ESTIMATION OF VERTICILLIUM IN PLANT DEBRIS, SOIL AND TAIL WATER. 1/

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INTRODUCTION

Yield reductions in Russet Burbank potato due to *Verticillium* wilt are increasing in the Columbia River Basin. Fields which once raised 25-30 T of potatoes per acre are now down to 11-15 T per acre. Potato production in our older potato growing areas such as the Yakima Valley, has been greatly reduced because of wilt. Last year potato production was started near Paterson, Washington. How long will it be before *Verticillium* is spread to this area? As other areas come into production, will they too become infested with wilt?

The *Verticillium* wilt organism, *Verticillium albo-atrum* Renke and Berth, [microsclerotial strain] is thought to invade the soil and not to be a natural inhabitant [8]. That is to say, it has to be spread to fields in Washington by some means of transportation. Dust storms, movement in irrigation water, and in-state and out-of-state movement of machinery are significant means of transporting *Verticillium*. Seed potatoes grown in soils infested with *Verticillium* and the infested soil clinging to seed tubers could serve as another means of transporting wilt.

The build-up of the *Verticillium* wilt organism, after it is once introduced, will depend on the presence of susceptible hosts. Agronomic hosts such as potato, tomato, eggplant, pepper, muskmelon, watermelon, and strawberry, or weed hosts such as lambs quarter and nightshade, permit rapid build-up of *Verticillium* in the soil [1]. Weeds and cereal crops previously thought to be non-hosts of *Verticillium* become infected but show no wilt symptoms when grown in soils infested with the potato strain [2].

The persistence of *Verticillium* in our Western potato-growing areas is due to the formation of a resting stage, called a microsclerotium. This stage forms in stems and roots killed by the wilt organism. *Verticillium* can also colonize

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1/ This investigation was made possible through a grant supplied by the Washington State Potato Commission.

dead, dry pieces of stems of such hosts as peppermint, alfalfa, pigweed, barley and oats when these are buried in naturally infested soil [3]. Sclerotia produced in infested dead stems can perpetuate the organism in the absence of the living hosts.

Microsclerotia have been reported to form between 50-70 degrees F [6]. Microsclerotia are resistant to adverse conditions such as long exposure to drying, even at high temperatures [122 degrees F for 6 months] [5]. The Verticillium wilt organism has been reported to still be present in soils after 14 years of successive plantings of non-susceptible crops in California [9]. Verticillium was detected in California soils at a depth of 3 ft; however, wilt infestation was 3 to 4 times greater in the upper foot of soil [7]. Type of soil, surface or subsoil, crop history or depth of root penetration had no relation to the vertical distribution of Verticillium.

The present research was initiated to determine the relative populations of Verticillium in soil, plant debris and irrigation tail water.

METHODS AND MATERIALS

Potato stems of Russet Burbank infested with Verticillium were collected in 1966 near Othello, Washington. These stems were ground in a Wiley mill with 40 mesh screen and stem debris with attached microsclerotia passing through a 200 mesh screen was collected. The stem debris [0.5 g] was diluted 1:50,000 with sterile tap water and thoroughly shaken [Table 1]. Each dilution [0.3 ml] was pipetted to petri dishes containing 15 ml of ethanol and streptomycin agar [4] modified by the addition of 50 ppm of Penicillin G and spread over the surface with a sterile glass rod. Propagules of Verticillium [microsclerotial colonies] were counted 2 to 3 weeks after plating with aid of a dissecting microscope at X16-60 magnification.

Infested soil was collected in the fall of 1966 near Othello and Prosser, Washington at random to a depth of 0-10 inches, mixed and stored at 4 degrees C until the assays were conducted. The soil near Prosser had grown irrigated crops since 1919 and had been cropped continuously to potatoes potatoes since 1958. The soil near Othello had been cropped to dry land wheat prior to irrigation and to alfalfa after the introduction of irrigation in 1962. This soil was infested with Verticillium in 1964 by planting potato seed pieces dipped into a suspension of conidia and microsclerotia of the organism and raised successive crops of potatoes in 1965 and 1966 without further artificial infestation. The soils [30g] were diluted to 1:50 and 1:500 with sterile tap water and thoroughly shaken [Table 2]. Methods of plating and propagule counting were the same as used for potato stems. Oven dry weights were taken in order to calculate percentage of moisture in the soil.

Tail water from Verticillium-infested soil was collected in 1967 near Othello, Washington for assaying in sterile test tubes at the tail ends of potato furrows. This soil was infested with Verticillium in 1963 by planting potato seed pieces dipped into a suspension of Verticillium conidia and microsclerotia. Potatoes were grown in 1964 and 1965, wheat in 1966, and potatoes in 1967. The tubes of tail water were held under ice in insulated containers in the field and in the laboratory at 4 degrees C for not over 24 hours until assays were made. Undiluted tail water [0.3 ml] was pipetted on the ethanol and streptomycin agar modified with Penicillin G. Method of propagule count was the same as for the potato stems. Three samples of tail water collected from 10 furrows on June 20 and July 28 were plated on 30 plates. Four measurements of time [seconds] to collect 1/2 gallon of water for each furrow were determined by use of a V-veir for each of the 10 rows.

RESULTS AND DISCUSSION

Verticillium propagule counts of microsclerotial colonies from infested potato stem tissue varied from 7 to 24 million per gram of tissue [Table 1]. Persistent microsclerotia found in infected stems of potato plants serve to perpetuate Verticillium for many years. Decomposition of stems and roots infested with microsclerotial bodies results in soils becoming more heavily infested with Verticillium. Continued yield reductions can be expected in the future unless wilt resistant varieties or chemical controls are developed.

