THE RELATION OF HUMIDITY TO INFECTION OF THE SWEET POTATO BY RHIZOPUS[1]

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INTRODUCTION

Air moisture is one of the most important environmental factors in plant responses, not only as it affects the physical conditions and physiology of the plant, but because of its influence on the infection and the development of diseases caused by microorganisms. For the most part, it has been assumed that high humidity favors, and is even essential to, infection. This generalization is based largely on observation rather than on experimental data. It seems quite likely that it is generally true, but like many generalizations it is too broad and may not hold in many cases. It has been assumed, also, that within the range of humidities at which infection occurs there is a tendency for the number of infections to increase with the increase in relative humidity. There are some data to justify this conclusion, but they are not a sufficient basis for a generalization. Neither of the assumptions just mentioned holds in connection with infection of the sweet potato by Rhizopus.

Manns (*5*),[2] who seems to have in mind the losses due to Rhizopus soft rot and black rot, regards a relative humidity of 80 per cent and above as inimical to the keeping of sweet potatoes. His conclusions were based on bell-jar and storage-house experiments. The bell-jar experiments were limited in number and there was no provision made for air exchange; and in the storage-house experiments the factors, such as temperature, humidity, and wounding, were not controlled or definitely isolated, and apparently he did not study the diseases separately. The present writers were able to confirm his results only in part.

The purpose of this paper is to present the results obtained from a study of the effects of air moisture on the infection of the sweet potato by Rhizopus (*nigricans* and *tritici*) under certain conditions.

APPARATUS AND CONTROL OF CONDITIONS

The experiments discussed below were conducted either in the infection chambers described in an earlier publication (*4*), or in a sweet-potato storage house constructed according to plans designed by the United States Department of Agriculture (*6*).

The temperature of the infection chambers was controlled in the manner described in the above-mentioned publication (*4*). The control of humidity was accomplished by means of water and saturated salt solutions in evaporation pans (*3*). Continuous air exchange

[1] Received for publication Mar. 2, 1926; issued September, 1926.
[2] Reference is made by number (italic) to "Literature cited," p. 538.

was provided in each instance (*4*). A storage house 40 feet long, 20 feet wide, and 9 feet high, was partitioned into two rooms of the same size. In the one room a high humidity was maintained by means of a fine spray of water, the small droplets of the spray being entirely evaporated in the part of the room in which the potatoes were placed. In the other room a lower humidity was obtained by means of calcium chloride in a large evaporating pan. The temperature of the two rooms was governed by the outside temperatures, and was nearly the same in both rooms in each experiment. The difference was believed to be insufficient to be a disturbing factor.

MATERIALS USED

The Yellow Jersey, Big Stem Jersey, and Porto Rico varieties of sweet potato were employed. The species of Rhizopus used were *Rhizopus nigricans* Ehr. and *R. Tritici* Saito.

EXPERIMENTAL DATA

HUMIDITY AND INFECTION OF HALVED ROOTS

The infection of the sweet potato by Rhizopus occurs almost exclusively through fresh wounds, so in order to study the influence of humidity on infection it is necessary to work with freshly wounded roots. In a series of 15 experiments the roots were cut in halves lengthwise and placed at various humidities at a constant temperature of 23° C. In 12 of the experiments the potatoes were inoculated by dipping them in a suspension of *Rhizopus nigricans* and *R. tritici* spores; in the other 3 experiments the potatoes were not inoculated. The effects of inoculation, if any, were merely to increase the percentage of infection at the various humidities. In previous work (*4*) it was found that the inoculation of wounded potatoes by means of a spore suspension did not alter the temperature range of infection of either of these species, obtained when the potatoes were not inoculated. The species isolated from decayed potatoes in these present experiments was mostly *R. nigricans*, *R. tritici* being isolated only in a few instances. This fact was in accord with previous experience (*4*). Since the absence of inoculation did not in any way alter the relations found in connection with the inoculated potatoes, the results from inoculated and uninoculated roots will be considered together.

Table 1 gives the results of seven experiments in which the Yellow Jersey was the variety of potato used. A range of five different humidities was employed in each experiment. Wherever the same humidity was obtained during the successive experiments, the results are considered collectively. The figures in the last column represent the number of times any particular humidity was employed during the seven experiments. The percentage of infecton rose from 21 per cent at humidities of 93 to 98, to 96 and 100 per cent at relative humidities of 76 to 82 per cent. At relative humidities of 48 to 53, the percentage of infection was 25 per cent. Only one experiment of this series included a relative humidity of 76, consequently the percentage of infection obtained may be high for this humidity, which will be iudicated by results recorded in Table 2.

