THE EFFECT OF RELATIVE HUMIDITY ON SPORE GERMINATION AND ON THE INCIDENCE OF BOTRYTIS LEAF ROT OF FORCED RHUBARB

THESIS FOR THE DEGREE OF M S

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By

William Lane Rushmore

AN ABSTRACT

Submitted to the College of Science and Arts of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Approved Harry H. Murakishi

ABSTRACT

Wm. Lane Rushmore

The effect of relative humidity upon germination of *Botrytis cinerea* spores in the laboratory and upon the incidence of *Botrytis* leaf rot of rhubarb under actual growing conditions was studied to provide further information which might be useful in reducing disease losses.

B. cinerea spores were germinated at different relative humidities at 20° C under controlled laboratory conditions. Dry spores from 10-day-old cultures were brushed onto clean cover slips and discs of rhubarb leaves and germinated at relative humidities from 93-100 per cent. In no case did germination occur below 93 per cent relative humidity.

The presence of free water on rhubarb leaves appeared to have a stimulating effect upon germination of *B. cinerea* spores. Germination of spores suspended in an extract made by steeping whole rhubarb leaves 24 hours in distilled water was compared with spore suspensions of similar concentrations in plain distilled water. The spores in extract germinated more rapidly and had a higher percentage of germination than those in distilled water. Spores either in extract or distilled water showed greater germination than spores depending upon air moisture alone.

Lowering the relative humidity from the near saturation levels at which rhubarb is normally forced to 85% was found to reduce the incidence of *Botrytis* leaf rot considerably while apparently not affecting yield or quality.

Sections in each of two hot-air-heated forcing houses were

sealed off with polyethylene and maintained at/or near 100% relative humidity and at or near 85% relative humidity.

In house number 1, 8.75% of the leaf area at low relative humidity was infected, compared with 25.4% under saturated conditions. In house number 2, at low relative humidity, 0.3% of the total leaf area was infected with leaf rot compared to 4.09% under saturated humidity.

On the basis of the study certain recommendations for reducing relative humidity and moisture condensation on leaves are given. These include the introduction of outside air into the intake fans of thermostatically-controlled hot-air furnace; a longer heating period during the season; possible use of reflective metal roofs and the construction or modification of forcing houses to allow adequate ventilation.

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INTRODUCTION

Rhubarb leaf rot, caused by the fungus Botrytis cinerea, is considered the most serious problem of the annual million dollar Michigan hothouse rhubarb industry (13). Infection occurring in the forcing house causes considerable loss and further serves as a source of inoculum for more serious losses later in shipping and marketing. The leaf breakdown reduces shelf life, discourages consumer purchases, increases product markup and during severe outbreaks causes distributors to condemn shipments and cancel orders.

Control of the disease with protectant fungicides has been demonstrated (12, 13) and is practiced by growers. However, sprays do not give 100% control, especially during the critical spring months when the relative humidity approaches saturation.

For years observant growers have believed that adequate ventilation to lower relative humidity is essential in reducing the incidence of the disease. Numerous checks made by the author in Macomb County and Ontario show a correlation between high humidity and serious leaf rot. Washington state and English growers feel that opening doors at night and forced air ventilation give them adequate control.

This investigation was undertaken to determine the effect of relative humidity upon germination of B. cinerea spores in the laboratory and upon the incidence of leaf rot under actual growing conditions in rhubarb forcing houses.

The host. Rhubarb, (Rheum raponticum L.) is a perennial grown outdoors throughout the world where the summers are humid and winters cold enough to freeze the ground. Originally cultivated by the Chinese for the medicinal effect of the roots, it is now grown for the petioles which are used for pies, sauce etc.

In certain concentrated areas rhubarb is forced for a winter crop. Macomb County, Michigan, areas of England, the Toronto and Montreal areas of Ontario and the Sumner area of Washington force considerable amounts of hothouse rhubarb.

Rhubarb usually is grown two years in the field before being forced. As much as two tons of high-analysis fertilizer per acre per year is applied. When the plants are dormant in the fall the crowns are plowed out and moved to the forcing houses. Approximately one acre of plants are required to fill the average size forcing structure (35 x 100 feet). Roots are covered with soil and then watered to saturation. Heat is applied and maintained at 50°- 60° F. Approximately two weeks after heat is applied, the buds swell and the stalks emerge. The first harvest occurs after six weeks of forcing and continues for 5-7 weeks. The forcing of houses is staggered to spread the harvest from January through May.

Forcing houses in Michigan are 3-4 feet high at the side walls and 7-10 feet high at the ridge. Most have removable roof boards which are covered with roofing paper and manure and are heated with stoves or by hot water systems. More recently constructed ones have permanent roofs and hot air furnaces.

Hothouse rhubarb is more tender, red and succulent than field-grown rhubarb. The leaf blade is yellow to pale green, due to the absence of light, and is much smaller in size than outdoor rhubarb.