Infested soils near Prosser and Othello had 2 to 4 and 24-32 thousand Verticillium propagules per gram of dry soil, respectively, at the 0 to 10 inch soil level [Table 2], indicating a high inoculum potential of Verticillium in these soils. Potato plants grown in these soils in past years were severely infected with Verticillium wilt. Future sampling and assaying of soils in Washington for Verticillium will provide information as to inoculum level and amount of infestation in Washington.

Tail water which had flowed down furrows in a potato field near Othello contained an average of 0.14 million/gal Verticillium propagules on June 20, 1967 [Table 3]. This average had increased to 1.14 million/gal by July 28. About 100 gallons of tail water flowed down the furrows each hour. Reuse of this tail water could be a means of disseminating Verticillium from field to field.

SUMMARY

Verticillium propagules varied from 7 million to 24 million per gram of infected stem tissue and 2 thousand to 32 thousand per gram of infested soil. Tail water flowing down furrows of potatoes, yielded an average of 0.14 million/gal propagules on June 20, 1967 which increased to 1.14 million/gal by July 28, 1967. This information indicates potentially large reservoirs of Verticillium in soil and its possible spread by reuse of irrigation water.

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Table 1. _Verticillium_ propagules in infested potato stems.

Grams dry stem debris[1/]	Propagules per plate[2/] Dilution		Propagules per gram stem debris (10^6)[3/] Dilution	
	1/50,000	1/500,000	1/50,000	1/500,000
0.5	45.5	14.7	7.58	24.50

1/ 0.5 g of dry stem debris was added to 24.5 ml of sterile tap water for an approximate 1/50 dilution; 1/50,000 and 1/500,000 dilutions were made by 10^3 and 10^4 dilutions of the 1/50 dilution.

2/ Mean count of 15 plates (0.3 ml per plate) for each dilution.

3/ Calculations:

1/50,000 dilution:

a. dilution factor = $\frac{25 \text{ (volume of 1/50 dilution)} \times 10^3 = \text{(volume of 1/50,000 dilution)}}{0.5 \text{ (g stem debris)} \times 0.3 \text{ (ml per plate)}}$

b. propagules per gram stem debris = dilution factor x plate count

1/500,000 dilution:

a. $\frac{25 \times 10^4}{0.5 \text{ g} \times 0.3 \text{ ml}}$

b. propagules per gram stem debris = dilution factor x plate count

Table 2. Verticillium propagules in infested potato soils

Soil location	Weight of soil		Propagules per plate[2/] Dilution		Propagules per gram dry soil[3/] Dilution	
	wet[1/]	oven dry	1/50	1/500	1/50	1/500
Prosser	30 g	28.44	13.5	2.6	2,373	4,571
Othello	30 g	26.64	132.5	17.2	24,868	32,282

1/ 30 g of wet soil added to 1470 ml sterile water to give approximate 1/50 dilution; 1/500 dilution was made by a 10^1 dilution of the 1/50 dilution.

2/ Mean count of 60 plates (0.3 ml per plate) for each dilution.

3/ Calculations:

1/50 dilution:

a. dilution factor = $\frac{\text{1500 ml (volume of dilution)}}{\text{28.44 g (oven dry wt) x 0.3 (ml per plate)}}$

b. propagules per g oven dry soil = dilution factor x plate count

1/500 dilution:

a. dilution factor = $\frac{\text{1500 ml x 10}}{\text{28.44 g x 0.3 ml}}$

b. propagules per g oven dry soil = dilution factor x plate count

Table 3. *Verticillium* propagules in tail water from furrows of potatoes growing in infested soil.

Time for 1/2 gal flow 1/ (sec.)	Gal tail water flow for 1 hr 2/	Propagules per plate 3/	Propagules per gal tail water (10^6) 4/
	June 20, 1967		
17	105	11.5	0.14
	July 28, 1967		
16	113	91.3	1.14

1/ Mean of four measurements (sec/1/2 gal) determined by use of V-weir for 10 rows on June 20 and July 28.

2/ Calculated by dividing 3600 (sec/hr) by sec/gal flow (2 x sec/1/2 gal flow).

3/ Mean count of 30 plates (0.3 ml per plate) from water collected on June 20 and July 28.

4/ Calculations of propagules per gal of tail water:

a. Propagules per ml = propagules per plate x 3.3 (3.3 x 0.3 ml/plate added 0.99 ml)

b. Propagules per gal = propagules per ml x 1000 (ml/liter) x 3.7853 (liters gal)

ENVIRONMENTAL FACTORS AFFECTING SOFT ROT OF POTATOES1/

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INTRODUCTION

The investigation on the bacterial soft rot problem in railroad car shipments of potato tubers began July 1, 1966, and was continued during 1967. Preliminary findings were reported in 1966 2/. Objectives are to determine casual agents, to determine environmental factors involved, and to develop control measures.

Railway reinspection certificates were analyzed to determine the extent of the shipping problems in 1967 3/. Results of this study were compared with the studies of 1965 and 19664/. Tuber defects were grouped into 2 categories - blackspot and tuber decay. The latter included soft rot, slimy soft rot, water rot, and leak, which were grouped together due to the difficulty in properly distinguishing these defects at the terminal markets.

