Market Diseases of Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables
Market Diseases of Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables
PREFACE

This handbook is an extensive revision of and supersedes Miscellaneous Publication No. 440, Market Diseases of Fruits and Vegetables, Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables, by Glen B. Ramsey and the late James S. Wiant. This is one of a group pertaining to market diseases of fruits and vegetables. The publications are designed to aid in the recognition and identification of pathological conditions of economic importance affecting fruits and vegetables in the channels of marketing, to facilitate the market inspection of these food products and to prevent losses from such conditions. Other publications in this group are:

MISCELLANEOUS PUBLICATIONS

168. Apples, Pears, Quinces. Revised November 1951.

AGRICULTURE HANDBOOKS

Acknowledgment is made to Dr. W. J. Zaumeyer, Agricultural Research Service, U.S. Department of Agriculture; Dr. J. C. Walker, Department of Plant Pathology, University of Wisconsin; and Dr. S. A. Wingard, Department of Botany and Plant Pathology, Virginia Polytechnic Institute, for the use of photographs for certain illustrations. Appreciation is also expressed to Dr. E. C. Grogan, Department of Plant Pathology, University of California, for suggestions on the virus diseases of celery and for the use of certain illustrations; to Dr. Howard W. Burdine, Florida Everglade Experiment Station, for suggestions on the pencil stripe disorder of celery; and to Dr. C. R. Benjamin and Dr. C. E. Smith, Jr., Agricultural Research Service, U.S. Department of Agriculture, for reviewing the nomenclature of fungi and seed plants, respectively.

CAUTION

If pesticides are handled or applied improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use pesticides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lily family</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Asparagus</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fusarium rot</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Phytophthora rot</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Watery soft rot</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Garlic and onions</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Aspergillus bulb rot</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Black mold rot</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Blue mold rot</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Chemical injury</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Diplodia stain</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Freezing injury</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Fusarium bulb rot</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Gray mold (neck rot)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Greening</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Purple blotch</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Smudge</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Smut</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Sour skin</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Sunscald</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Translucent scales</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Waxy breakdown</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Pulse family</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Beans, Lima</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Bacterial blights (Common, Fuscous, and Halo)</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Bacterial spot</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Downy mildew</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Pod blight</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Seed spotting</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Seed stickiness</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Yeast spot</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Beans, Snap</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Anthracnose</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Bacterial wilt</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Cottony leak</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Mosaics and other virus diseases</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Rhizopus soft rot</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Russetting</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Rust</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Sclerotium rot (southern blight)</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Soil rot (Rhizoctonia pod rot)</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Pulse family—Continued</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans, Snap—Continued</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunscald</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Watery soft rot</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Anthracnose</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Bacterial blight</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Downy mildew</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td></td>
<td>33</td>
</tr>
<tr>
<td>Mosaics and other virus diseases</td>
<td></td>
<td>33</td>
</tr>
<tr>
<td>Pod spot</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Scab</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Parsley family</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Carrot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Black mold</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>Black mold</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>Crater rot</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>Fusarium rot</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Rhizopus soft rot</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Root knot</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Scab spot complex</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Sour rot</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>Watery soft rot</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>Celery</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>Bacterial blight</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Black heart</td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>Brown spot</td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>Cracked stem</td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>Crater spot</td>
<td></td>
<td>46</td>
</tr>
<tr>
<td>Early blight</td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Freezing injury</td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Late blight</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Mosaics and other virus diseases</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Pencil stripe</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Phoma root rot</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Pithiness (hollow stem)</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Watery soft rot</td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>Finocchio</td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>Watery soft rot</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Parsley</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Parsnip</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Bacterial soft rot</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Gray mold rot</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Parsnip canker</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>Root knot</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>Literature Cited</td>
<td></td>
<td>56</td>
</tr>
</tbody>
</table>
Market Diseases
of
Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables

By Marion A. Smith, Lacy P. McCulloch, and Bernard A. Friedman

INTRODUCTION

The vegetable crops included in this handbook have widely different problems of culture, field disease control, harvesting methods, and handling practices, and each commodity must be considered separately in controlling postharvest diseases.

Each commodity has a natural population of bacteria and fungus spores on its surface at harvest; these bacteria and spores are a potential hazard to keeping quality. Subsequent infection and disease development will depend on such factors as commodity vigor, natural resistance, extent of mechanical injury, relative humidity, and temperature.

In addition to the fungus and bacterial diseases, these vegetable crops are subject to virus and physiological diseases. Some of the physiological diseases and all of the virus diseases, as well as a few of the blemish-type diseases caused by bacteria or fungi, not only originate in the field, but are obvious at harvest. If blemished vegetables are included in the pack, it is either because they are acceptable or because they are overlooked during packing. Certain rots that are normally field diseases may also appear after harvest. These may have been small lesions that were overlooked during sorting and packing or that may have developed from invisible infections or from spores present at harvest. In addition there are certain diseases that occur or are important only after harvest.

The basic control for diseases that occur in the field must be applied during the preparation for and production of the crop. Recommendations for such control measures are available from the State agricultural experiment station or extension service. This handbook is concerned primarily with those control measures that can be successfully

1 Dr. Friedman is deceased.
applied after harvest. In general, careful handling practices and prompt and proper temperature and humidity controls are standard recommendations for disease control after harvest. In certain situations chemical treatment may also be recommended.

**LILY FAMILY**

Botanically, asparagus, onion, garlic, shallot, leek, Welsh onion, and chive belong to the Lily family (*Liliaceae*), a family noted mainly for ornamental plants.

**ASPARAGUS**

The edible portion of the asparagus plant (*Asparagus officinalis* L.) consists of the young unbranched shoots or spears. Asparagus for fresh consumption is grown principally in California, New Jersey, and Washington.

Good quality asparagus marketed for fresh use is green for most of its length. The spears are straight, crisp, and tender, and their tips are tightly closed. They are free from soil, decay, and mechanical injuries. Asparagus loses edible quality very rapidly after harvest and it should be moved from the field promptly, packed and cooled rapidly, and maintained at 32° to 36° F.

There are several diseases that attack asparagus plants in the field but seldom affect directly the marketable spears. The most serious field disease is rust (*Puccinia asparagi* DC.). Severe infections of rust reduce vigor and yield of the plants the following season. Cercospora blight (*C. asparagi* Sacc.) causes minor damage in the field.

In 1953 asparagus dieback, apparently caused by water shortage, was reported prevalent in fields in a number of northeastern States.

Several insect pests attack asparagus plants in the field. However, the asparagus beetle (*Crioceris asparagi* L.) may occasionally damage marketable spears by deposits of small, black egg masses or by feeding marks, which may open the way to decay-producing microorganisms.

The most serious market diseases of asparagus at the present time are described below. In addition, a rusty discoloration caused by *Rhizoctonia* species is occasionally seen after harvest.

(See 37, 61, 94, 114, 148, 153.)

**Bacterial Soft Rot**

*Erwinia carotovora* (L. R. Jones) Holland

Bacterial soft rot is probably the most frequent and serious decay of asparagus after harvest. It usually occurs at the tips or at the cut ends of the spears, but may be found wherever injuries occur. The rot is soft, slippery, and watery, especially if it develops in the tender tissues at the tip ends of the spears (pl. 1, A). Unlike other decays...
on asparagus, a very disagreeable odor is produced in the advanced stages of bacterical soft rot. The bacteria causing this decay occur commonly in soil and water. They readily attack injured asparagus tissue under warm and humid conditions.

The development of bacterial soft rot after harvest may be controlled by careful handling to avoid injuries, by rigid culling of bruised spears, and by rapid cooling to 40°F. or below and maintaining the temperature at 32°F. to 36°F.