<u>The disease</u>. <u>Botrytis</u> leaf rot appears first as a small, water

soaked area on the leaf blade. The area enlarges, turns brown and the typical grey-brown tufts of *Botrytis* conidia appear. Infection spreads over most of the leaf area and if left in the forcing house or on the shelf, infection can quickly spread to the petiole causing complete infection.

Leaf rot may occasionally be found in the field during wet periods in the spring but does little direct damage. These infections do, however, aid in over-summering the pathogen.

Environmental conditions in the forcing house are ideal for the development of the disease. The roots are concentrated in the forcing house, often allowing the stalks to touch. Movement of the roots from the field into the house injures the crowns so that the first leaves are weak and subject to the disease. These serve as the initial source of infection if not removed. Frequent harvesting causes bruise damage to unpicked stalks and the succulent leaves provide easy entrance of the organism.

REVIEW OF LITERATURE

Ramsey, Friedman and Smith (14) reported that grey mold rot, caused by Botrytis sp. is the most serious transit and market disease of field-grown rhubarb. Although vigorously growing plants in the field are seldom affected by the everpresent causal fungus, injured plants and old leaves become infected readily under humid conditions. Infection occurs on the leaf blade, particularly at the base, during harvesting and marketing.

According to Murakishi, Potter and Rushmore (12, 13) leaf rot is the major factor in quality loss of Michigan hothouse rhubarb. Losses occur in the forcing house and during the marketing process. They found that B. cinerea was the causal organism and that the disease became more damaging in early spring when inoculum has built up and humid weather prevails. Research in Michigan forcing houses revealed that protectant fungicidal sprays gave considerable control of the disease.

Carew, Barry and Carpenter (7) listed leaf rot as a principal problem of the hothouse rhubarb industry and indicated that "High leaf rot incidence can generally be related to excessive humidity." English workers (2) reported that "The common grey mold, B. cinerea, is apt to be troublesome under conditions of high humidity but can be kept in check by adequate ventilation."

Botrytis is a common pathogen, attacking more than one-hundred different host plants (1). Brown (4) reported the pathogen as early as 1885. It is a serious problem of strawberries during humid weather. Miller and Waggoner (11) found that most spores were caught during periods of high humidity. The employment of cultural

practices to induce air movement and to lower the humidity in the microclimate of strawberries is a standard control measure. The disease is destructive to greenhouse crops of cucumbers and tomatoes (10) during the humid spring months.

Reducing relative humidities to control or reduce the incidence of tomato Cladosporium leaf mold has been advocated for greenhouse-grown tomatoes. Guba (9) recognized the need for humidity reduction as a step in leaf mold control.

Florists have serious difficulties with Botrytis in their greenhouses, 16 major flower crops being attacked by the pathogen. The disease is most serious in the spring and fall when humidity is high. Sanitation and fungicides are used but reducing relative humidity by ventilation and maintenance of heat is considered the most important and basic control measure and is universally recommended (14).

Spores of B. cinerea are disseminated by cultural operations, contact with infected tissues and by air currents (11). The pathogen has a large capacity for germination and growth at low temperatures (5). Blackman found that the spores penetrate unwounded cuticle by means of a fine infection peg. No enzyme is needed for penetration of the cuticle but Brown (6) reported that the pathogen killed host tissue in advance of fungal growth by enzyme action.

According to Brown (5) the germination of B. cinerea spores is increased by the exosmosis of nutrient substances arising from plant tissues such as leaves. Acid substances increased germination and conditions of feeble nutrition produced a drastic stimulation.

MATERIALS AND METHODS

Laboratory methods of germination. Studies were made under laboratory conditions to determine the minimum relative humidity at which *B. cinerea* spores will germinate.