TABLE 1.—*The relation of humidity to infection of Yellow Jersey sweet potatoes by Rhizopus*

Temperature, ° C.	Depression of wet bulb, ° C.	Relative humidity	Number of halved roots used	Number of halved roots infected	Percentage infected	Time of exposure in days	Number of experiments at each humidity
23.6	0.2–0.8	93–98	170	35	21	3–11	5
23.1	1.0–1.3	90–92	496	216	44	3–11	13
23.2	1.6–1.9	84–87	98	63	64	3–11	3
23.7	2.2–2.6	79–82	308	295	96	3–11	9
23.4	3.1	76	18	18	100	11	1
22.5	6.2–6.9	48–53	120	30	25	3–9	3

TABLE 2.—*The relation of humidity to infection of Yellow Jersey sweet potatoes by Rhizopus*

Temperature, ° C.	Depression of wet bulb, ° C.	Relative humidity	Number of halved roots used	Number of halved roots infected	Percentage infected	Time of exposure in days	Number of experiments involved
23.4	0.2–0.4	97–99	90	9	10	7–11	3
23.5	0.6–0.9	93–95	240	58	24	3–12	5
23.0	1.0–1.5	87–92	696	262	38	3–15	18
23.3	1.6–1.9	84–86	178	101	57	3–11	5
23.0	2.0–2.5	80–84	388	320	82	7–11	11
23.0	2.6–2.8	78–79	120	105	88	3–12	3
22.7	3.0–3.4	72–76	138	89	64	7–15	4
22.4	4.4–5.3	59–65	200	19	10	7–15	5
22.6	6.2–6.9	48–52	160	36	23	3–12	4

In Table 2 are recorded the results given in Table 1, combined with the results of five other experiments conducted later. These latter five experiments also had to do with the Yellow Jersey variety of sweet potato. The purpose of giving the two tables is to show the variation in the results obtained from different experiments, and at the same time to show the general consistency of the data obtained.

The percentage of infection rises from 10 per cent at relative humidities of 97 to 99, to 82 and 88 per cent at relative humidities of 78 to 84, and drops to 10 per cent at relative humidities of 59 to 65, and rises to 23 per cent at relative humidities of 48 to 52. It is not known whether this last rise has any significance, although a similar relation was found in an experiment with the Porto Rico variety. Possibly if a larger number of experiments were conducted, a higher percentage of infection at relative humidities of 59 to 65 per cent or a lower percentage of infection at relative humidities of 48 to 52 might have been obtained.

In Table 3 are given the results in which the Porto Rico variety was used. The percentage of infection increased from 15 at relative humidities of 93 to 97, to 98 at relative humidities of 75 to 76. There is a slight drop in the number of infections as the humidity is lowered. At a relative humidity of 63 the percentage of infection was 81, and at a relative humidity of 52 the percentage of infection was 75. The percentage of infection at these latter humidities is high in contrast to that obtained with Yellow Jersey. It should be noted, however, that the results were obtained from one trial at each of the two humidities from two experiments. In a third experiment run late in the season, when the outside temperature was high and consequently that of the chambers (27° C.), the percentage of infection at a relative

humidity of 61 was 22. It is possible that if a larger number of experiments were conducted at these humidities the percentage of infection might be lowered. There is a close correspondence in the percentage of infection of Porto Rico to that of Yellow Jersey at humidities between 75 and 98.

TABLE 3.—*The relation of humidity to infection of Porto Rico variety of sweet potatoes by Rhizopus*

Temperature, °C.	Depression of wet bulb, °C.	Relative humidity	Number of halved roots used	Number of halved roots infected	Percentage infected	Time of exposure in days
25	0.4–0.8	93–97	54	8	15	6–7
24	1.2–1.6	86–91	110	41	37	6–7
23.5	3.1–3.2	75–76	56	55	98	6–7
22.0	4.8	63	32	26	81	7
22.6	6.2	52	24	18	75	6

Figure 1 represents graphically the results recorded in Tables 1, 2, and 3. The percentage of infection is plotted against the depression of the wet bulb, because these figures are more exact than the relative humidities. The relative humidities are also given, so that the relation of infection to relative humidity can be seen at the same time. The correspondence of the three curves at relative humidities between 75 and 98 is striking. At the lower humidities there is considerable variation in the number of infections. It should be stated, however, that the higher humidities were obtained a larger number of times in each case than the lower humidities, thus tending to remove the effects of variation in the individual experiment. The values given in the three tables and in Figure 1 involve considerable variation and are not to be regarded as absolute, but relative. They represent general relations only.