The analysis of reinspection certificates revealed that 6.1% of the cars shipped in 1967 were rejected as compared with 8.6% and 12.2% in 1965 and 1966, respectively [Table 1]. There were 408 cars rejected in 1967 as compared with 686 in 1965 and 984 in 1966. In each year there were additional unknown numbers of cars with serious defects for which prices were adjusted at the terminal markets without reinspection and, therefore, not reported.

The survey revealed that blackspot was responsible for 28% of the total cars rejected in 1967 as compared with 43% and 48% in 1965 and 1966, respectively [Fig. 1]. Rejections for tuber decay increased sharply in 1967 over previous years amounting to 36%, 17% and 58% of the total rejections for 1965, 1966 and 1967, respectively. Cars rejected because of combined tuber defects of blackspot and tuber decay were 21%, 35% and 14% in 1965, 1966 and 1967, respectively.

Shipping records were compared over the same 3-year period. Shippers were grouped into categories on the basis of percentage of cars rejected during the 3-year period [Table 2].

1/ This investigation was made possible through a grant supplied by the Washington State Potato Commission.
2/ 1966 Washington State Potato Conference Proceedings, pp. 149-154.
3/ Based on records provided by Mr. W. J. Irey, Supervisor, Fresh Products Inspection, Federal-State Inspection Service and Mr. Fred Ramsey, Manager, Washington State Potato Commission, Yakima, Washington.
4/ 1967 Washington State Potato Conference Proceedings pp. 127-135.

Table 1. Railroad car shipments and rejections in 1965, 1966 and 1967.

	Total Cars Shipped	Total Cars Rejected[1/]	Cars Rejected Percent
1965[2/]	8009	686	8.6
1966[3/]	8045	984	12.2
1967[4/]	6696	408	6.1

1/ Based on Reinspection Certificates only

2/ By 31 shippers from July 1 to November 19, 1965

3/ By 29 shippers from July 1 to October 31, 1966

4/ By 32 shippers from July 1 to November 14, 1967

Table 2. Shippers grouped according to percent of cars rejected due to black spot and tuber decay for a combined 3-year period, 1965, 1966 and 1967[1/]

Category[2/]	Percent of cars shipped rejected	Number of shippers	Cars shipped number	Cars shipped percent[3/]	Cars rejected number	Cars rejected percent[4/]
1	> 10	4	2,482	8.9	489	23.6
2	5-10	3	2,761	9.9	250	12.0
3	1.5- 5	10	13,379	48.0	826	39.7
4	< 1.5	6	4,879	17.5	98	4.7
5	various	15	4,398	15.7	416	20.0
Total			27,891	100.0	2,079	100.0

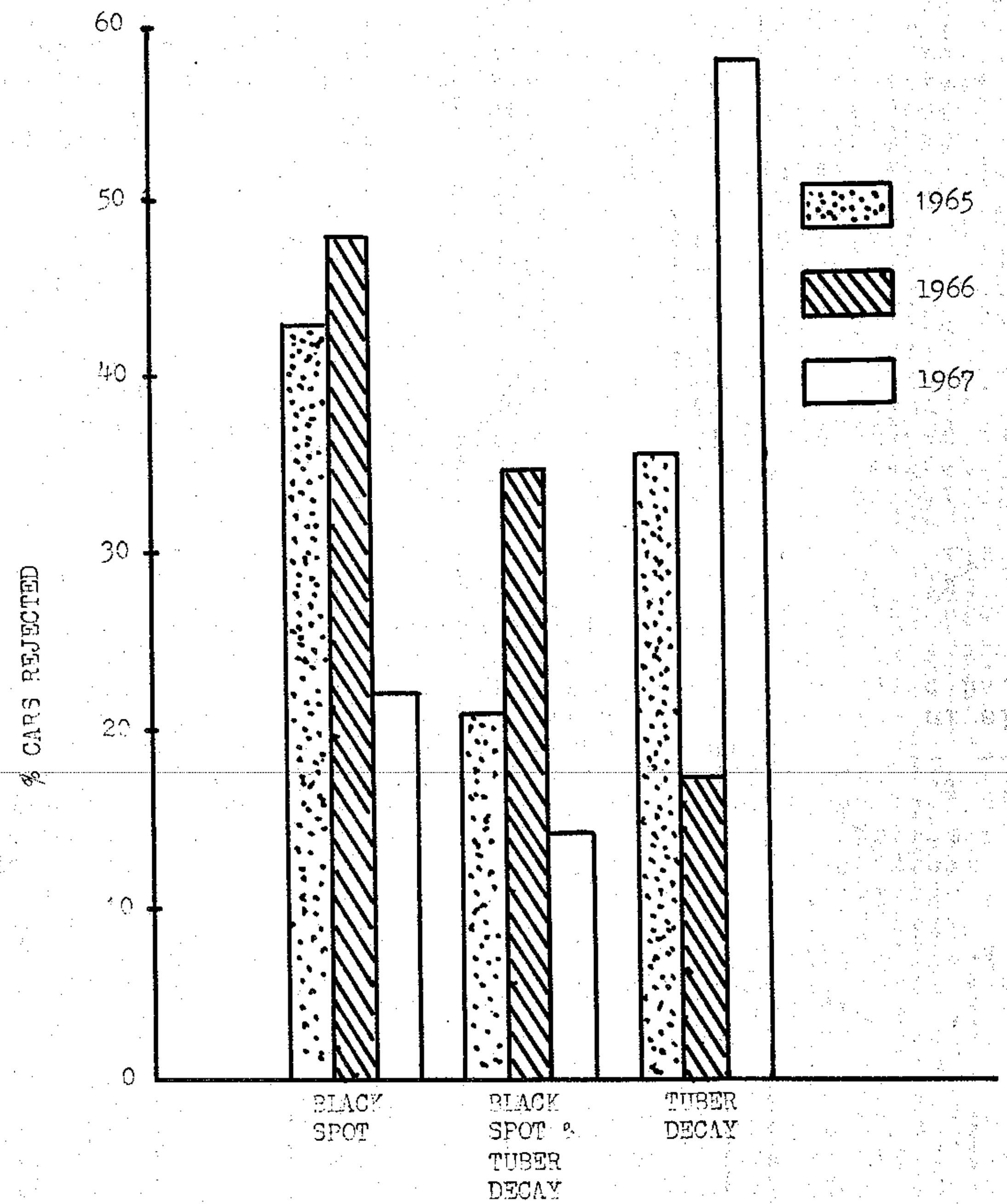
1/ Based on Federal and state inspection and reinspection certificates only.