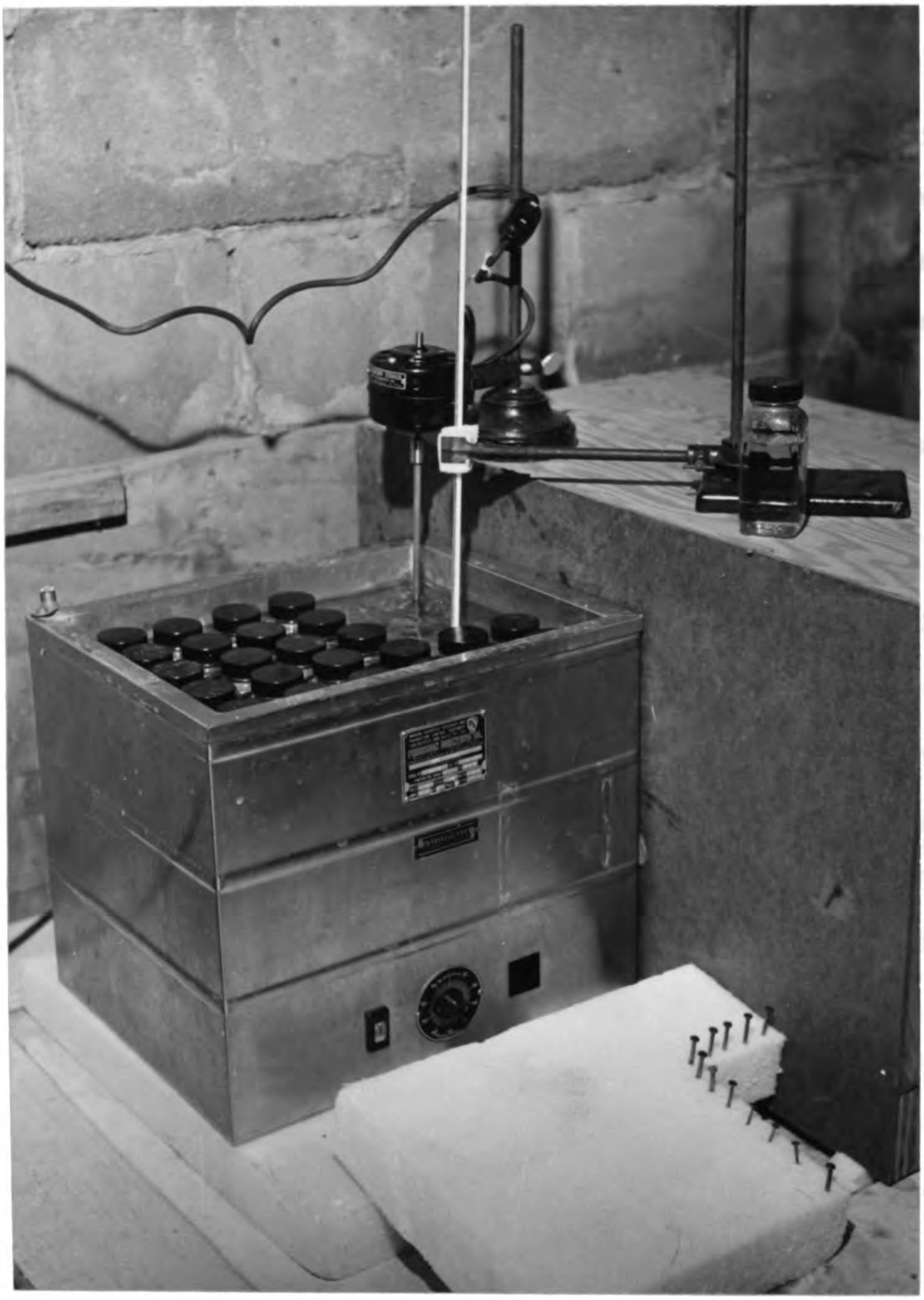
Spore germination was tested in humidity chambers at the following relative humidities: 100%, 98.0%, 97.2%, 95.0%, 93.2%, 92.0%, 90.0% and 86%. Distilled water was used for the 100% chamber with saturated solutions of various electrolytes used to obtain the other relative humidities at 68° F. (see Figure I) in the manner of Clayton (8). New 250 mm. bottles and plastic caps were carefully washed, rinsed in distilled water and filled three-quarters full with saturated solutions of analytical grade electrolytes and distilled water. The bottles were steamed to disolve the chemicals and cooled to 68° F.

Corks were cut to a three-eights-inch width on the lower two thirds. The corks were fitted snugly into the bottles and projected to one-eighth inch of the solution levels. A razor slit was made to allow the horizontal insertion of cover slips one-fourth inch from solution levels. Corks were then carefully washed and rinsed.

New round cover slips were cut in half, cleansed in a hot acid bath and washed for two weeks in frequently changed distilled water.

The bottles were immersed in a water bath with the water level to the top of the glass but not covering the plastic tops. The water bath was set up in a potato storage cellar where a constant temperature of 65-67° F. was maintained by thermostatically-controlled, hot-water-heated fan systems. A constant temperature of 68°± .02 F. was established and maintained in the water bath. Agitation was

FIGURE 1



WATER BATH CONTAINING HUMIDITY CHAMBERS

provided with a mechanical stirrer to prevent stratification of the water. A two-inch-thick piece of styrofoam was fitted snugly on top of the bottles to insulate against the effects of external temperature changes and to prevent bottle movement.

The half cover slips were carefully inserted into the corks with tweezers, the corks slipped into the bottles and the caps tightened. Extreme care was taken during this and the subsequent delicate operations not to allow any moisture to get on the cover slips or corks from the edge of the bottles or by movement of the solutions within the bottles. The apparatus was left for two weeks at 68° F. to allow the vapor pressure of the solutions and corks to come into equilibrium.