**Fusarium Rot**

*Fusarium spp.*

Fusarium rot may occur on the tips, bracts, and other parts of asparagus spears. At first a white, fluffy mold may develop, which may turn slightly pinkish later. Affected asparagus tissues are at first watersoaked, then turn to yellow and brown. When attacked by *Fusarium* the tips of the spears may become completely covered with white, fluffy mold and the affected tissues become soft and watery (pl. 1, B). Lesions on the sides of spears may be 2 to 3 inches in length. Unless bacteria are present fusarium rot has no marked odor.

The fungi that cause fusarium rot are soil inhabitants and are present on the spears when they are harvested. The specific identity of *Fusarium* causing postharvest decay of asparagus spears has not been determined. *Fusarium oxysporum* Schlecht. f. *asparagi* Cohen has been shown to cause crown rot and plant wilting in the field. In inoculation tests this fungus also caused a rot of cut spears.

Precooling to about 40°F. and maintaining a temperature range of 32°F. to 40°F. controls fusarium rot.

(See 53.)

**Gray Mold Rot**

*Botrytis cinerea* Pers. ex Fr.

The fungus that causes gray mold rot is usually present in most vegetable-growing areas, but is seldom serious on asparagus. Cool, wet weather favors the development of *Botrytis*, which may cause a tip wilt in the field or a decay after harvest. In the early stages of gray mold rot a small amount of white mold is usually present in the watersoaked lesions (pl. 1, D). Later, the grayish-brown mold and smoky granular spore masses serve to identify gray mold rot. Prompt cooling and maintaining temperatures of 32°F. to 36°F. will give practical control of gray mold rot.

(See 127.)

**Phytophthora Rot**

*Phytophthora spp.*

Phytophthora rot is occasionally serious in California-grown asparagus shipped to eastern markets in the spring of the year.

Phytophthora rot is characterized by large watersoaked, greenish or light-brown lesions generally on the sides of the spears above the
base. In more advanced lesions the decay may completely encircle the spears, and there may be some collapse of the tissue resulting in flattened or creased areas. Generally, there is no surface mold, but under humid conditions a slight, grayish-white, appressed mold may develop, especially in advanced stages of decay (pl. 1, C). The decay has no odor unless bacteria are also present.

The fungi that cause phytophthora rot are soil inhabitants. They may cause serious losses during transit and marketing in seasons when wet or flooded conditions prevail in asparagus fields.

(See 4, 170.)

**Watery Soft Rot**

*Sclerotinia sclerotiorum* (Lib.) DBy.

Watery soft rot is a minor disease of asparagus but may occur wherever the crop is grown. Lesions are irregular, watery, and odorless. As the lesions enlarge they become covered with a white to grayish-white, appressed mold. In advanced stages hard black sclerotia form in the mold on the rotted surface.

Watery soft rot may be confused with fusarium rot at stages before mold develops. Fusarium rot, however, is usually restricted to the tissues adjacent to the bracts, whereas watery soft rot may occur anywhere on the spears. If, however; surface mold of *Fusarium* is present, its white color soon changes to pink. *Fusarium* never develops sclerotia, as described for watery soft rot.

**GARLIC AND ONIONS**

Garlic (*Allium sativum* L.), onion (*A. cepa* L.), and the closely related plants, leek (*A. porrum* L.), chive (*A. schoenoprasum* L.), and the Welsh onion (*A. fistulosum* L.), are all members of the lily family. They are used as food, both fresh and cooked, and for flavoring and seasoning.

The onion and its relatives are subject to a considerable number of diseases. Some of these occur on the plant in the field, affecting the yield or quality or both; others are important primarily in storage and transit; and some cause serious damage both in the field and on the market. Among the more important field diseases are downy mildew (*Peronospora destructor* (Berk.) Casp.), smut (*Urocystis cepulœ Frost*), fusarium bulb rot, purple blotch (*Alternaria porri* (Ell.) Cif.), pink root (*Pyrenochaeta terrestris* (Hansen) Gorenz et al.), and mosaics and other virus diseases.

The most destructive postharvest diseases of onions are bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland), gray mold rot (*Botrytis* spp.), fusarium bulb rot (*Fusarium* spp.), black mold rot (*Aspergillus alliaceus* Thom & Church), blue mold (*Penicillium* spp.), white rot (*Sclerotium cepivorum* Berk.), and smudge (*Colletotrichum circinans* (Berk.) Vogl.).

Garlic is subject to some of the diseases that affect the onion. The diseases of garlic most often encountered on the market are blue mold
rot and waxy breakdown. Aspergillus, fusarium rot, and gray mold rot are also important diseases of the bulbs.

(See 48, 49.)

**Aspergillus Bulb Rot**

*Aspergillus alliaceus* Thom & Church

Aspergillus bulb rot has not been found on onions or garlic grown in the United States. Garlic from Italy and onions from Sweden affected by this disease have been intercepted at United States ports of entry. However, aspergillus rot appears to be of minor importance on imported onions.

The fungus requires high temperatures for maximum growth and production of active decay. The complete decay of inoculated mature onions required 21 days at about 97° F.; only slight infection occurred during 3 months at about 61°.

Early symptoms of aspergillus bulb rot on inoculated onions and garlic are characterized by a slight swelling and darkening of the tissues. The affected area becomes watersoaked and soft, and a sharp line of demarcation occurs between the diseased and the healthy tissues. In advanced stages the tissues shrink and become brownish, and a white mat of mycelium forms between the bulb scales. Eventually, small white sclerotia form, which become brown at maturity. The spore clusters appear yellowish-brown and are produced in great abundance on the surface of the decaying tissues if the humidity is high.

It is unlikely that aspergillus bulb rot will become established and cause economic losses in this country. The fungus does not attack growing onions. Temperatures recommended for storing or holding onions are well below that at which extensive decay was reported.

Aspergillus bulb rot should be readily controlled by holding onions and garlic under refrigeration of 32° F., and about 65 to 70 percent relative humidity.

(See 161, 162.)

**Bacterial Soft Rot**

*Erwinia carotovora* (L. R. Jones) Holland

**Occurrence, Symptoms, and Effects**

Bacterial soft rot is one of the more prevalent causes of loss in storage onions. The soft rot bacteria may enter the neck tissues as plants approach maturity and invade one or more scales without passing from one scale to another. At this stage the affected tissues are glassy or watersoaked and are pale yellowish to light brown (pls. 2, E, and 17, A, B). As the rot progresses, the invaded fleshy scales become soft and the diseased bulbs may be detected if pressure on the bulb forces a watery, foul-smelling fluid out at the neck. Onions with mechanical injuries, sunscald, or bruises are particularly susceptible to bacterial soft rot, especially if they have been held under warm, humid conditions.
Causal Factors

The bacterial soft rot organism *E. carotovora* (L. R. Jones) Holland, described under carrot, celery, and other hosts, is the organism most generally responsible for this decay.

Control Measures

Tops should be allowed to mature well before harvesting. Care should be exercised to avoid bruising during harvest and packing. Storage houses should be provided with adequate ventilation to avoid accumulation of moisture on the surfaces of bulbs. Onions should be stored at 32° F. and about 65 to 70 percent relative humidity.

(See 160.)

Black Mold Rot

*Aspergillus niger* Tiegh.

Occurrence, Symptoms, and Effects

Black mold may be destructive during storage and transit on onions grown in Louisiana, Texas, and California; it also occurs on garlic.

The principal symptoms of the disease are the presence of black powdery spore masses of the fungus on the outside scale or between that and the next inner one. When these masses occur between the scales they tend to follow the veins (pl. 3, B). Sometimes there are no apparent lesions, and the fungus itself constitutes the only blemish. At times the tissues show symptoms, such as sunken discolored areas, which underlie the powdery fungus mass (pl. 5, G). Under dry conditions the affected tissues are dry and papery and sometimes highly colored; under moist conditions they are semiwatery.