2/ Shippers included in categories 1 through 4 shipped all three years; shippers in category 5 shipped in only 1 or 2 years of the 3-year period.

3/ Percent of the total cars shipped for the 3-year period.

4/ Percent of the total cars rejected for the 3-year period.

FIG. 1 PERCENT OF CARS REJECTED DUE TO TUBER DEFECTS IN 1965, 1966 AND 1967



1/ BASED ON TOTAL CARS REJECTED AND NOT CARS SHIPPED

These categories were as follows: greater than 10% , 5-10%, 1.5-5% and less than 1.5% 5/. A fifth category was made for those who shipped in only one or 2 years of the 3-year period.

Four shippers had greater than 10% of their shipments rejected [Category 1]. These 4 shipped but 8.9% of the total cars shipped for the 3-year period, but had 23.6% of the cars rejected [Table 2]. In contrast, those in category 4, each of whom had less than 1.5% of their cars rejected, shipped 17.5% of the total cars and had only 4.7% of all rejections. The largest proportion of the shippers who shipped in all 3 years fell into the third category, 1.5 to 5% rejections. These 10 shippers shipped 48% of the total cars and were involved in 39.7% of the rejections. The three shippers in category 2, 5-10% rejections, shipped 9.9% of the total cars and had 12% of all cars rejected.

Effect of Pre-Storage Conditions on Bacterial Soft Rot of Potato Tubers

INTRODUCTION

Environmental conditions such as moisture, temperature and oxygen, as well as available food supplies are important factors in the growth of micro-organisms. After harvest, potato tubers are washed, sorted, packaged prior to being loaded into railroad cars. These operations result in wounds and bruises through which micro-organisms may enter and provide a wet and warm environment for their growth, especially during the summer and early fall when ambient temperatures are high. Tubers may remain warm and wet for several days after loading before icing lowers temperature in the car to a point where decay will be prevented or greatly reduced.6/ Low levels of oxygen increase decay caused by bacteria. This condition might occur in polyethylene bag or box packaging where tubers utilize the oxygen in their normal respiration processes within the containers and replenishment of this oxygen is restricted. The following experiment was designed to determine the influence of various conditions on bacterial soft rot.

5/ For example, to be grouped in the "greater than 10%" rejection category, a shipper would have had to have more than 10% of the cars shipped rejected for blackspot [irrespective of tuber decay] and, at the same time, greater than 10% of cars shipped would have had to have been rejected for tuber decay [irrespective of blackspot] in at least 2 of the 3 years reported.

6/ Weaver, M.L., and T.A. Merrill. Amer. Potato J. 42:223-239. 1965.

OBJECTIVE: To determine the effect of moisture and high temperature on bacterial soft rot of potato tubers during storage under 2 oxygen levels.

MATERIALS AND METHODS:

Environmental chambers: Environmental chambers were designed to control moisture and oxygen surrounding the tubers. Each chamber consisted of an 8" x 10" x 24" polyethylene bag supported at the outside by a wire frame. The chamber was placed upon a 9" x 14" tray for ease of handling.

Potato tubers: Potato tubers [4-8 oz.] were washed, sorted and transported from the shipping point to the laboratory. At the laboratory they were dipped in tap water so that all were uniformly wet. Ten tubers were placed in each chamber. Both Russet Burbank and Norgold Russet potato varieties were tested.

Temperature rooms: Four temperature rooms provided temperatures of 40, 50, 60, and 70 degrees F, respectively.

Oxygen treatments: Each temperature room was equipped to maintain atmospheric air [20.5% oxygen] or introduce nitrogen gas to reduce oxygen level to about 4% in each chamber.

Moisture treatments:

Wet: Five hundred milliliters of tap water were added to the bottom of each chamber. The water level was approximately 3/4" deep after placement of the 10 tubers.

Dry: Previous experiments showed that tubers with dry surfaces did not break down under normal or low oxygen level at 50, 55, 60 or 70 degrees F.7/ Low oxygen and high temperature [70 degrees F] are the conditions most likely to stimulate breakdown of dry tubers. Only one dry treatment, 70 degrees F and low oxygen level, was therefore included. For this treatment, tubers were placed on a wire frame within the chamber with no moisture added, except that the tubers were dipped initially in tap water.

Pre-storage: Pre-storage consisted of holding the chamber containing the tubers and tap water at 70 degrees F for 0, 1, 2 or 3 days and then transferring the chambers to the respective temperature rooms, where they were held for 8 days under the oxygen treatments.