Spores were then dusted on the cover slips. The corks were first removed with a dissecting needle and the spores dusted on the cover slips with a clean camels hair brush. During these and subsequent operations the caps were replaced on the bottles so that they were not uncapped more than six seconds at a time. The corks were replaced, caps tightened and bottles returned to the water bath. The bottles were not out of the water bath for more than one-half minute.

All spores used in this series of tests were harvested from PDA agar tube slants. Spores came from a single spore isolation of B. cinerea from an infected rhubarb leaf and grown for ten days at room temperature.

At 24, 48 and 72 hours one bottle at a time was taken from the water bath, the cork removed and the cover slip removed. The spores were killed immediately and semi-permanently mounted in cotton blue-lactophenol for subsequent spore counts. The number of spores germinated out of two-hundred counted at random was determined and germ tube measurements made. This experiment was repeated twice with three replications at each relative humidity.

To determine possible differences between Botrytis spore germination on cover slips and on rhubarb leaves, spores were germinated in the humidity chambers on discs cut from rhubarb leaves. The rhubarb leaves for the experiment were obtained by forcing rhubarb in darkness at 50% relative humidity in the potato storage cellar. No leaf rot developed at any time at that humidity and no spores were present upon the leaves.

Three-eighths-inch-diameter discs were cut from the mid rib at the base of leaves of similar size and appearance. These were fastened to the bottom of the corks with small staples. The discs were dusted with spores and handled as in the previous experiment except that the discs were removed only at 24 hours.

Leaf discs were cleared with pyridine and semi-permanently mounted in cotton blue-lactophenol. When spore counts were made, the areas around staple holes and the edge of the leaf were avoided.

Spore germination in rhubarb leaf extract versus distilled water. The germination of B. cinerea spores in rhubarb leaf extract was compared to germination in distilled water to determine if free moisture on hothouse rhubarb leaves releases substances that stimulate spore germination.

The extract was prepared by soaking young hothouse rhubarb leaves in distilled water for 24 hours at room temperature. Leaves were obtained from rhubarb grown at low relative humidity to minimize the possibility of introducing germinating spores into the extract.

The p.H. of the extract and distilled water was determined with a Beckman p.H. meter.

Spore suspension drops were placed on new slides washed in a hot acid bath and rinsed in distilled water. Slides were placed in a saturated humidity at room temperature. The 25,000 spore per ml suspensions were obtained by mixing equal parts of distilled water and the rhubarb leaf extract with a freshly made 50,000 spore per ml. suspension. Spores were obtained from the same single-spore suspension as before and grown 10 days in PDA test tube slants. Each test was replicated and repeated.

At the end of $1\frac{1}{2}$, 2, 3, 4, 8, 12 and 24 hours slides were removed, dried by gentle heating over a gas flame and mounted in cotton blue-lactophenol. Germination of 200 spores selected at random were counted and recorded as before.

Forcing house methods. During the forcing season of 1958 the author assisted Dr. Murakishi and Scott Hedden of Michigan State University in an attempt to reduce leaf rot by lowering forcing house humidity. A polyethylene barrier was erected to separate a hot-water-heated house. In one half, powerful fans were installed to circulate and exhaust air. The other half was the control. No difference was determined between leaf rot in the two sections. Hygrothermograph records revealed that the relative humidity in the ventilated half was not significantly lower than that of the control.

The author repeated the above in another hot-water-heated house the following season. Results obtained were similar to those of the previous attempt.

In the 1960 forcing season a different approach was used to lower humidity. A number of growers had constructed forcing houses heated with forced-air furnaces. Numerous determinations of relative humidity in all types of forcing houses revealed that many of the houses heated with hot air had lower humidity than those heated with hot water or stoves. Furthermore, there appeared to be a correlation between the amount of leaf rot and humidity. Where the humidity was below 85%, leaf rot was not a problem.

Two such hot-air-heated houses were chosen for the 1960 experiment, one operated by Don Campbell of Romeo and one operated by Joe Reinhardt of Washington. Both farmers are experienced rhubarb growers who expressed an interest in leaf rot control and were willing to cooperate fully, even though some inconvenience to them was experienced.

Don Campbell's house (hereafter referred to as house number 1) measures 40' x 75' with an 8½' peak. It is built on Brookston clay loam soil. Sidewalls are 4½' high. The roof is constructed of 1" boards covered with tar paper. Six inches of straw manure covers the roof during forcing and manure is piled around the side walls. The coal-fired, hot-air furnace is located in an adjacent room and also heats another similar forcing house. When both houses are being heated simultaneously air is exchanged freely. Hot air is circulated through pipes by a fan. Rhubarb roots were placed in the house in the fall and allowed to lie dormant until early March when heat was applied and maintained at a relatively constant 53° F. by a thermostat.

An early crop of rhubarb in the house adjacent to house number 1 was free of leaf rot until the later stages of forcing when serious leaf rot developed. This coincided with the opening up and heating of house number 1 and a rapid general increase in humidity resulting from the presence of excessive water in house number 1. Watering plus seepage from early spring rains caused wet conditions and standing water.