The experiments conducted in the infection chambers were supplemented by two experiments run in a storage house partitioned into two rooms. In one room a high humidity was maintained and in the other a low. The Porto Rico and Big Stem Jersey varieties of sweet potato were used. The roots were not inoculated in either experiment. The results are recorded in Table 4.

TABLE 4.—*The relation of humidity to infection by Rhizopus, storage-house experiments*

Variety	Temperature, °C.	Depression of wet bulb, °C.	Relative humidity	Number of roots employed	Number of roots infected	Percentage infected	Time of exposure in days
Porto Rico	19.6	0.23	97	286	28	10	7
Porto Rico	28.0	0.53	96	115	33	29	5
Porto Rico	22.0	1.4	87	581	178	31	7
Porto Rico	29.0	2.6	82	125	108	86	5
Big Stem Jersey	28.0	0.53	96	173	48	28	5
Big Stem Jersey	29.0	2.6	82	98	65	66	5

The data are arranged in Table 4 for each variety of potatoes according to the humidities irrespective of the temperatures, which differed in the two experiments. In spite of this difference in temperature, there is an increase in the percentage of infection with the lowering of the humidities in the case of Porto Rico. The results of each experiment, however, should be considered separately. The first experiment had to do with Porto Rico, and had a duration of seven days. The high-humidity room was run at an average tem-

perature of 19.6° C., and the low humidity room at 22°. The average relative humidities of the two rooms were 97 and 87 per cent, respectively. The percentage of infection at a relative humidity of 97 was 10, in contrast to 31 at a relative humidity of 87.

In the second experiment both Porto Rico and Big Stem Jersey were used. The two rooms were run at an average temperature of

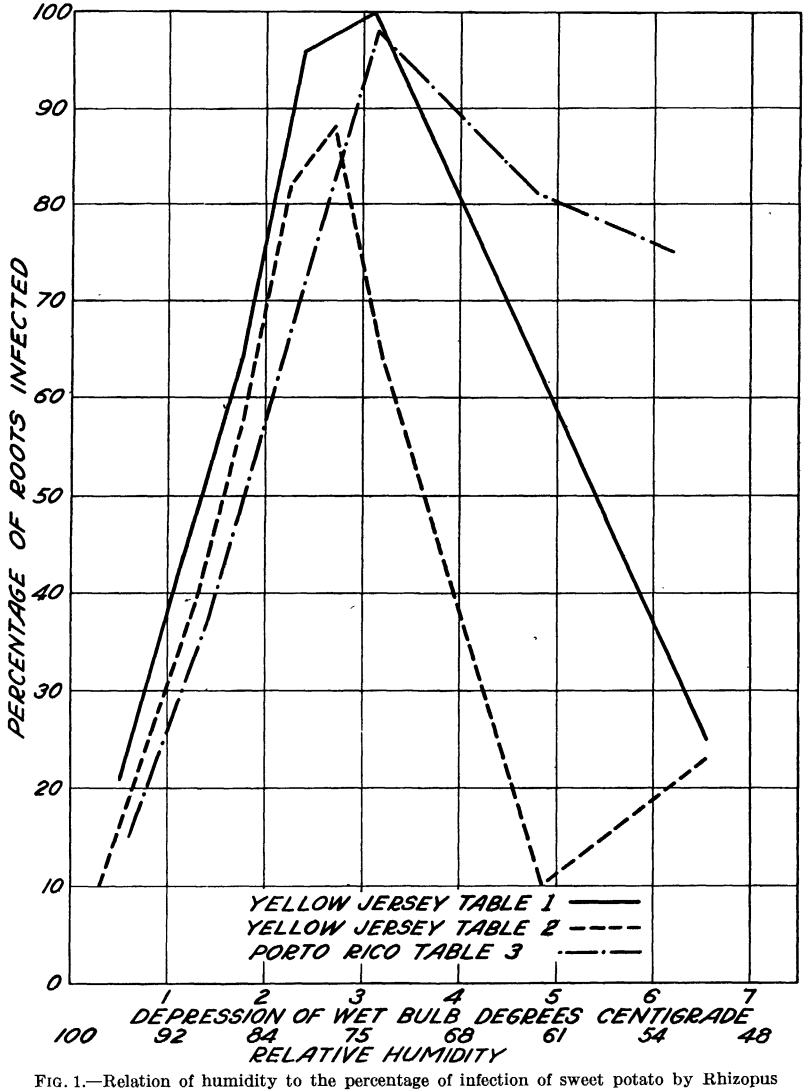

FIG. 1.—Relation of humidity to the percentage of infection of sweet potato by Rhizopus