Replication: Each treatment for atmospheric level of oxygen, low level of oxygen and for the 0, 1, 2 and 3-day pre-storage was replicated 4 times in each of the 5 temperature rooms. The experiment was repeated twice using Norgold Russet and once using Russet Burbank varieties.

Tuber decay measurements: Each tuber was rated on a "0" to "10" scale, where "0" indicated no decay and "10" indicated practically all of the tuber decayed. These ratings were changed

7/ 1967 Wash. State Potato Conf. Proc. pp. 127-135.

to percent of tuber area decayed. Decay was evaluated at the end of each of the 0, 1, 2 and 3 days in the 70 degree F pre-storage condition and at the end of 8 days in the 40, 50, 60 and 70 degree F storage conditions.

RESULTS:

No apparent differences in soft rot were noted for Russet Burbank or Norgold Russet, so the results of the 3 trials were combined. Tubers receiving the dry moisture treatment and stored for 8 days at 70 degrees F under low oxygen did not decay.

In the wet treatment, decay was initiated in the area of the tuber touching water. Wet tubers receiving low oxygen treatment were considerably more decayed than those receiving an atmospheric level of oxygen. This increase in decay was noted for each storage temperature and for each pre-storage treatment, except at 40 degrees F temperature and 0 day pre-storage where no soft rot occurred [Fig. 2].

Tubers examined after 0, 1, 2 and 3 days of pre-storage treatments had 0%, 0%, 3% and 5% soft rot, respectively. Although there was no soft rot after 1 day of pre-storage treatment, 4% soft rot occurred in this treatment after 8 days at 40 degrees F under low oxygen, but none occurred under the atmospheric level of oxygen. No decay occurred when tubers received 0 day pre-storage treatment and were stored at 40 degrees F with either level of oxygen. Even a 40 degree F temperature did not prevent further decay when soft rot was evident prior to storage. A temperature of 50 degrees F and atmospheric level of oxygen did not completely prevent decay even with 0 day pre-storage. The amount of soft rot was greatest in tubers which decayed in pre-storage followed by storage in the highest temperatures [70 degrees F].

Effect of various cooling methods on tuber decay in rail car shipments.

Introduction

Potato tubers which are warm, wet from washing, and bruised through harvest and sorting operations, are very susceptible to decay by bacterial decay organisms. Any treatment which quickly lowers their temperature in railroad cars should inhibit or reduce decay caused by bacteria. Low levels of oxygen increase decay. This condition might possible occur in a tightly closed mechanically refrigerated car after about a week in transit. The following experiment was designed to study the effect of different methods of cooling on decay and to determine if low levels of oxygen developed in railway shipments.

Objectives: To compare the effectiveness of icing and mechanical refrigeration and pre-chilling on tuber decay. To determine if low levels of oxygen existed in rail cars.