Joe Reinhardt's house (hereafter referred to as house number 2) is 30' x 100' x 10'. Construction is similar to Campbell's. The house is located on well-drained Berrien fine sandy loam. The hot-air furnace is located in one end of the forcing house proper. An early crop of rhubarb was forced in the house, the spent roots removed and the house refilled with roots. Heat was applied in mid March. The early crop was almost entirely free of leaf rot and humidity was much lower than most houses at that time.

To be assured of low humidity during the critical spring months the author encouraged both growers to install air ducts to introduce outside air directly into the fan of the furnace. Campbell ran an 8" round duct through the ceiling on April 1 and Reinhardt ran an 8" square duct through the side wall (see Figure 5). Operation of the fan drew considerable amounts of outside air into the furnace. Warming of this outside air reduced the relative humidity. Stale air was forced out of sidewall vents or other openings. Later in the season, Reinhardt opened one end of house number 2, allowing considerable outside air to enter.

In each house a control was established by maintaining normal (high relative humidity) rhubarb forcing conditions. This was accomplished by constructing an 8' x 10' tent of 8 mil polyethylene in the center of the house. The polyethylene extended from the ceiling to the ground. An opening consisted of a flap of polyethylene which was held to the door jamb by wood lath. Stapled wood lath on the sides and ceiling and an earth barrier at the bottom of the polyethlene made the tents sufficiently air tight. No ventilation was provided to either high humidity section but all other cultural practices were the same as the rest of the house.

Two hygrothermographs were installed in house number 1 at leaf level in each section and one in the low-humidity section of house number 2. The operation of these instruments was checked weekly with a sling psycrometer and record charts changed. The high humidity section of house number 2 was checked similarly until April 22 when a hygrothermograph was moved from the high humidity section of house number 1.

Both growers followed their normal cultural practices. House number 1 was watered at the first application of heat only. House number 2 was watered at first heat and again in early April. House number 1 was sprayed with Captan (2 lb. 50% W P/100 gals. water) weekly from bud break. One half of the high-humidity section was left unsprayed and a number of the beds in the low-humidity section were unsprayed. House number 2 was not sprayed. Deadheads and diseased leaves were picked and removed from house number 1 twice. This sanitation program was followed in house number 2 weekly until the last two weeks of the experiment.

The incidence of leaf rot was evaluated by determining the percentage of all leaf area with visible leaf rot. At least 200 leaves were carefully inspected for each reading, all leaves from a root being counted regardless of size. Readings were made of the

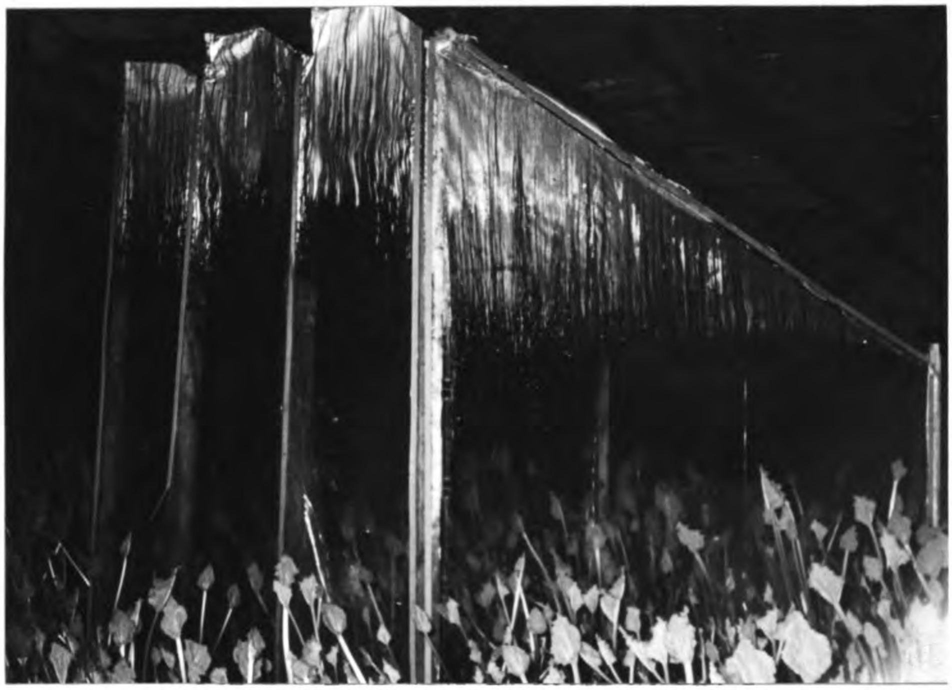
FIGURE 2

RHUBARB LEAF INFECTED WITH BOTRYTIS
LEAF ROT

FIGURE 3

HYGROTHERMOGRAPH IN HIGH-HUMIDITY SECTION
OF HOUSE NUMBER 1 SHOWING HIGH INCIDENCE OF LEAF ROT

FIGURE 4



TO PRODUCE HIGH HUMIDITY

FIGURE 5

DUCT INTRODUCING OUTSIDE AIR
INTO FURNACE BLOWER FAN OF HOUSE NUMBER 2

entire sprayed and unsprayed beds of the high-humidity section and random sprayed and unsprayed beds of the low-humidity section.