28° and 29° C., and at an average relative humidity of 96 and 82 per cent, respectively. The experiment ran for five days. The percentage of infection of the Porto Rico at a relative humidity of 96 was 29, and 86 at a relative humidity of 82. At a relative humidity of 96 only 28 per cent of the Big Stem Jersey roots were infected, in contrast to 66 per cent at a relative humidity of 82.

The results of these two experiments within the range of humidities used correspond with the results obtained in the infection chambers, although there was not complete duplication of varieties. Yellow Jersey was not available at the time.

One experiment was conducted at a temperature of 12° C. The results, which will be published in another paper, correspond with those obtained at 23°, except that the range of infection was shifted nearer to 100 per cent humidity.

THE EFFECTS OF HUMIDITY ON HOSTS AND PATHOGENES

An effort was made to determine whether or not the relation of humidity to infection found in the foregoing experiments was due, on the one hand, to some reaction on the part of the host or, on the other, to a reaction on the part of the pathogenes, or to a combination of both.

A series of experiments were conducted in which halved roots were first subjected to one humidity for a time and then exposed to another for another interval of time at the same temperature (23° C.).

Very few potatoes (Table 5) which had first been subjected to high relative humidities (89 to 95) for from 4 to 12 days and then exposed to lower humidities (48 to 85 per cent) for 6 to 13 days became infected. If on the other hand halved roots were first exposed to low humidities (51 to 74) for 4 to 12 days and then placed at high relative humidities (84 to 95) for 6 to 31 days, a large number of infections resulted. For example, out of 48 potatoes which had been held at relative humidities of 89 to 91 and then removed to relative humidities of 80 to 85 there were no infections (Table 5). Out of 62 potatoes held at 89 to 95 and then removed to humidities of 48 to 73, 2 (or 3.2 per cent) were infected, while out of 182 potatoes held at humidities of 51 to 74 and then removed to humidities of 84 to 95, 123 (or 68 per cent) were infected.

TABLE 5.—*The effects of humidity on infection of halved roots exposed first to one humidity and then to another*

Temperature °C.	First depression of wet bulb, °C.	First relative humidity	Time of exposure in days	Second depression of wet bulb, °C.	Second relative humidity	Time of exposure in days	Number of halved roots used	Number infected	Per centage infected	Number of experiments at each humidity
23	0.4–1.3	89–97	6– 9	0.5–1.3	89–95	8–31	160	9	6	7
23	1.1–1.2	90–91	9	1.9–2.2	80–85	9	32	0	0	2
23	0.6–1.3	89–95	6–12	3.3–3.6	71–73	10–13	34	0	0	2
23	0–6–1.3	89–95	9–12	6–4–6.9	48–51	12–13	28	2	7	2
23	1.3–2.4	79–89	4–12	0.5–1.2	90–95	6–31	131	12	9	6
23	1.4	89	4	2.0	84	6	16	0	0	1
23	2.1	81	12	3.3	73	13	14	0	0	1
23	3.2–3.4	73–74	6– 7	0.5–1.1	91–95	8–31	11	3	27	2
23	4.8–5.3	59–63	6– 7	0.5–1.1	91–95	8–31	101	79	78	3
23	6.2–6.5	51–52	6–12	1.0–1.3	89–92	9–13	29	29	100	3
23	5.5–6.3	52–57	4– 9	1.9–2.0	84–85	6– 9	41	12	29	3
23	6.5	51	12	3.3	73	13	10	0	0	1
23	6.3–6.5	51–52	9–12	6.4–6.9	48–51	9–13	21	0	0	2

The potatoes held at high and low humidities were examined at the time the potatoes were changed from one humidity to another. The decayed potatoes were removed from the experiment and some of the remaining potatoes were retained at these humidities while others were removed to other humidities for a certain period (Table

5). At the end of this period very few of the potatoes retained at a high humidity (80 to 97 per cent) were infected, and none of the potatoes retained at a low humidity (48 to 73 per cent) were infected (Table 5).

