composition 136, 137–38
for control of apple blotch549-75	Stem rot, Carnation, sec Carnations
Dusting and liquid spraying	Sunshine, average amount for Illi-
compared	
Incidental observations	
561, 570–71, 573, 575	Syringing, Effect on snapdragon
Objects 551 561	rust of
Objects	Temperature of Illinois25-46
Recommendations	Meteorological summary (1889-
Summary of results, 1916560	1916)
1917	Records
1918 573	Timothy, germination at various
for control of snapdragon	
rust	
Sprays for apple trees	Toledo experiment field, Crop
Arsenate of lead551, 552	yields in soil experiments. 478-79
with lime sulfur568, 569	Union Grove experiment field,
	Crop yields in soil experi-
Bordeaux	ments
Formula	Unionville experiment field, Crop
with lime sulfur, see Sprays	
for apple trees, Lime sulfur	yields in soil experiments. 483-83
Copper sulfate551, 552, 562, 563	Urbana, Variety tests of spring
Lime sulfur551, 552, 562, 563	wheat
arsenate of lead562, 563	Urbana experiment field, Crop
copper sulfur mixture562, 563	yields in soil experiments. 486-97
Lime sulfur and Bordeaux	Valsas on fruits 376
Effect of interchanging559-60	on Rosaceous hosts372-73
Relative values	Vermicularia circinane 507 520 530
553–55, 563–65, 571–73	Vermicularia circinans507, 529, 530
Value of different applies	Vermiculariose on onion sets 507
Value of different applica-	Virginia experiment field, Crop
tions555-59, 565-68, 573, 574	yields in soil experiments.498-500
Scalecide551, 552, 562, 563	Volutella circinans507-33
Spring Valley experiment field,	Volutella, Falcate-spored forms
Crop yields in soil experi-	of
ments 477	
Steam sterilization for control of	Voris Orchard, experiments at .386-87
carnation stem rot602-06	Weather
Steers, Experiments to determine	affecting apple blotch 553
fertilizing constituents ex-	maps 6, 7
ereted by two-year-old127-62	See also Climate
	West Salem experiment field, Crop
Conclusions	yields in soil experiments501-02
Equipment and methods of ex-	Wheat, germination at various
periment	
Feces	
Amount	WHEAT, SPRING, FOR ILLI-
Chemical composition135, 136	NOIS
Feeds	Culture
Amount	Drills
Composition	Time to sow
Cost	Variety tests317-18
Rations	Yields and value318-20
Financial statement155-59	Wind in Illinois 48 50 55 64
Nitrogen excreted143–50	Wind in Illinois48-50, 55-64 Winter injury to peach trees383-94
UG-641	winter injury to beach trees 355-94

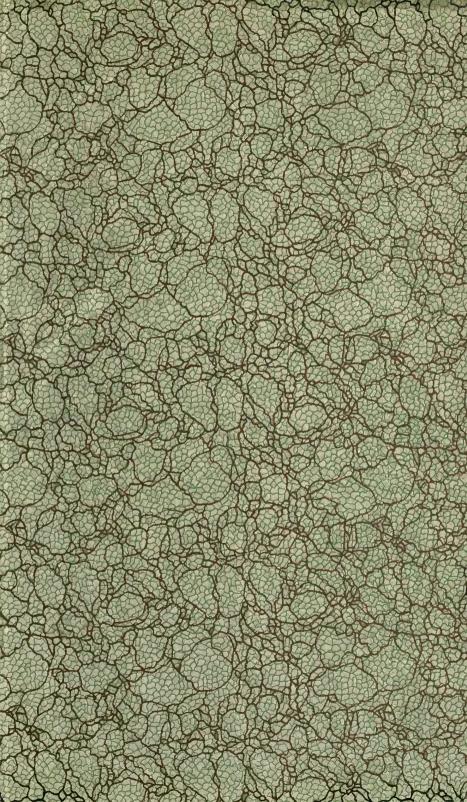












UNIVERSITY OF ILLINOIS-URBANA

Q.630.7IL6B BULLETIN. URBANA 208-223 1918-19

C002

3 0112 019529087