EXPERIMENTAL

Germination under controlled humidity. Results of this experiment are shown in Table I and graphically presented in Figure 6. Spore germination was observed at all humidities from 93.2% to 100% with an increase in germination as humidity increased. No spores germinated at relative humidities below 93.2%. Spore germination was not complete, the highest being 18.3% on the rhubarb leaf discs at 100% relative humidity. Germination rate on the rhubarb leaf discs was greater than on the cover slides in all but the 93.2% humidity.

Germ tube growth was generally increased with time of incubation and decreased as relative humidity was reduced.

Spore germination in rhubarb leaf extract vs. distilled water. Results of this experiment are shown in Table II. The p.H. of rhubarb leaf extract was determined to be 5.5 as compared to 6.3 of distilled water. Spores in the extract germinated much more rapidly than in the distilled water. After four hours incubation 94.9% of the spores in extract had germinated compared to 2.8% in distilled water. Practically all of the spores in extract had germinated at the end of 24 hours while only 44.5% had germinated in distilled water. This increase in germination may be due to an exosmosis of nutrient substances, the lowering of p.H. or a combination of these factors (15). Regardless of the specific cause, the effect of condensed water on rhubarb leaves appears to have effects beyond providing water for spore germination. Where these factors were not present, such as in distilled water or on clean cover slides at 100% relative humi-