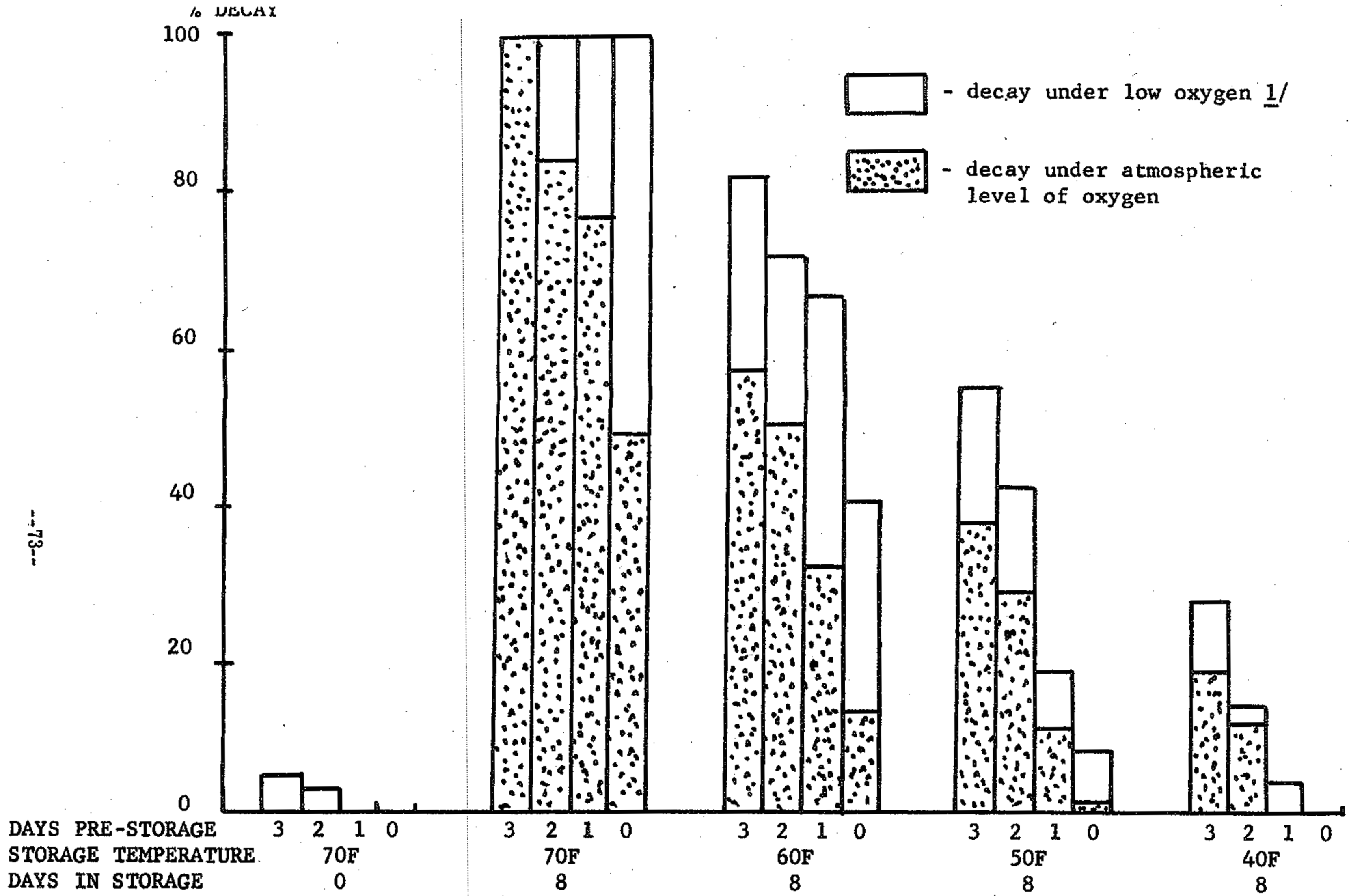


Fig. 2. Effect of pre-storage (70°F) followed by storage at various temperature and oxygen environment on decay in potato tubers.

1/ Decay at low oxygen is represented by the total height of the bar.

Methods: Two shipments of 4 rail cars each of Russet Burbank potatoes were shipped August 16 and August 26 by Balcom & Moe, Inc., Pasco, Washington to Newark, New Jersey. These shipments arrived at Newark 7 days later. Information concerning types of cars used, and handling procedures is listed in Table 3. Sacked tubers were placed in a mechanically refrigerated storage room for 24 hours to pre-chill. Two Ryan temperature recorders were placed in each car - one on the floor and the other on the wall 8/ approximately 6 feet above the floor. Fifty feet of polyethylene tubing [1/4 OD] was placed in each car at loading in Pasco for later determinations of oxygen in Newark. One end of the tubing was located at the center of the car and the other end at the middle door. At Newark, the door was cracked, the tubing was connected to a Beckman Model D oxygen analyzer, and air was drawn through the tubing from the center of the car for analysis.

Results: One mechanically cooled car in the first shipment was turned down by USDA inspectors with 1% soft rot. These decayed tubers were personally inspected by Gene D. Easton at Newark and found to have water rot caused by the fungus, PYTHIUM ULTIMUM, and not soft rot caused by bacteria. Bacterial soft rot did not develop under the conditions of this experiment. The temperature records for this mechanically refrigerated car showed the floor temperature to have been lowered to about 47 degrees F 24 hours after loading, and to have remained at that temperature during transit. Water rot had been found in these potatoes during the sorting operations at Pasco and therefore probably developed from infected tubers during transit. That water rot occurred in the mechanically cooled car but not in the iced cars is thought to have resulted by chance alone and not due to the effect of any cooling treatment.

The cooling treatments which lowered the temperature below 50 degrees F on the car floor after the doors had been closed, based on records in the August 16 and 25 shipments, [Figs. 3,4], were as follows: [1] tubers pre-chilled and car pre-iced [quickest]; [2] car mechanically refrigerated; [3] car pre-iced or tubers pre-chilled, loaded dry, and car iced after loading; [4] car iced after loading [slowest]. Floor temperatures in the mechanically refrigerated cars were down to 50 degrees F or below within 24 hours after the doors were closed. It took 48 hours or longer for temperatures in the cars which were iced after loading to get down to 50 degrees F.

Lack of oxygen in the test cars did not appear to be a problem [Table 3]. Normal amounts of oxygen were found at Newark before unloading in all 4 cars shipped from Pasco on August 16.

8/ Wall temperature data not included in this report.