Causal Factors

The pathogen *Aspergillus niger* is a common saprophyte living in dead or dying plant material. It is apparently capable of growing and multiplying throughout the year in the soil or on dead refuse. Under very moist conditions the pathogen may cause a slow rot. Unlike neck rot and smudge, black mold is as severe on colored as on white varieties of onions. Infection may spread in transit or storage from onion to onion by contact through bruises or wounds, by mechanical means, or by dissemination of spores by air currents.

Observations in the field, in storage, and in transit indicate that moisture and high temperature favor the growth and spread of the fungus. It grows slowly at 55° F. and most rapidly at 95° F.

Control Measures

Bulbs should be protected from moisture in the field during and after pulling and during transit. Prompt and thorough curing and good ventilation and storage at 32° F. and a relative humidity of about 65 to 70 percent are recommended.

(See 1, 97, 139.)
Blue Mold Rot

*Penicillium* spp.

Blue mold rot occurs occasionally on bulbs of onions but it is most prevalent on garlic. The disease is occasionally severe on garlic if it is harvested before proper maturity or stored without proper ventilation or at too high humidity.

The early symptoms of blue mold rot on garlic are light-yellowish lesions in the outer cloves. As spores are produced on the surface of the lesion, the color changes to blue or bluish green (pl. 5, F). Garlic bulbs affected with blue mold rot may show little or no evidence of the disease externally. Once the decay begins, the breakdown of tissues is rapid. Affected bulbs are generally light in weight, and pressure on individual cloves will reveal a soft, spongy or powdery-dry condition, depending upon the extent of the decay. In advanced stages of decay the cloves are completely broken down into greenish-tan or gray powdery masses.

Several species of *Penicillium*, which are common and widespread, may bring about this decay.

Control measures consist of harvesting at proper maturity, adequate curing of bulbs before they are stored, adequate ventilation in storage, and storage at 32° F. and a relative humidity of about 65 to 70 percent. (See 1, 97, 139.)

Chemical Injury

Onions in cold storage are sometimes injured by accidental exposure to ammonia fumes from the storage plant. The fumes cause an alkaline reaction with the color pigments in the outer scales of the onions and often produce such pronounced discoloration (pl. 5, A) that their marketability is greatly reduced. As a result of exposure to ammonia fumes, yellow onions show brown blotches or a uniform brown color over all the exposed surfaces; red onions change to a deep greenish black or metallic black; and white onions become greenish yellow. If onions are exposed to strong fumes for several hours the fleshy, edible portion of the bulbs becomes watery, yellowish green, and worthless.

Experiments have shown that ammonia injury will take place at a temperature as low as 31.5° F., and that the rate and severity of discoloration are approximately the same as at higher temperatures.

The color changes take place more rapidly in a humid atmosphere or when the onions are slightly moist. Less than 1 percent of ammonia in the air will cause marked discoloration if the onions are exposed for 24 hours or longer. With stronger concentrations the color changes are noticeable almost immediately and large brownish-black blotches are produced within a few minutes.

In the past a chemical injury known as "alkali spot" or "bag print" occurred frequently on colored onions that had been in contact with moist bags or damp storage for some time. Under present handling practices this injury rarely occurs.

(See 122, 123, 147.)
Diplodia Stain

*Diplodia natalensis* P. Evans

A superficial disease of Texas-grown Crystal wax onions has been observed in the midwestern and eastern markets. On market onions the characteristic symptom of this disease is a silvery-gray to black discoloration of the outer dry scales about the upper half of the bulbs. Occasionally the dry scales all over the onion are discolored. In more advanced stages black fruiting bodies (pycnidia) singly or in groups of two or three are visible on the inactive scales (pl. 3, C). Apparently the fungus is unable to infect the fleshy scales of the onion.

The disease is caused by *D. natalensis*, which attacks the outer scales of white onions. Colored onions are not affected. Control measures have not been developed.

(See 124.)

Freezing Injury

Onion bulbs will freeze at about 30° F. Under some conditions onions standing on track or in storage may be undercooled to a temperature of 25° or lower for a short time without becoming frozen or otherwise injured. A slight jar will cause undercooled products to freeze immediately; consequently, undercooling rarely occurs during transit.

There is considerable variation between individual onions in their reaction to low temperature. Some bulbs in a lot may freeze quickly when they reach a temperature of 30° F. and show severe injury when they are thawed out. Others may not freeze or if they are frozen they may thaw out without injury.

Onions affected with freezing injury show watersoaked, grayish-yellow fleshy scales when cut. In slight freezing the outer fleshy scales alone are affected, but when the bulbs are exposed to low temperatures for a prolonged period the inner scales may also become watersoaked and discolored. Usually the entire scale is injured all the way around the bulb, but the neighboring inside and outside scales may or may not show injury. Irregularly shaped opaque areas occur in many of the watery transparent scales.

Garlic bulbs will freeze at temperatures of about 27° to 30° F.

In cases of slight freezing injury of onions and garlic there may be less loss if the bulbs are spread out so that the injured scales can dry thoroughly. Frozen onions will be injured less and remain in a better general condition if thawed out at 40° F., rather than at a higher temperature.

(See 95, 166, 175, 177.)

Fusarium Bulb Rot

*Fusarium* spp.

Occurrence, Symptoms, and Effects

Fusarium bulb rot occurs in most onion-growing sections in the United States. Losses from this disease occur in the field and continue after harvest from storage rot. The fungus lives in the soil and from
this it can attack the growing bulbs. It may also winter in debris and containers in storage houses. Decay can start on uninjured areas of bulbs, but it often follows bruises or insect injuries.

Examination of the base of the bulb often reveals that roots have been rotted off. At the base of the bulb a whitish to pinkish mold appears on the surface of decayed portions of the scale. Decay may be dry or watery depending on the species of Fusarium causing the rot and on moisture and temperature conditions. The decay usually progresses very slowly and may not appear until onions have been in storage for some time.

**Causal Factors**

Various species of *Fusarium* are able to induce bulb rot of onions. The fungi most often mentioned are *F. oxysporum* Schlect., *F. cepae* (Hanz.) Snyd. & Hans., and forms of *F. zonatum* (Sherb.) Wr. In storage there is relatively little decay between 46° and 59° F. At 68° the rot progresses rapidly but the tissues remain watery for a long time; at 86° the tissues decay and dry out rapidly.

**Control Measures**

Crop rotation is recommended where bulb rot is likely to become severe. Allow tops to mature well before harvest. Prevent mechanical injuries during harvesting and handling. After curing, tablestock onions and onion sets should be stored promptly at 32° F. and at a relative humidity of 65 to 70 percent.

(See 31, 92, 98, 113, 159.)

**Gray Mold (Neck Rot)**

*Botrytis* spp.

**Occurrence and Importance**

Gray mold rot is one of the most serious diseases affecting onions during transit, storage, and marketing. Losses during storage are often extensive because the fungus is slowed, but not inhibited, at cold storage temperatures. Apparently all varieties of onions, shallot, and garlic are susceptible. White onions, however, are the most seriously affected. Colored onions have a considerable measure of resistance because of their chemical composition.

The typical gray mold rot may occur wherever onions are grown. Another type of gray mold rot, however, caused by *Botrytis squamosa*, is confined to onions grown in the Midwest.

**Causal Factors**

Three closely related species of *Botrytis* cause types of gray mold rot or “neck rot.” *Botrytis allii* Munn is probably the most widely distributed and causes more rot (pls. 2, A, B, and pl. 4, A, B) than the other two species. The rot (pl. 4, C) caused by *B. byssoidae* J. C. Walker in general is second in importance, but in some of the North Central States it is the principal cause of neck rot. Much less pathe-
genic than the other two is the rot caused by *B. squamosa* J. C. Walker (pl. 4, D). At times *B. byssoides* invades and overruns lesions caused by *B. squamosa*, thus altering the symptoms.