TABLE I

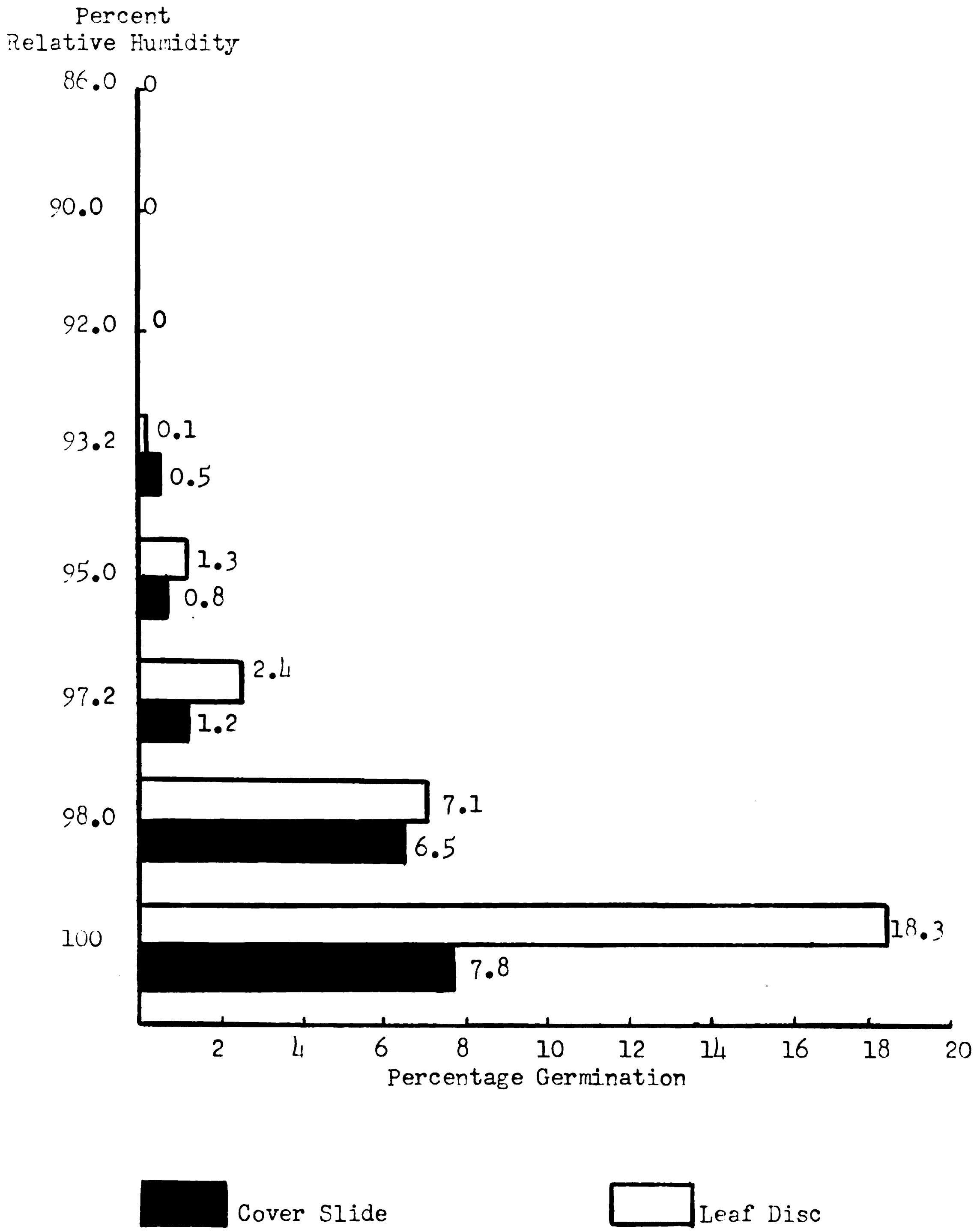
THE EFFECT OF RELATIVE HUMIDITY
ON GERMINATION OF *BOTRYTIS CINEREA* SPORES

Relative Humidity	Saturated Solutions of	Germination on Cover Slides						Germination on Rhubarb Leaves
		24 Hours		48 Hours		72 Hours		24 Hr.
		Per Cent Germination	Germ* Tube	Per Cent Germination	Germ* Tube	Per Cent Germination	Germ* Tube	Per Cent Germ.
1. 100%	Distilled Water	4.3	172.7	9.4	199.7	9.6	219.0	18.3
2. 98%	$CaSo_4.5H_2o$	3.3	85.8	6.3	144.1	9.9	138.9	7.1
3. 97.2%	K_2So_4	0.1	23.2	2.0	100.2	1.6	81.1	2.4
4. 95.0%	$Na_2HPo_4.12H_2o$	0.9	99.4	0.6	94.2	0.8	195.0	1.3
5. 93.2%	$NH_6H_2Po_4$	0.5	48.0	0.4	20.2	0.4	72.6	0.1
6. 92.0%	$KHPo_4$	0.0	00.0	0.0	00.0	0.0	00.0	0.0
7. 90.0%	$ZnSo_4.7H_2o$	0.0	00.0	0.0	00.0	0.0	00.0	0.0
8. 86.0%	$KHSo_4$	0.0	00.0	0.0	00.0	0.0	00.0	0.0

*Average Length in Millimicrons

FIGURE 6

PERCENT GERMINATION OF *BOTRYTIS CINEREA* SPORES AT A RANGE OF RELATIVE HUMIDITIES



Average of 24, 48 and 72 Hours

dity per cent spore germination was observed to be less.

TABLE II

GERMINATION OF *BOTRYTIS CINEREA* SPORES IN RHUBARB LEAF EXTRACT VS. DISTILLED WATER

Hours Incubated	Percentage of Spores Germinated	
	Distilled Water	Rhubarb Leaf Extract
1½	0.3	2.1
2	1.0	10.8
3	1.1	21.5
4	2.8	94.9
6	41.1	99.4
12	40.4	99.5
24	44.5	98.3

Forcing house studies. Table III summarizes the mean temperatures and relative humidities in the two rhubarb houses as determined by hygrothermograph records.

In the low-humidity section of house number 1 temperature remained relatively constant. Relative humidity was also fairly constant, remaining in the range of 86% - 91% until April 1st, when the outside air duct was installed and the humidity dropped. Average relative humidity was 87.8%. Shutting down the furnace on April 11th resulted in greater fluctuations in temperature and humidity and a general increase in humidity to levels in the low 90's. Roof boards remained dry until the heat was turned off, at which time they became wet to the touch.

TABLE III

MEAN TEMPERATURES AND RELATIVE HUMIDITIES
IN TWO RHUBARB FORCING HOUSES

	House Number 1 March 18-April 22		House Number 2 March 25-May 10	
	High Hum. Section	Low Hum. Section	High Hum. Section	Low Hum. Section
Max. Temp.	52.7°F.	54.7°F.	60.0°F.	63.4°F.
Min. Temp.	49.1°F.	52.3°F.	48.3°F.	50.5°F.
Average Temp.	50.9°F.	53.5°F.	54.2°F.	56.9°F.
Max. Rel. Hum.	98.3%	89.0%	99.4%	90.5%
Min. Rel. Hum.	98.2%	86.6%	97.9%	77.0%
Aver. Rel. Hum.	98.2%	87.8%	98.7%	83.7%

In the high-humidity section of house number 1 temperatures averaged 2.6° F. lower than in the low-humidity section. The humidity quickly built up to 90% and increased to 99%, averaging 98.2%. Roof boards, polyethylene and the rhubarb petioles and leaves were constantly wet.