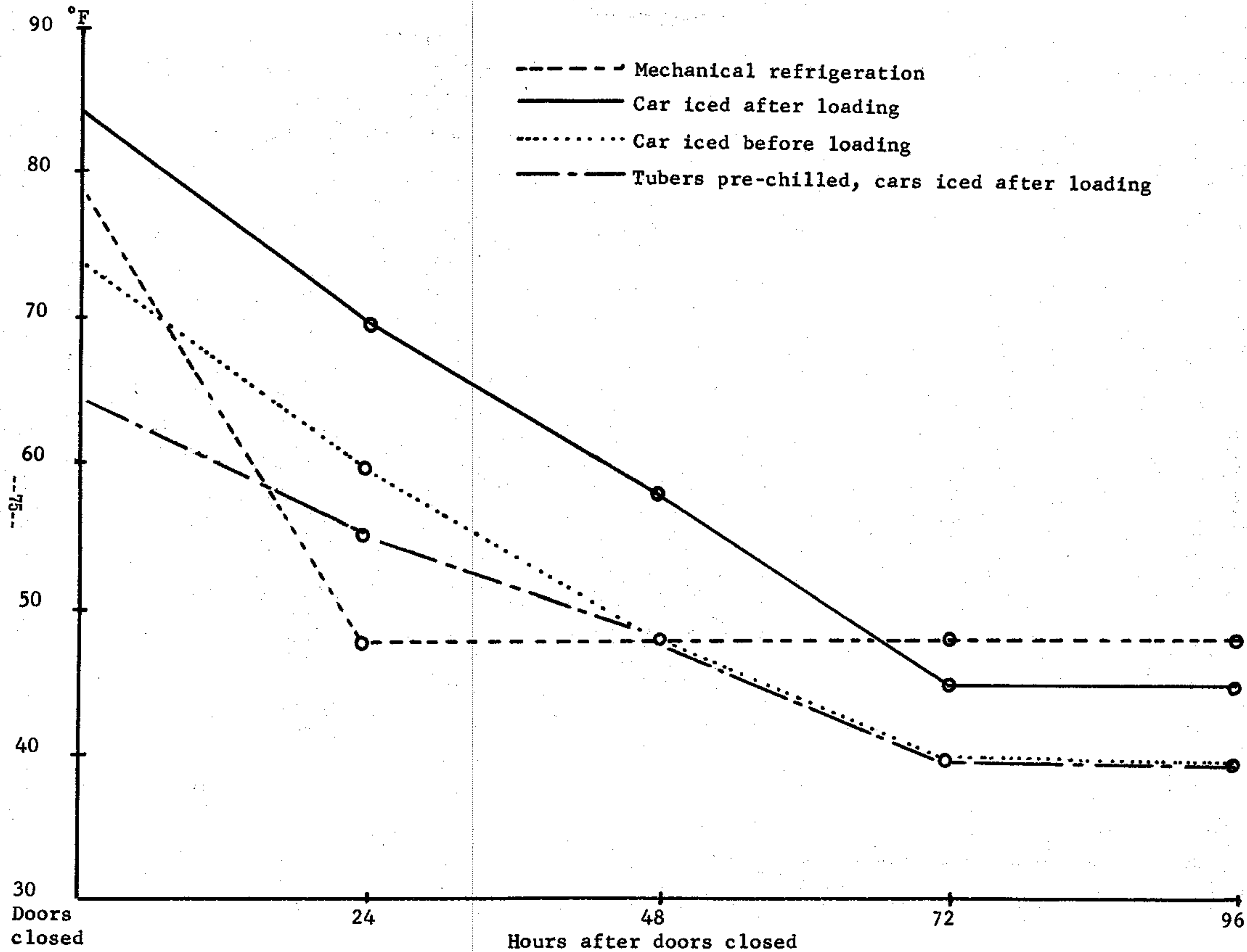


Fig. 3. Effect of various methods of cooling on floor temperature in rail cars shipped from Pasco on August 16, 1967

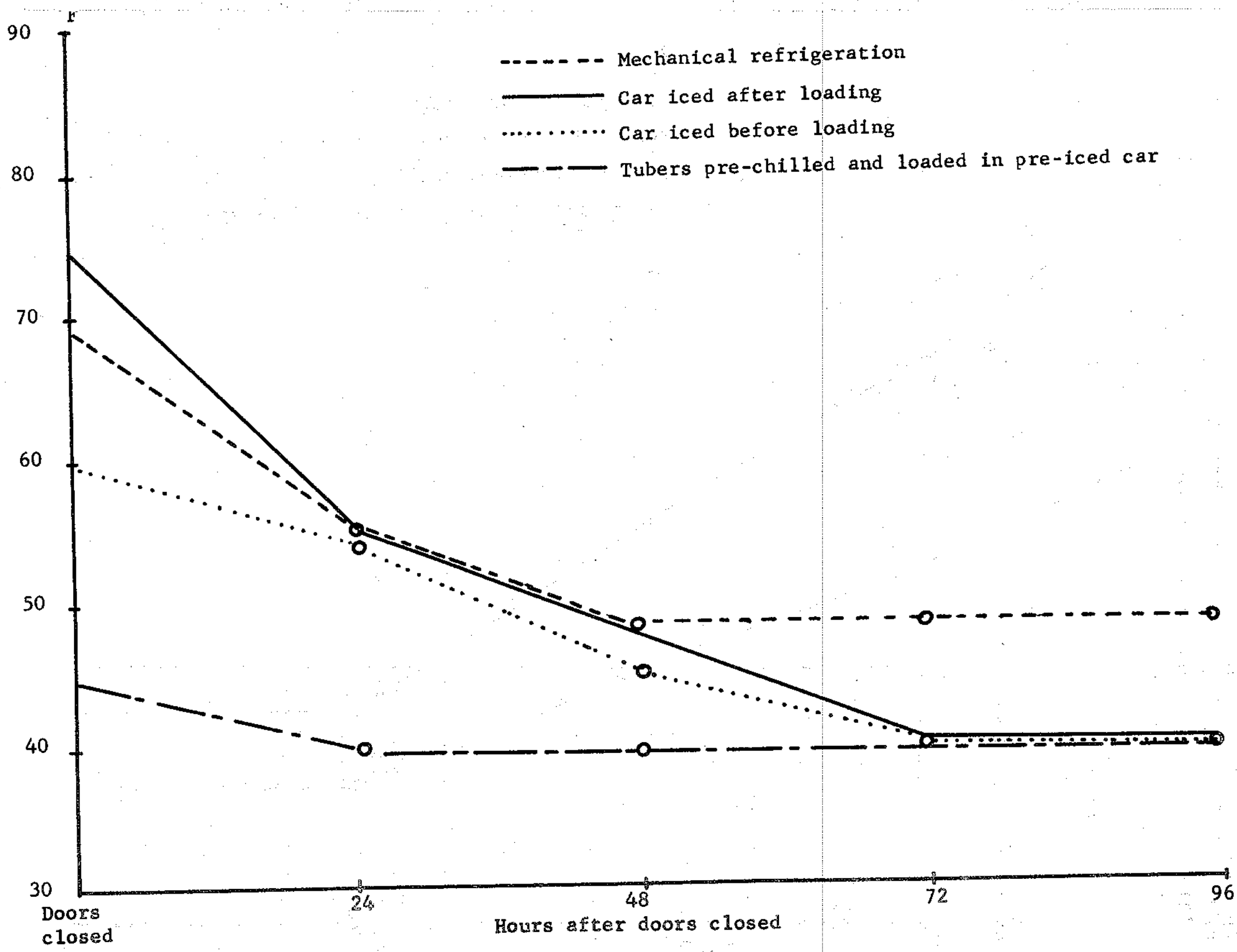


Fig. 4. Effect of various methods of cooling on floor temperature in rail cars shipped from Pasco on August 25, 1967