These fungi live from season to season as sclerotia in the soil and on dying plant parts and debris during the growing season. The disease is generally most prevalent when cool, moist weather prevails before and during harvest.

Decay develops most rapidly at a temperature range of 59° to 68° F. The rot is slowed greatly at temperatures below 37° but will develop at 32° during several months' storage.

### Symptoms and Effects

Infection usually takes place through the remnants of the top at the neck of inadequately cured bulbs after harvest. Infection through the neck has led to the use of the term “neck rot” as a descriptive name for the disease, although frequently infections take place through wounds made on other parts of the onion.

The symptoms of the decay caused by *B. allii* and *B. byssoides* are in many respects so similar that a careful study is needed to separate them. Their symptoms are therefore discussed together in this publication.

The first indication of the disease is a watersoaking and softening of affected scales. The watersoaked condition gives the affected scales a cooked appearance. The decayed tissues lose moisture and become sunken. As the fungus develops within the decaying tissues they become grayish brown. In advanced stages of decay a dense mat of mycelium may show around the base of the neck and between the scales. In some cases the mycelium is covered with a granular mass of grayish-brown spores. The disease progresses rapidly down the scales from the original infection at the neck. The spread from scale to scale proceeds more slowly. The line of demarcation between the diseased and healthy tissues is quite definite, although the advancing edge of the lesion usually shows a slight watersoaking of the fleshy tissues. No odor accompanies this decay. In advanced stages of decay the affected tissues become sunken and fairly firm. In stored onions in an advanced stage of decay firm, black, sclerotia ½ to ¼ inch in diameter may develop in the tissues about the decayed neck.

The symptoms of neck rot caused by *B. squamosa* are sufficiently distinct to warrant a separate discussion. The rot caused by this fungus has been found on the market only on white onions. Decay of the succulent scales is much slower than that caused by *B. allii* or *B. byssoides*. The extent of decay is often limited to an area around the base of the neck. The first evidence of the disease is often the presence of small, thin, black sclerotia attached to the dry outer scales at the base of the neck of the onion (pl. 4, D). Decayed tissues at first have a watersoaked appearance, but gradually lose moisture and become sunken. The presence of the small, thin sclerotia, the limited decay, and the brownish color of decayed tissues in old lesions aid in distinguishing this type of neck rot from that caused by *B. allii* and *B. byssoides*. 
Control Measures

The control of gray mold neck rot depends largely on weather favorable to the maturing of the tops at the end of the growing period and on adequately curing the neck tissues after harvest. If necessary, artificial means of curing should be used.

Colored varieties possess natural resistance absent in white onions. Table stock onions and onion sets should be stored at 32° F. and a relative humidity of 65 to 70 percent. Even 32° will not completely prevent the development of the rot if the onions had active infections at time of storage.

(See 60, 65, 105, 131, 156, 157, 158, 176.)

Greening

(See Sunscald, p. 13.)

Purple Blotch

*Alternaria porri* (Ell.) Cif.

Purple blotch is generally distributed over the United States. It affects leaves, stems, and bulbs. Infection of bulbs occurs at harvest-time usually at the necks of the topped bulbs or through wounds. The decay is at first semiwatery and is especially conspicuous because of the color associated with it. The causal organism secretes an abundance of pigment that diffuses through the scale tissues somewhat in advance of the fungus threads. The affected tissue is deep yellow at first but turns gradually to a wine red. Eventually the old decayed tissue becomes dark brown to black (pl. 2, F).

The causal organism develops most rapidly between 72° and 86° F. Very little growth takes place above 93° or below 50°. At temperatures of 70° to 72°, bulbs may be completely rotted in about 2 weeks.

In regions where the disease is likely to become important, it may be controlled by rapid drying of the bulbs after harvest and then prompt storage.

Onions should be stored at 32° F. and a relative humidity of 65 to 70 percent.

(See 3, 138.)

Smudge

*Colletotrichum circinans* (Berk.) Vogl.

**Occurrence, Symptoms, and Effects**

Smudge is present in most of the onion districts of the United States. The disease occurs on field onions, onion sets, leeks, and shallots. It is most pronounced on the white onion and sets. Its importance consists chiefly in the reduction in market value due to blemishes on the outer scales. Under very moist conditions in transit and storage scales are destroyed, bulbs shrink, and often sets sprout pre-
maturely. Smudge is confined almost entirely to the scales and lower portions of the unthickened leaves.

The disease is characterized by small, dark-green to black dots that appear on the outer scales. These small dots may be grouped together to form concentric rings or blotches, giving an unsightly appearance to the white bulbs (pl. 2, C, D).

**Causal Factors**

The causal organism is the fungus *C. circinans*. It occurs on onion scales in the soil or in bulbs and sets in storage. The disease appears shortly before harvest. Under favorable conditions the fungus attacks the outer scales; and spores, which are borne in the infected areas, are carried by drops of water to other scales, where they germinate in a few hours and start new lesions. If weather is warm and moist a relatively small amount of disease in the field before harvest will supply enough spores to blemish a crop severely during harvesting or while crates are stacked in the field.

The fungus grows throughout a temperature range of 36° to 89° F. but develops best at about 78°. The spores germinate at temperatures ranging from 40° to 89°; the optimum is between 68° and 78°. Infection may occur at 50° but development is very slow below 68°. The disease develops and spreads most rapidly in the field when the soil temperature ranges between 68° and 86° and when there is an abundance of rainfall.

**Control Measures**

Protect onions from rain after harvest and cure promptly. When possible use colored varieties of onions. White onion sets should be thoroughly cured. Storage at 32° F. and at about 65 to 70 percent relative humidity is desirable.

(See 65, 75, 130, 154, 160.)

**Smut**

*Urocystis cepulae* Frost

Onion smut causes losses in many of the onion-growing areas throughout the Northern States from coast to coast. It has not been reported south of Kentucky due largely to climatic conditions. Onion and leek are very susceptible to the disease; it causes poor yields and stunts the growth of affected plants. Smutted bulbs shrink excessively in storage. Green onions and onion sets affected with smut are occasionally found on the market.

The disease is characterized by dark-colored slightly raised streaks or blisters on the leaves and young bulbs of green onions. These pustules are filled with greenish-black, powdery masses of spores (pl. 2, G). Sets may be greatly shrunked, with the whole exterior covered with blisters. On such specimens, or on others that survive and get into the trade channels, the lesions consist of slightly raised brown to black pustules, that are more prevalent near the base of the outer fleshy scale. They also may occur as deeply as the third or fourth scale.
The disease does not develop or spread in transit or in storage. Post-harvest control should consist primarily of grading out diseased bulbs. For field control of the disease, consult the State agricultural experiment station or extension service.

(See 2, 39, 79, 108, 160.)

**Sour Skin**

*Pseudomonas cepacia* Burkh.

Sour skin, a scale rot of onion bulbs, was originally observed in New York State where it has become prevalent in onion-growing sections. The disease has also been seen on Wisconsin onions.

The disease, as seen on the Yellow Globe variety, attacks only certain of the outer fleshy scales of the bulb, although not necessarily the outermost one. Infected scales are slimy and yellow. Infected onions may show a shrinkage of the upper portion of the bulb (pl. 5, B), and in advanced stages of the disease the outer dry skin readily slips off during handling, while the portion of the bulb within the diseased slimy scales remains firm. Fungi and yeast may be present as secondary invaders. These latter organisms may be responsible in part for the sour vinegarlike odor attributed to this disease. There is no evidence that the bacteria spread from infected bulbs to healthy ones in storage. Control measures have not been developed.