Figure 2A represents the effects of exposing halved roots first to a relative humidity of 59 for 7 days, then to a humidity of 93 for a period of 11 days, at a temperature of 23° C.; figure 2B represents potatoes held at a relative humidity of 93 throughout the 18 days. The contrast is striking. Rhizopus has grown over the cut surfaces of the potatoes first exposed to a low humidity and then placed at a high humidity, whereas the potatoes exposed to the high humidity through the entire period have remained sound. At the end of the first period (7 days) the potatoes decayed at this time were removed from the experiment, so that the results represented in Figure 2

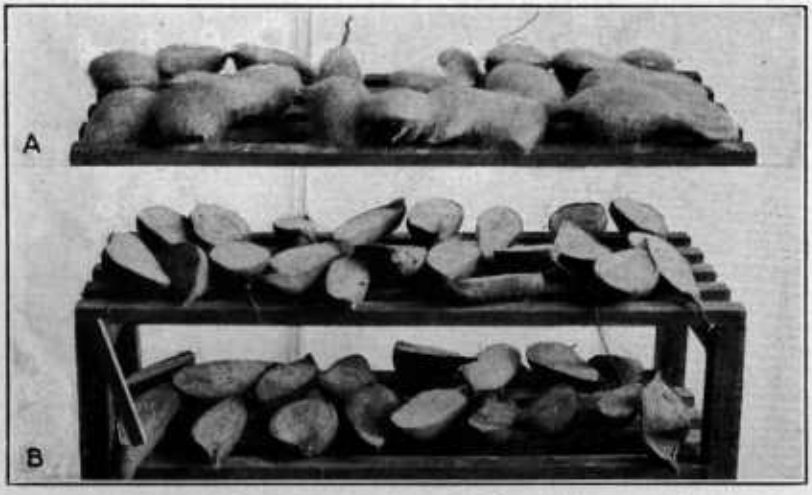

FIG. 2.—Infection of the sweet potato by Rhizopus. A, Sweet potatoes held at a relative humidity of 59 per cent for 7 days, and then at a humidity of 93 per cent for 11 days; B, Sweet potatoes held at a relative humidity of 93 per cent throughout the 18 days. Temperature 23° C. in both cases

afford a comparison of the effect of high humidity on potatoes which had previously been exposed in the one instance to a high humidity and in the other to a low humidity. It is suggested from these results that some reaction occurred in the host and not in the fungus at humidities of 85 to 100, which interfered with infection, because the fungus is capable of causing infection at high humidities if the potatoes have been subjected first to low humidities. On the other hand, very few potatoes that have been exposed to high humidities become infected no matter to what humidities they are exposed later.

It is believed that the effects of air moisture on the pathogenes interfere with infection at the low humidities, since roots that have been subjected to low humidities readily become infected when removed to high ones.

THE CHARACTER OF THE RESISTANCE EXHIBITED BY THE HOST AT HIGH HUMIDITIES

Is the resistance shown by sweet potatoes to the attack of Rhizopus at high humidities due to a reaction of the entire root, or is it located

in the wounded surface? An effort was made to answer this question in the following experiments.

Table 6 contains the results of two experiments conducted in the storage house in which Porto Rico and Big Stem Jersey varieties were used, Yellow Jersey not being available at the time.

TABLE 6.—*The effects of cutting a fresh slice from halved roots that have been exposed to high humidities*

First temperature and humidity readings			Second temperature and humidity readings			Treatment of roots	Number of roots used	Number of roots infected	Percentage infected
Temperature, ° C.	Depression of wet bulb, °C.	Relative humidity	Temperature, ° C.	Depression of wet bulb, ° C.	Relative humidity				
[a] 19.6	0.23	97	29	2.6	82	Freshly cut	40	37	93
[a] 19.6	.23	97	29	2.6	82	Old cut	39	2	5
[a] 22.2	1.4	87	29	2.6	82	Old cut	30	16	53
[b] 28	.53	96	29	2.6	82	Freshly cut	74	62	84
[b] 28	.53	96	29	2.6	82	Old cut	67	10	15

[a] These lines of figures are concerned with Porto Rico variety of potatoes.
[b] These lines of figures are concerned with Big Stem Jersey variety.