Summary

A. Reinspection certificate analysis.

1. Analysis of certificates showed that 6.1% of the cars shipped were rejected due to tuber defects in 1967 as compared to 8.6% and 12.2% in 1965 and 1966, respectively.

2. Tuber decay was much more of a problem than blackspot in 1967.

B. Effect of pre-storage conditions on bacterial soft rot of potato tubers.

Newly harvested Russet Burbank and Norgold potato tubers were placed under a wet treatment for 0, 1, 2 and 3 days [pre-storage] at 70 degrees F and then placed at 40, 50, 60 or 70 degrees F for 8 days under either atmospheric oxygen level [20.5%] or low oxygen level [about 4%].

1. Dry tubers held at 70 degrees F and low oxygen did not decay after 8 days.

2. Tubers receiving a wet treatment showed more decay under low oxygen than those under atmospheric levels of oxygen for all storage room temperatures.

3. No visible decay was observed after 1 day of pre-storage at 70 degrees F; however, 4% of the tubers from this pre-storage treatment decayed when stored for 8 days at 40 degrees F under low oxygen, but no decay occurred at normal atmospheric level of oxygen.

4. A 40 degree F storage temperature completely prevented soft rot in tubers with 0 days pre-storage held at atmospheric levels of oxygen for 8 days [20.5%] while the 50 degree F temperature did not.

C. Rail car shipments from Pasco, Washington to Newark, New Jersey.

1. Two shipments of 4 cars each were shipped August 16 and 26. Each shipment consisted of: a mechanically refrigerated car; a car iced before loading; a car iced after loading; a car iced after being loaded with pre-chilled tubers. [In the second shipment, the later car was iced prior to loading with pre-chilled tubers.]

2. Cooling treatments which quickly lowered the temperature at the floor level after the doors were shut, were as follows: [1] tubers pre-chilled and car pre-iced [quickest]; [2] car mechanically refrigerated; [3] car pre-iced or tubers pre-chilled, loaded dry, and car iced after loading; [4] car iced after loading [slowest].

3. Floor temperatures in the pre-iced car loaded with chilled tubers were approsimately 40 degrees F within 24 hours after the doors were closed.

4. Floor temperature in the mechanically refrigerated car was 47 degrees F [which was the temperature set on the car thermostat] within 24 hours after doors were closed.

5. Other treatments required 48 hours of longer for the floor temperature to reach 50 degrees F.

6. Lack of oxygen did not appear to be a problem, since all the test cars contained normal levels of oxygen at destination.

Table 3. Information and data recorded from two rail car shipments of Russet Burbank potatoes shipped from Pasco, Washington to Newark, New Jersey

A. Loading information at Pasco

Treatment number	Date of shipment	Car Type 1/	Car Iced 2/	Tuber Treatment 3/	Sacks (cwt)
1	Aug. 16	M.R.	--	S.T.	670
2	Aug. 16	S.B.	A.L.	S.T.	500
3	Aug. 16	S.B.	B.L.	S.T.	500
4	Aug. 16	S.B.	A.L.	P.C.	425
5	Aug. 26	M.R.	--	S.T.	665
6	Aug. 26	S.B.	A.L.	S.T.	500
7	Aug. 26	S.B.	B.L.	S.T.	500
8	Aug. 26	S.B.	B.L.	P.C.	442

1/ S.B. = Standard Bunker; M.R. = mechanical refrigeration
2/ A.L. = After loading; B.L. = before loading
3/ S.T. = Standard treatment (not pre-chilled); P.C. = Pre-chilled

B. Environmental data taken at Pasco and Newark

Treatment number	Ambient temp. °f at time of		Tuber pulp temp. °F at time of		Oxygen content in car prior to unloading
	Loading	Unloading	Loading Av.	Unloading Av.	
1	105	68	79	48	normal
2	105	76	80	43	normal
3	105	70	79	46	normal
4	105	76	53 1/	47	normal
5	95	-- 2/	75	--	--
6	95	--	75	--	--
7	95	--	73	--	--
8	95	--	50 1/	--	--

1/ Tubers in chiller 24 hours prior to loading
2/ No records taken

Table 3 (continued)

C. Inspection and environmental data taken at Newark

Treatment number	Doorway temp. °F Top	Bottom	% Grade Defects1/	% Black Spot	% Soft Rot2/	Car Rejected
1	47	47	3	1	a	yes
2	43	39	--	1	b	no
3	44	42	--	1	--	no
4	44	41	--	2	b	no
5	--	--	--	--	--	no
6	--	--	--	--	--	no
7	--	--	--	--	--	no
8	--	--	--	--	--	no

1/ Cuts and bruises

2/ a, average 1%, but up to 3% in same parts of the car

b, less than 1%