(See 18.)

**Sunscald**

Onions harvested in regions where the temperature is high and the sunlight extremely bright are often severely affected with sunscald. Immature uncured bulbs are more subject to injury, since the more succulent tissues are likely to be exposed. Affected tissues, 1 to 2 inches in diameter, appear bleached and become soft and slippery. They lose moisture rapidly and when dried become disfiguring blemishes.

Sunscald is often a serious factor in marketing onions, particularly if soft rot bacteria gain entrance to the injured tissues when they are still succulent. Bacterial soft rot following sunscald can cause serious decay during transit and marketing.

Sunscald can be prevented in districts subject to the damage by protecting the bulbs from direct exposure to the sun during curing.

If onions are allowed to cure too long in moderate light chlorophyll may form in the outer scales and cause a greening of the bulbs. This may cause an unpalatable taste but no shrinkage or decay occurs. Greening may be avoided by removing the bulbs to dark storage as soon as sufficient curing has taken place.

(See 160.)

**Translucent Scales**

Translucent scales, a physiological disease, occurs on onions grown in widely separated areas. Previously the disorder was known as physiological breakdown, internal breakdown, or storage breakdown.
The term "breakdown," however, implies a disintegrated condition not present in this disorder, and the name "translucent scales" is proposed as a more descriptive term.

The disorder is first characterized by the grayish, watersoaked appearance of a part or all of one or more fleshy scales giving them a translucent appearance (pl. 5, E). All fleshy scales may be affected in severe cases, but the second and third ones seem to be most frequently affected. Seriously affected scales frequently develop a smoky to brown color as viewed in cross section.

Translucent scales may be confused with freezing injury; affected fleshy scales of both conditions appear watersoaked and translucent. There are certain symptoms, however, that aid in distinguishing between these conditions. In freezing injury the damage is always from the surface inward. In severe freezing injury the neck and base of the bulb may also be affected. These tissues are never affected in translucent scales. Other symptoms of freezing injury that are lacking in onions with translucent scales are: areas of white, opaque tissues in the watersoaked scales; loosening of the epidermis on the concave side of affected scales; and a grainy texture of the tissues exposed by the loosened epidermis.

Translucent scales was previously thought to occur to some extent in the field, but it is now believed to develop only after harvest. In some years translucent scales causes considerable loss in California-grown onions. Also, it is an important problem on yellow-globe-type onions grown in Michigan and Wisconsin, held in common storage, and then shipped to southern markets. Onions that show little or none of the disorder when removed from storage may show an appreciable amount of translucent scales at the market.

The cause of translucent scales is not known. Early researchers held that growing conditions were probably a factor. They also reported onions were more susceptible to the disorder if stored at 40° to 50° F. and high relative humidity than if stored at 32° and low humidity. Recent research in California indicated that high temperatures during the last 3 weeks before onions are stored or cooled to 32° are probably the most important factor in predisposing them to translucent scales. The percentage of onions that developed the disorder at 32° increased after 3 to 4 months' storage. No research has been done recently on the effect of high humidity during storage or after withdrawal on the occurrence of translucent scales. Popular opinion, however, continues to hold that humidity above that recommended is a factor.

The evidence thus far indicates that for best control of translucent scales, onions should be stored promptly after they are cured, and cooled quickly and held at 32° F. and about 65 to 70 percent relative humidity.

(See 95, 175, 176.)

---

*Unpublished data of Werner Lipton of the Market Quality Research Division.
**Waxy Breakdown**

A yellow waxy breakdown of the outside cloves of garlic bulbs has been found on garlic from California, Texas, Louisiana, Italy, and Chile. This disorder is occasionally so serious that it affects the marketability of this crop. Since no organism seems to be associated with it as a causal agent, it is considered to be a physiological disorder.

The early symptoms of waxy breakdown are small, slightly sunken, light-yellow areas in the flesh of the clove. As the breakdown progresses the clove shows an amber color throughout (pl. 5, C, D). The clove is then somewhat translucent and sticky or waxy to the touch but not soft, as when tissues are broken down by parasitic organisms. The outer dry protective scales are not affected. No indications of breakdown may show externally until the advanced stage is reached, when the shrinking of the clove and the amber or amber-brown color may become noticeable through the white papery scales.

**White Rot**

*Sclerotium cepivorum* Berk.

White rot is a common and sometimes destructive disease of onion, garlic, shallot, Welsh onion, and leek. It has been reported in Virginia, Kentucky, New Jersey, California, New York, and Louisiana, where it is severe on set-propagated shallots. It is widespread in Europe; it is destructive on onion and leek in the British Isles and on garlic in Italy and Spain.

White rot is principally a field disease and usually develops on onions grown under cool, moist weather conditions. In late infection, the fungus invades the base of nearly mature bulbs and decay may continue in these bulbs while in storage or transit.

The symptoms on the bulb are like those of other bulb rots such as gray mold and fusarium bulb rot. However, the mycelium is whiter and more cottony and the sclerotia are much more spherical than those of the *Botrytis* species that cause bulb rot (pl. 3, A.) In fusarium bulb rot no black sclerotia are produced.

The pathogen *S. cepivorum* lives over winter in the soil, from which it attacks the new crops. It can also live in bulbs and thus be carried into noninfested fields. Temperatures below 41° and above 84° F. prevent growth of the causal organism.

No data are available regarding the development and spread of this disease in transit and storage.

(See 88. 110, 149, 155.)

**PULSE FAMILY**

The pulse family (*Leguminosae*) contains a number of important vegetable and forage crops. In this group there are several genera and species of beans and peas that produce fruit pods and seeds, which
are classed as vegetables on the market. Of these the common bean, lima bean, and garden pea are of greatest importance.

**LIMA BEANS**

Lima beans (*P. lunatus L.*) are sold either in the pod or shelled. Lima beans of good quality have fresh, well-filled, disease-free pods with succulent beans. Loss of dark green color in the pods and the development of hard, starchy beans are indications that the beans were either overmature at harvest or held too long after harvest.

Lima beans are subject to such field diseases as bacterial spot, downy mildew, and powdery mildew, but these diseases do not develop after harvest. Field diseases such as sclerotium rot and soil rot may also develop after harvest. Shelled lima beans are more perishable than beans in the pod and are subject to a bacterial deterioration known as stickiness and to a fungus deterioration known as seed spotting.

**Bacterial Blights (Common, Fuscous, and Halo)**


**Occurrence, Symptoms, and Effects**

The bacterial blights are of major importance in bean production. The losses they cause vary considerably from year to year, depending primarily upon weather conditions. One or another of three types of blight occurs in most bean-producing areas of the United States and Europe. Most varieties of garden, field, and lima beans may be affected. None of the varieties are immune, although some varieties are quite resistant. In the United States halo blight is less destructive than common blight, mainly because most field-bean varieties are resistant to halo blight. Pods from badly infected fields may be worthless by the time they reach the market. Incipient pod infections or small spots that are barely visible at shipping point may enlarge during transit and reduce the market value of the pods or render them worthless.

In the field, plant symptoms may sometimes be used to distinguish between the three blights. In many cases, however, isolation and identification of the causal bacteria provide the only means to separate the different blights. Infections may occur any place on the pods and start as small watersoaked spots that gradually enlarge (pl. 6, B). In severe pod infections adjacent lesions may coalesce. Spots may have a distinct zoning and a narrow, reddish-brown or brick-red band of tissue around the lesion. Lesions may occur along the sutures of pods. Seeds are often infected, the infection resulting in discoloration or shriveling and, in severe attacks, rotting. Sometimes a bacterial ooze or exudate forms on lesions. In halo blight this
exudate is light-cream or silvercolored, while the exudates of common and fuscous blights are yellow. In addition, halo blight lesions tend to show more watersoaking (pl. 8, B), are usually more circular in outline, and may remain grayish green instead of taking on the yellow and reddish brown shades typical of common and fuscous blights. In Europe halo blight is also known as grease spot because of the appearance of the spot on pods.