Two hundred and twenty halved roots which had been held at relative humidities of 96 and 97 per cent for a period were divided into two lots. A fresh slice, about 2 mm. thick, parallel to the cut surface, was removed from the one lot of 114 halves. The remaining 106 halves were left uncut as controls. Both lots were then placed at a relative humidity of 82 per cent. After 6 and 12 days 99 out of the 114 freshly cut potatoes (or 87 per cent) were infected, while only 12 out of the 106 (or 11 per cent) of the control potatoes became infected. Likewise 30 halved roots that had been held at a relative humidity of 87 per cent were also placed at a relative humidity of 82 per cent. Sixteen of them (or 53 per cent) became infected after 6 days. This latter percentage is high in contrast to that obtained from potatoes held first at relative humidities of 96 and 97 per cent and then placed at a relative humidity of 82 per cent, indicating that there was not as much resistance developed at a relative humidity of 87 per cent as at 96 and 97 per cent.

These results indicate that the resistance shown by sweet potatoes at high humidities is located in the surface layers of the wounded areas, because when this layer is removed the roots become infected readily when subjected to humidities that are favorable for infection. If this layer is not removed very few infections occur, even though the potatoes are placed at humidities which are favorable to infection.

Weimer and Harter (*7*) found that cork formation, in connection with wounded surfaces of sweet potatoes, took place more readily at high humidities than at low. Hauman-Merck (*2*) claims that there is some connection between cork formation and infection of sweet potatoes by *Mucor stolonifer* Ehrb. (*Rhizopus nigricans*). It is not unlikely that cork formation interferes with infection at the higher humidities, and that lack of cork formation at the lower humidities permits infection. To be certain that this relation holds it will be necessary to connect these factors more directly than has been done.

EFFECTS OF HUMIDITY ON UNWOUNDED ROOTS

Experiments were conducted during three seasons to determine whether it was possible to keep unwounded sweet potatoes at high humidities and at various temperatures throughout the season. The results are recorded in Table 7. Only 6 out of 350 potatoes held at various temperatures and at humidities ranging between 91 and 97 for 56 days during the autumn of 1921 became infected with Rhizopus. Of course, relative humidities are not comparable at different temperatures, but in any case the relative humidities were high. Table 7 gives the depression of wet bulb and humidity at each temperature so that the results can be interpreted directly.

TABLE 7.—*The relation between the exposure of Yellow Jersey sweet-potato roots to high humidities for long period and infection by Rhizopus*

Date and season	Temperature °C.	Depression of wet bulb °C.	Relative humidity	Duration of experiment in days	Number of roots used	Number of roots infected with Rhizopus	Percentage of roots infected with Rhizopus
Oct. 18, 1921–Dec. 13, 1921	28.0	1.1	92	56	50	0	
	25.5	.7	94	56	50	1	
	24.0	.8	93	56	50	0	
	20.5	.8	93	56	50	0	
	18.5	.6	95	56	50	0	
	14.0	.9	91	56	50	0	
	11.0	.3	97	56	50	5	
Total					350	6	1.7
Jan. 1, 1922–May 10, 1922	26	1.2	90	114	20	1	
	25	.9	93	114	20	1	
	24.5	.8	93	114	20	3	
	20.5	.5	95	114	20	1	
	18.0	.5	95	114	20	5	
	12.0	.3	97	114	20	4	
	11.5	.5	94	114	20	1	
Total					140	16	12
Nov. 13, 1922–Dec. 15, 1922	28	1.0	93	32	50	0	
	25	1.2	90	32	50	0	
	23	1.0	91	32	50	0	
	20	.2	98	32	50	0	
	18	.8	92	32	47	0	
	13	1.1	89	32	50	0	
	11.5	1.1	88	32	50	0	
Total					347	0	0
Nov. 13, 1922–Mar. 17, 1923	28	1.2	90	124	50	0	
	25	1.0	92	124	50	0	
	23	1.0	92	124	50	0	
	20	.2	98	124	50	0	
	18	.8	92	124	47	0	
	13	1.1	89	124	50	0	
	11.5	1.1	88	124	50	0	
	10	.5	94	124	50	1	
Total					397	1	.3
Oct. 26, 1923–Dec. 19, 1923	27	1.2	90	54	59	0	
	25	.7	94	54	74	0	
	23	.8	93	54	70	1	
	20	.7	94	54	74	0	
	18	.5	95	54	68	0	
	14	.5	94	54	79	0	
	12	.6	94	54	76	0	
	9.6	.2	97	54	77	0	
Total					577	1	.2
Oct. 26, 1923–Mar. 24, 1924	28	.5	97	149	59	8	
	25	.7	94	149	74	3	
	23	.8	93	149	70	2	
	20	.7	93	149	74	0	
	18	.5	95	149	67	0	
	14	.5	95	149	77	3	
	12	.6	94	149	73	0	
	9.6	.2	97	149	77	2	
T					[a]571	18	3.2

[a] The discrepancy between this figure and 577, the number of potatoes used during the fall, is explained by the act that 5 potatoes were removed for other purposes.