In the low-humidity section of house number 2 considerable fluctuation in temperature and humidity existed because the coal furnace was hand-fired and not thermostatically controlled. Humidity built up to as high as 92% during the night and during cold periods but fell to as low as 55% during warm periods with an average of 83.7%. Except for a few brief periods of low temperature, roof boards and the rhubarb remained dry.

In the high-humidity section of house number 2 humidity quickly built up to 98% or more and an average of 98.7% was maintained.

Table IV shows the effect of lowering humidity upon the incidence of leaf rot. In the high-humidity section of house number 1, 25.4% of the total leaf area, sprayed and unsprayed, displayed visible evidence of rot as compared to 8.8% in the low-humidity section. In the high-humidity section, leaf rot was much less where sprayed but at low humidity no significant difference was noticed between sprayed and unsprayed plots. Even the low humidity section was very seriously infected with the disease. This may be attributed to a compounding of several factors. Throughout house number 1 many roots developed seed stalks, an extremely rare occurrence in forced rhubarb. The leaves on seed stalks were observed to develop leaf rot more readily than leaves of non-flowering plants. The late buildup of leaf rot in the adjacent early house served as a source of inoculum to infect the weakened leaves and build up to high levels quickly. With fairly high general humidity conditions it is possible that the microclimate of the leaves was favorable for many spores to germinate. The situation became so bad that Mr. Campbell neglected to maintain the sanitary practices necessary for control.

In the low-humidity section of house number 2 leaf rot never was severe, 0.8% of the total leaf area being the highest reading with an average of 0.3%. Most of these infected leaves were either deadheads or had mechanical injury. Most deadheads dried up without developing any rot, a situation not found in most forcing houses. The weight of rhubarb harvested did not appear to be reduced by the low humidity. The crop was light in both high and low humidity sections.

In the high-humidity section, leaf rot reached serious levels once the humidity exceeded 95%, to a high of 8.5% and an average of 4.1%.

TABLE IV

THE EFFECT OF HUMIDITY IN RHUBARB FORCING HOUSES UPON THE INCIDENCE OF BOTRYTIS LEAF ROT

HOUSE NUMBER 1

	Percent of Total Leaf Area Infected			
	Low Humidity		High Humidity	
	*Sprayed	Unsprayed	Sprayed	Unsprayed
April 1	3.6	3.8	6.4	8.3
April 8	4.9	5.1	10.2	18.3
April 14	9.5	9.4	23.7	29.6
April 22	16.8	17.4	32.3	73.9
Average	8.8	8.7	18.3	32.5
Average Sprayed and Unsprayed	8.75		25.4	

*Weekly Captan Sprays

HOUSE NUMBER 2

	Percent of Total Leaf Area Infected	
	Low Humidity	High Humidity
April 21	0.1	0.6
April 28	0.1	1.4
May 4	0.3	5.9
May 10	0.8	8.5
Average	0.3	4.1

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the laboratory and forcing house studies, certain recommendations can be made to growers. The incidence of Botrytis leaf rot in rhubarb forcing houses can be reduced considerably by proper ventilation to obtain lower relative humidity. The use of ventilation coupled with fungicidal sprays and good sanitation practices should enable growers to force rhubarb during the critical spring months with a minimum of leaf rot in the house and during transit.

Ducts to introduce outside air into the intake fans of hot-air furnaces can be used effectively to reduce relative humidity in forcing houses. Heat should be utilized later in the season than presently practiced to maintain reduced humidity conditions during the spring months. To overcome the effects of heat build up during sunny spring days, late crop houses should preferably be constructed with reflective metal or white-painted roofs, and be well insulated. Furnaces should be thermostatically controlled to avoid fluctuations in temperature which result in condensation of water on leaves and stimulate spore germination. Houses constructed to allow for an adequate volume of air in relation to total leaf area are advisable.

Growers should maintain a constant relative humidity of 85%. With adequate air movement within the house the leaf microclimate should then be below 93% R. H. At this humidity rhubarb appears to grow favorably without weight loss. Rhubarb grown at relative humidity below 80% is reduced in weight and the leaves tend to discolor and dry.

Forcing at lower humidities than commonly practiced may necessitate a change in the watering practices of many growers to avoid desiccation. Subirrigation may be the most favorable method.

Growers with hot-water-heated furnaces (who do not wish to change) will have difficulty in maintaining a relative humidity approaching 85% during spring months. Considerable relief from serious leaf rot should result from maintaining a constant temperature and as low a relative humidity as possible by ventilation. Even though Botrytis spores will germinate at 93% relative humidity, germination is considerably lower at humidities below the 98-100% commonly found in forcing houses. Ventilation shafts in the roof, openings in the side walls or open doors at night have all proven effective to lower humidity slightly. Fans to circulate air within the house prevent the leaf microclimate from building up to high levels and prevent condensation of free water. The rapid introduction of unheated cold air at leaf level should be avoided, however, as this will cause condensation of moisture in the saturated air and wetting of the leaves.

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