**Causal Factors**

The pathogenic bacteria of common blight (*X. phaseoli*), fuscous blight (*X. phaseoli* var. *fuscans*), and halo blight (*P. phaseolicola*) survive from year to year in or on diseased or contaminated seed, or in bean trash that remains in soil. Pods are infected by bacteria that develop in leaf, stem, and other pod lesions. Halo blight is favored by cool weather and common blight by warm weather. This accounts for the prevalence of common blight on snap beans in the South.

As noted before, incipient infections may develop or small spots enlarge in transit and marketing, but there is no evidence that new infections develop on pods after harvest.

The bacterial blight organisms can infect bean leaves and pods over a wide temperature range. There is a difference, however, in the optimum temperature range for infection. The common blight bacteria infect most rapidly at about 90° F., whereas the halo blight bacteria have an optimum for infection of between 75° and 82°. Typical halo symptoms fail to develop, however, at temperatures above 70°.

Prompt cooling of the beans and maintaining temperatures at 45° to 50° F. will check the development of incipient infections.

(See 17, 36, 50, 86, 183, 189.)

**Bacterial Spot**

*Pseudomonas syringae Van Hall*

Bacterial spot of lima beans occurs in many areas of the United States. Reduction in yield from defoliation and pod damage is heaviest along the Atlantic coast and in the Southern States. Some varieties of lima beans show some resistance. Rarely, the organism may cause a ring spot of green lima bean pods.

On lima bean pods lesions are nearly circular, small, and brown at first with a watersoaked halo (pl. 8, C). A cream-colored exudate usually develops on the spots. Spots may occur on any part of the pod. Lesions are frequently found along the sutures. The bacteria may penetrate the walls of pods and cause a reddish discoloration of the seeds. Spongy excrescences are sometimes found protruding from the inner walls of the pod beneath the surface lesions. The pods’ spots are smaller than those produced by the bacterial blight organism on lima beans.

Diseased seed are a source of infection. Frequent rains and temperatures between 80° and 86° F. favor the dissemination of the pathogen
and the infection, which takes place through stomata. The pathogen may also be disseminated from a number of other host plants that it attacks.

Precooling the beans to 45° F. and prompt shipment under adequate refrigeration are recommended. For further control measures consult the State agricultural experiment station or extension service.

(See 189.)

**Downy Mildew**

*Phytophthora phaseoli Thaxt.*

Downy mildew may be a serious field disease of lima beans in the Middle Atlantic and certain Atlantic Seaboard States. This fungus disease attacks both the bush and the pole varieties under favorable weather conditions. The disease is so dependent for development on cool, wet weather that a practical forecasting system has been developed.

The fungus attacks all young tender parts of the plant. Young forming pods are highly susceptible. If infection on young pods is extensive, they wilt, shrivel, and gradually die. If the infected area is slight to moderate, as the beans continue to develop they bear one or more irregular patches of white, woolly or feltlike mycelium and fruiting structures (pl. 8, A) or sometimes most of the pod is covered. A purplish border may separate the healthy green tissues from the diseased area. The fungus may penetrate the pod and infect the beans.

Optimum temperature for radial growth of the fungus on oatmeal agar was 68° F. No growth occurred at 41° or 86°. Zoospore production, needed for infection, was best at 50° to 59°; zoospore germination and germ-tube elongation increased as the temperature was increased from 50° to 77°, but they decreased at 86°.

Unless affected pods are accidentally included in the pack, the chances of finding downy mildew on lima beans during marketing are remote. Downy mildew has not been observed to develop during transit on beans that appeared sound when packed, nor to spread from diseased to healthy pods during an 8- to 10-day favorable holding period at 50° to 75° F.4

(See 25, 30, 67, 70, 102, 189.)

**Pod Blight**

*Diaporthe phaseolorum* (Cke. & Ell.) Sacc.

Pod blight of the lima bean occurs along the Atlantic seaboard and in the Southern States. Occurrence of the disease is correlated with hot, rainy weather. Pod blight starts as a leaf spot in the field and later spreads to the pods. The disease generally does not become serious on the pods until the plants are nearly full grown. Young pods are rarely affected.

In the early stages the lesions appear as reddish-brown, circular or oval spots (pl. 9, A). They may occur anywhere on the pod, but there

* Unpublished data of Marguerite S. Wilcox and L. P. McColloch of this Division.
is a tendency for them to develop around the edges of the pod. Eventually the lesions become studded with minute gray pimplelike elevations that may be arranged in concentric patterns. These small structures soon break the skin of the pod and emerge as black pustules or fruiting bodies (pycnidia) (pl. 9, B). In pods that are severely affected or that have large lesions centered over the seeds, the fungus may penetrate the pod and damage the seeds. Affected beans may show small brown spots, or if more severely affected, the entire seed may be discolored and shrunked. Lesions may coalesce until the entire pod is affected and becomes covered with pycnidia.

Losses from pod blight are generally not extensive because the disease affects the pods late in the season, and pods may show numerous small spots without affecting the seeds. The market price may be depressed more by the unsightly pods with lesions than by the quality of the beans. However, appreciable losses may be experienced during seasons when weather conditions favor disease development. Lima beans should be cooled quickly to 32° to 36° F. and maintained at that range if quality is to be maintained. At those temperatures pod-blight lesions will not develop nor will established lesions enlarge. However, if the beans are allowed to warm to 60° or above, the disease may develop. The fungus enters through wounds, and under favorable conditions the first symptoms of disease appear about 4 days after inoculation.

Pod blight is of field origin. The fungus is known to be seed borne, but since the disease does not occur where the seed crop is grown, commercially produced seeds should be free of the disease. It appears that the pathogen is carried over the winter by other means. For further information on control measures, consult the State agricultural experiment station or extension service.

(See 63, 189.)

**Seed Spotting**

*Cladosporium herbarum* (Pers. ex Fr.)

Shelled green lima beans frequently develop a fungus spotting during marketing that greatly reduces their value or may cause complete loss. A species of *Cladosporium* that flourishes in the field on dead or dying plant material causes the spotting. The seeds are contaminated with the fungus during shelling, and spotting follows if temperature and moisture conditions are favorable. Superficial brown spots 1/16 to 1/8 inch in diameter are produced on the seed coat (pl. 9, C). The spots enlarge and under humid conditions they become covered with the olive-green fungus. Eventually, the mold has a granular appearance because of the dense mass of spores, and the fungus penetrates the seeds (Cotyledons).

Shelled beans held for 4 to 6 days at 50° F. or above may develop superficial mold due to such fungi as *Rhizopus, Penicillium*, and *Fusarium* but without any relationship to the brown spotting caused by *Cladosporium*.

Shelled green lima beans are very perishable and quality is difficult to maintain. Refrigeration is the best method of preserving quality. In addition to preventing fungus spotting, proper refrigeration slows
the conversion of sugar to starch, a chemical process which causes lima beans to lose quality and become hard and starchy.

A temperature of 40° F. will control spotting for about a week, but 32° is more effective in controlling spotting and in preventing the beans from becoming starchy. Shelled lima beans should not be held even under ideal conditions for more than a week.

Washing the pods in a 4-percent solution of calcium hypochlorite before shelling controls fungus spotting, but refrigeration is needed to prevent starchiness. (See 15, 78.)