A new lot of potatoes was used the latter part of the same season, and in this case 16 out of 140 roots (or 12 per cent) became infected. Some of the chambers in which the potatoes were stored were opened during the storage period and the temperature allowed to drop to that of the surrounding air. The humidity also dropped considerably during this period. Mice entered through the open doors in some of the chambers and gnawed some of the roots. Eight of the 16 infections took place at the point of gnawing. This fact accounts for at least 50 per cent of the infections. It is entirely possible that more of these infections may have been due to wounding caused by mice that was not macroscopically evident.

During the seasons of 1922 and 1923, 1 out of 397 roots held at constant temperatures ranging between 10° and 28° C. and at relative humidities varying from 88 to 98, became infected after 124 days.

During the season of 1923 and 1924, 19 out of 572 potatoes (or 3.2 per cent) became infected after 150 days. The temperature ranged from 9.6° to 28° C., and the relative humidities from 90 to 97 per cent.

During the three seasons, 42 out of 1,464 (or 3 per cent) became infected with Rhizopus. At least 8 of these became infected because of the gnawings of mice. It is believed that in most of the other cases of infection it was the wounding which was the chief predisposing condition for infection by Rhizopus, rather than humidity or temperature. The potatoes were handled two or three times during a season, and it is almost impossible to handle sweet potatoes without some wounding. There is nothing in the data in Table 7 to suggest that there is any relation between infection and either temperature or moisture when there is no wounding. There was not a large variation in the humidity, but the infection that did occur bore no relation to this variation. In any case, unwounded sweet potatoes can be kept at high humidities for long periods without becoming infected with Rhizopus.

DISCUSSION AND CONCLUSIONS

The optimum relative humidities for infection of sweet potatoes by Rhizopus at a temperature of 23° C. range between 75 and 83 per cent. The percentage of infection decreases rapidly as the humidity is raised above 83 per cent or lowered below 75. The decrease is more consistent above 83 per cent than below 75. This consistency may have some relation to the number of times the higher humidities were attained in these experiments in contrast with the lower humidities. Whether there is some disturbing factor at the lower humidities that may account for this irregularity in results is not known.

The consistency of the results, whether considered in connection with the individual experiment or the experiments as a whole, is striking, when it is understood that the percentage of infection is used as the measure of the effects of humidity.

The relation of humidity to infection is similar in the case of the Yellow Jersey and Porto Rico varieties. Big Stem Jersey responded in a similar fashion to the humidities to which it was exposed.

The relation between humidity and infection of sweet potatoes by Rhizopus would seem to be governed by reactions on the part of the host and the pathogenes. Why is it that sweet potatoes become infected with Rhizopus less readily at humidities above 90 per cent

than at humidities of 75 to 85? Is it because the higher humidities are less favorable to the pathogenes? This is believed not to be the case, for if it were, why do potatoes that have been held at the lower humidities become infected when removed to humidities of 90 and above? It is believed, rather, that some change occurs in the host that renders it immune, because potatoes that have been held at high humidities become infected but rarely when subjected to lower humidities.

In what does this resistance consist? We have a hint from Weimer and Harter's work, "Wound-Cork Formation in the Sweet Potato" (*7*). They found that cork formation in connection with wounded surfaces occurs more readily at high humidities than at low. The concomitant relation of infection and cork formation to humidity would seem to have some significance, particularly since the resistance exhibited by roots at high humidities is located in the wounded surface. However, further work is required to determine more definitely the relation of cork formation to infection.

Why is it that infection does not take place as readily at relative humidities below 74 per cent as it does at humidities between 75 and 83? This question can not be definitely answered at present. It is believed that it is because moisture becomes a limiting factor to the pathogenes; i. e., these low humidities do not furnish sufficient moisture for the germination of the spores and the penetration of the germ tubes. Of course it is possible that the host may resist infection at these humidities, but it seems unlikely, because these same roots become infected when they are placed at high humidities. At any rate, if the absence of infection is due to the condition of the host, other than the lack of sufficient moisture for the pathogenes, this condition is transitory.