**Seed Stickiness**

A number of soil-inhabiting bacteria may cause a sticky condition on the surface of shelled green lima beans during marketing. Research on this problem, however, showed that *Pseudomonas ovalis* (Ravenel) Chester, *Achromobacter coadimatum* (Wright) Bergey et al., and an organism similar to *A. lipolyticum* (Huss) Bergey et al., are the most common causes of stickiness. These organisms are present on the pods and contaminate the beans during shelling. Favorable temperature and moisture permit the bacteria to multiply on the surface of shelled lima beans and develop a sticky or slimy condition.

Prompt refrigeration at 32° to 40° F. is the best method of controlling stickiness. These temperatures also retard the development of starchiness in the beans.

Washing the pods in a 4-percent solution of calcium hypochlorite before shelling gives good commercial control of stickiness. (See 15.)

**Yeast Spot**

*Nematospora phaseoli* Wingard

Yeast spot was reported on the seeds of lima beans in 1922. It is a field disease that enters the pods through insect injuries. Small-seeded varieties are especially susceptible. The disease has been of importance in the Southeastern States and has been reported as far north as Minnesota and Illinois and west to Oklahoma.

The pods show no external evidence, as only the seeds are affected. Seeds may be attacked by the yeast at any stage. Those infected before they are half grown are most seriously damaged. Slight infection may arrest seed development and reduce yield. Active infection produces dark-brown, irregular, sunken areas (pl. 9, D). The seedcoats may remain unbroken, but in some crater-like lesions the seedcoat is ruptured and the affected tissues appear grayish brown and granular.

The organism grows best at temperatures of 77° to 86° F. and ceases to grow at about 65°. Infection from inoculations were successful only when the pods were punctured. Insects have been most often associated with the spread of the disease, but the relationship has been shown to be entirely mechanical.

The use of new varieties of lima beans, together with improved control of insects, appears to be effective in the control of yeast spot. (See 173, 174.)
SNAP BEANS

The pods of the wax and green-podded varieties of the common bean (*Phaseolus vulgaris* L.) are marketed for table and processing purposes. Marketability of snap beans is determined primarily by tenderness, crispness, good color, and freedom from blemishes and decay. Toughness, stringiness, and poor color are usually due to overmaturity. Too long a period between harvesting and consumption, however, may cause similar deterioration. Lack of crispness, especially of immature pods, is due to wilting because of loss of moisture.

There are several field diseases of beans that seriously curtail yield, but do not affect the pods directly. The size and quality of pods may be indirectly affected, however, by such diseases as fusarium root rot (*Fusarium solani* (Mart.) Appel & Wr.), virus diseases, leaf spot diseases (*Cercospora canecens* Ell. & G. Mart., *Cercospora cruenta* Sacc., and *Phylllosticta phaseolina* Sacc.), ozonium root rot (*Phytophthora omnivorum* (Shear) Dug.), ashy stem blight (*Macrophomina phaseoli* (Maubl.) Ashby), root knot (*Meloidogyne* spp.), and root rot (*Thielaviopsis basicola* (Berl. & Br.) Ferr.)

Diseases that occur in the field but may also be found during the marketing of snap beans are anthracnose, bacterial blights, bacterial wilt, powdery mildew, sclerotium rot, soil rot, cottony leak, virus diseases, and rust. Plants and pods also may be affected with heat injury or sunscald.

There are a number of diseases that rarely cause losses in the field but may be important during the marketing of snap beans. Such diseases are bacterial soft rot, gray mold rot, watery soft rot, rhizopus rot, and russetting.

**Anthracnose**

*Colletotrichum lindemuthianum* (Sacc. & Magn.) Scrib.

Anthracnose, a disease of worldwide distribution on snap beans, can occur in any of the moist areas of production in the United States. For many years anthracnose was one of the most serious diseases in the production and marketing of snap beans. At that time much of the seed used for growing beans east of the Mississippi River was grown in Michigan and New York. Conditions there were favorable for the anthracnose fungus, and infected seed distributed the disease to other moist areas. Infected seeds saved from locally grown crops also perpetuated anthracnose.

The first symptoms of anthracnose on pods are minute, oval or circular greenish-brown specks, which later become brick or rust red to black around their borders as they enlarge (pl. 6, A). The spots may range in size from specks to areas one-half inch in diameter. As the spots enlarge, their centers sink and become dark. Under moist conditions the centers become covered with flesh-colored dots of fungus spores, which later may run together in a slimy mass. Under dry
conditions the spore clumps dry down to a gray, brown, or black granular surface or to black pimplelike bodies.

Since the fungus is seed borne, anthracnose can be prevented by planting disease-free seed. Snap beans grown in the Rocky Mountain and Western States are free of anthracnose because of the dry climate. This affords a reliable source for anthracnose-free bean seed. The use of anthracnose-free seed has been so effective in controlling the disease that this disease has not been reported on marketed beans for more than a decade.

(See 189.)

**Bacterial Soft Rot**

*Erwinia carotovora* (L. R. Jones) Holland

Snap beans under transit conditions are affected less frequently with bacterial soft rot than most other vegetables. However, soft rot may follow bacterial blight or some of the fungus rots.

While the causal organism is not always able to enter sound pods through the unbroken epidermis, it may enter through tissues weakened by wounding, aging, sunscald, or freezing. Pods become more readily infected when they are wet and warm. The organism causes a slimy, somewhat watery rot accompanied by a putrid odor.

Prompt cooling to about 45° F. and maintaining a temperature range of 45° to 50° during transit and marketing will control bacterial soft rot or hold it to a minimum.

**Bacterial Wilt**

*Corynebacterium flaccumfaciens* (Hedges) Dows.

Bacterial wilt of beans has been reported from widely separated areas, but the exact distribution of the disease is unknown. Serious losses have been reported in some years since 1946 in Colorado and Wyoming. The disease is seldom found, however, on snap beans during marketing. Bacterial wilt occurs in some of the same localities as common and halo blight, and because of the similarity of certain symptoms these diseases may be confused. In general, however, the typical symptoms of each serve to distinguish the diseases.

The seed-borne bacteria furnish the primary source for field infection. The bacteria move through the vascular system, and if the plant survives, the pods and seeds become diseased. Some pods bearing infected seeds appear normal, but others show dark green, watersoaked, elongated spots on the suture to which the seeds are attached. These lesions develop from infected vascular tissues, which die and turn brown. The circular, watersoaked spots, which are typical of common and halo blight, do not occur on pods affected by bacterial wilt. Pods seriously affected by the wilt organism, especially immature ones, tend to wither. The bacteria may enter the hilum of the seed and form yellow masses of bacteria under the seedcoat, or they may multiply on the surface of the seeds and form small, yellow, crustlike deposits.

No resistant bean varieties are known, and the principal means of control is by the planting of disease-free seed. Prompt cooling to
about 45° F., and maintaining a temperature range between 45° and 50° during marketing are recommended.

(See 66, 189.)

**Cottony Leak**

*Pythium butleri* Subr.

**Occurrence, Symptoms, and Effects**

Cottony leak is a fungus disease of beans that may occur wherever beans are grown. High temperatures and heavy rainfall are necessary to initiate the disease. Such weather conditions often occur in most bean-producing areas at some season. For example, cottony leak may become a problem in Florida from April until the end of the shipping season in June; at times it occurs in the fall; but it is not a problem during the winter months. Cottony leak, often misidentified as watery soft rot, is one of the most serious diseases of beans after harvest. If the disease is present on beans at harvest they rarely remain free of the rot during marketing even though precautions are taken to pack apparently sound beans and to use proper refrigeration. Because of this hazard to quality, the price of affected lots is markedly reduced.

Cottony leak usually starts where bean pods were in contact with the soil. The abrasive action of the soil usually damages the cuticle and some browning of affected areas occurs. In the early stages of the rot the typical watersoaked condition may occur in normal tissues or in the browned area described above. At temperatures between 75° and 90° F. decay develops rapidly and white cottony mycelium is produced profusely (pl. 6, G).