These results may explain the inability of Harter, Weimer, and Adams (*1*) to obtain infection of sweet potatoes by Rhizopus in moist chambers. The humidity in the moist chambers was too high to permit of infection. By use of the "well" method of inoculation they were able to obtain infection in moist chambers. The success of the "well" method of inoculation, may possibly be explained on the basis that the process of infection was thus hastened because of the amount of inoculum used, thereby preventing the development of the condition which prevents infection at high humidities. It is possible by other means (*4*) to prevent the development of the resistance at high humidities sufficiently to permit of infection. If the roots are severely wounded by striking them over the edge of a wire basket they become infected readily at high humidities. This fact may possibly be explained by Weimer and Harter's work on cork formation in wounded surfaces. They found (*7*) that when roots were wounded by striking them over the edge of a wire basket, cork formation did not take place at the bottom of the wounds. Such interruption of this process would account for infection in deep and severe wounds at high humidities, even though cork formation normally occurs in an atmosphere of high moisture content.

The success in keeping unwounded sweet potatoes at high humidities throughout the season without their becoming infected can be explained on the basis that Rhizopus rarely infects sweet potatoes except through fresh wounds.

It is possible that if freshly dug potatoes—which of course are freshly wounded—were placed at low humidities, they might become infected if they were exposed to high humidities later. Experiments are now under way to determine whether this is true.

Weimer and Harter's work (7) suggests that excessive drying of freshly dug sweet potatoes renders them more susceptible to the attack by Rhizopus. How often sweet potatoes are excessively dried during the process of curing is not known.

SUMMARY

The data recorded in this paper, and those obtained from other experiments, show that infection of sweet potatoes by Rhizopus occurs almost exclusively through fresh wounds.

The optimum relative humidities at a temperature of 23° C. for the infection of halved roots of sweet potatoes by Rhizopus range from 75 to 84 per cent.

The percentage of infection decreases rapidly as the humidity is raised above or lowered below the optimum humidities.

This decrease is more consistent above the optimum than below it; i. e., there is less variation in the number of infections above the optimum than below it.

Very few infections of halved roots occurred at relative humidities of 93 to 99 per cent at a temperature of 23° C.

Very few halved roots which had been subjected to relative humidities of 89 to 97 per cent (temperature 23° C.) for a period of 4 to 12 days became infected when they were retained at these humidities for another period or were placed at humidities of 48 to 89 per cent.

On the other hand, a high percentage of the halved roots which were subjected to relative humidities of 51 to 73 per cent for a period of 4 to 12 days became infected when they were placed later at relative humidities of 84 to 95 per cent.

Halved roots that had been exposed to relative humidities of 51 to 52 per cent for a period of 9 to 12 days did not become infected when they were subsequently placed at relative humidities of 48 to 73 per cent.

A resistance to infection by Rhizopus developed in the halved roots that had been held at relative humidities of 89 to 97 per cent.

This resistance is located in the surface layers of the wounded areas and has a possible relation to cork formation.

The Yellow Jersey, Big Stem Jersey, and the Porto Rico varieties of sweet potato responded in a similar fashion (within the range of humidities used in each case) to the action of air moisture.

The Yellow Jersey variety was kept for periods of 56 to 150 days during three seasons with only a few infections with Rhizopus occurring.

LITERATURE CITED

(1) HARTER, L. L., WEIMER, J. L., and ADAMS, J. M. R.
1918. SWEET-POTATO STORAGE-ROTS. Jour. Agr. Research 15: 337–368, illus.
(2) HAUMAN-MERCK, L.
1913. CONTRIBUTION À L'ÉTUDE DES ALTÉRATIONS MICROBIENNES DES ORGANES CHARNUS DES PLANTES. Ann. Inst. Pasteur 27: 501–522.
(3) LAURITZEN, J. I.
1919. THE RELATION OF TEMPERATURE AND HUMIDITY TO INFECTION BY CERTAIN FUNGI. Phytopathology 9: 7–35.
(4) ——— and HARTER, L. L.
1923. SPECIES OF RHIZOPUS RESPONSIBLE FOR THE DECAY OF SWEET POTATOES IN THE STORAGE HOUSE AND AT DIFFERENT TEMPERATURES IN INFECTION CHAMBERS. Jour. Agr. Research 24: 441–456, illus.
(5) MANNS, T. F.
1920. SWEET POTATO STORAGE IN DELAWARE. Del. Agr. Expt. Sta. Bul. 127, 64 p., illus.
(6) THOMPSON, H. C.
1918. SWEET-POTATO STORAGE. U. S. Dept. Agr. Farmers' Bul. 970, 27 p., illus.
(7) WEIMER, J. L., and HARTER, L. L.
1921. WOUND-CORK FORMATION IN THE SWEET POTATO. Jour. Agr. Research 21: 637–647.