Infection of healthy beans in the pack through contact with a mycelium occurs readily, and the mat of mycelium binds the pods together to form a “nest” of decay. Decayed beans are soft and watery and that condition together with the mass of white fluffy mycelium has prompted the term “cottony leak,” a name well established for this kind of decay on many vegetables.

Cottony leak is most similar in appearance to watery soft rot, caused by *Sclerotinia sclerotiorum* (Lib.) DBy. (see p. 30), but the two diseases may be separated by the following characteristics: The cottony leak fungus is of fine texture, and is pure white and fluffy when fresh. The fungus never produces sclerotia or resting bodies. The watery soft rot fungus, in contrast, has coarser, slightly grayish mycelium, which soon produces conspicuous, hard, brown to black sclerotia.

**Causal Factors**

Several species of *Pythium* such as *P. butleri*, *P. ultimum* Trow, and *P. myriotylum* Drechs. attack bean plants and are able to cause a soft rot and nesting of inoculated pods, but only *P. butleri* has been isolated from naturally infected bean pods.
Control Measures

The presence of cottony leak at harvest presents a hazard in keeping the beans sound during marketing. Invisible infection makes their keeping quality unpredictable. Beans should be dry when harvested, and precautions should be taken to keep them as cool as possible during harvesting and packing. All pods showing watersoaked spots should be discarded during packing. Best control follows if beans are pre-cooled, but not hydrocooled, to at least 50° F. as quickly as possible after harvest and then the recommended temperature range of 45° to 50° maintained during marketing. Infection can occur at temperatures between 54° and 96°. If the beans are permitted to warm much above 50° and moisture condenses, the disease will probably develop on pods with incipient infection and spread to other pods. Beans from diseased fields should not be shipped long distances nor stored, but should be moved rapidly through nearby marketing channels.

(See 32, 33, 64, 86, 126, 189.)

Gray Mold Rot

Botrytis cinerea Pers. ex. Fr.

The Botrytis fungus is present in all of the humid regions where snap beans are grown. Gray mold rot could become a problem following prolonged periods of cool, wet weather. Under normal weather conditions and under present marketing practices, however, this is not a serious disease of snap beans.

Infection may occur through weakened, dead, or wounded tissues. Decayed tissues are soft and watery but not mushy. Affected areas are watersoaked or pale brown, and under moist conditions smoky-colored mycelium soon develops (pl. 6, D). In advanced stages the mycelium may produce granular-spore masses typical of the fungus.

Mosaics and Other Virus Diseases

Snap beans are subject to a number of virus diseases that dwarf, disfigure, and interfere with normal plant function. The curly top virus may kill young bean plants; other viruses prevent pod setting. All virus diseases greatly reduce yield.

The symptoms of these virus diseases vary due to such factors as age and variety of plant, genetic composition, strain of virus, environment, and degree of severity of the disease. Irregular dark-green areas on the pods that appear watersoaked, in contrast to the grayish green of normal areas on the same pod, cause the mottled appearance typical of the symptoms of certain viruses. Pods that are mottled, malformed, or lumpy or have many irregular, sunken areas generally may be suspected of having a virus disease.

All virus diseases of snap beans develop in the field. Affected pods will be found during marketing only if they are overlooked during sorting and packing.

Although common bean mosaic, bean yellow mosaic, and curly top are considered the most prevalent of the virus diseases in the production of snap beans, with the exception of common bean mosaic, pods
affected by these viruses are usually not found on the market. More likely to be found are pods affected by southern bean mosaic, two strains of common bean mosaic, pod mottle, and pod-distorting mosaic. This is not because of the greater abundance of these virus diseases, but because the pods are more generally affected without becoming actually spoiled. Although the four virus diseases that follow are treated separately, their symptoms on pods overlap and visual identification cannot be made.

**Southern Bean Mosaic**

Southern bean mosaic occurs in such widely separated areas as Louisiana, Illinois, California, Maryland, Mississippi, Georgia, Colorado, and Idaho.

The pod symptoms are quite striking. Seriously affected green-podded beans show irregular shaped, dark green, watersoaked areas intermingled with normal gray-green areas, producing a strongly mottled appearance (pl. 7, B). The pods are also malformed.

**Common Bean Mosaic**

Greasy pod is a descriptive name applied to beans affected by a strain of the common bean mosaic virus. The disease occurs wherever beans are grown, and the pods are most severely affected during periods of high temperatures in the field.

The disease is characterized by shiny or greasy appearance of the pods because of a lack of pubescence on the affected areas. The symptoms are similar to those of southern bean mosaic.

Another strain of common bean mosaic was found in Florida in 1961 (pl. 7, A). The virus is different from other strains of common bean mosaic. Symptoms on pods are also distinct from the types of mottling found on pods affected by other bean mosaic viruses. Instead of the usual irregular mottled areas, there is a strong tendency for the pattern to follow long, fairly broad, stripes of normal and affected tissues. Absent also is the greasy or watersoaked condition of the affected areas.

**Pod Mottle**

Pod mottle is a relatively new disease, first described in 1945. Information on its distribution is limited, but the virus has been obtained from beans grown in South Carolina, Illinois, and Florida.

Pod symptoms are similar to those of southern bean mosaic, but the symptoms of pod mottle are more pronounced. Affected pods are often malformed, showing either abnormal curvature or a constriction at points between seeds. The most obvious symptom, however, is the striking mottled appearance. Affected areas are dark green, and watersoaked, with a glassy appearance, and somewhat sunken in contrast to the normal gray-green tissues (pl. 7, C, D).

Many varieties of green-podded bush and pole snap beans are commercially resistant.
Pod-Distorting Mosaic

The pod-distorting mosaic virus is a strain of bean yellow mosaic. The distribution of bean yellow mosaic and its strain are not definitely known. Although the disease occurs in widely separated areas, it is seldom found in the Southern States.

As the name implies, affected pods are distorted and malformed, having irregular, rough, warty areas. Pod distortion and malformation are much more pronounced than those symptoms induced by other viruses. Mottling of the pods, however, is not nearly as pronounced as it is on beans with pod mottle, greasy pod, or southern bean mosaic. No variety is resistant to bean yellow mosaic.

(See 7, 8, 55, 62, 69, 73, 137, 185, 186, 187, 188, 189.)

Powdery Mildew

Erysiphe polygoni DC.

Powdery mildew of beans is a disease of major importance in the field. It occurs in the Southern States on the fall crop and is prevalent along the Pacific coast every year on snap and lima beans.

In severe outbreaks the pods often develop the disease. In the earliest stages of the disease the fungus may be found in the spots on the pods. When the fungus disappears, affected areas are yellowish to reddish brown. Seriously affected pods may be twisted and malformed. Severe infections result in spots of dead, discolored tissues, which may be somewhat sunken. Generally, however, infection is mild and causes a reddish-brown speckled to fringed discoloration, which is superficial and has indefinite margins.

E. polygoni, the cause of the disease, is representative of a large group of parasitic fungi. It draws its nourishment from its host by haustoria attached to the leaf, stem, or pods. Two types of reproductive bodies are produced: (1) conidia or summer spores and (2) ascospores borne in perithecia. The latter are rarely found on beans. Spores will germinate and germ tubes will penetrate at quite low humidities. It has been shown that low soil moisture tends to result in more severe damage to infected plants. This disease is of minor importance in snap beans on the market. For field control, consult the State agricultural experiment station or extension service.

(See 28, 103, 182, 189.)

Rhizopus Soft Rot

Rhizopus stolonifer (Ehr. ex Fr.) Lind, and R. tritici K. Saito

Rhizopus soft rot may be serious on beans if they are held under moist conditions and high temperatures after harvest.

Under such conditions Rhizopus causes a soft watery rot. The fungus soon develops a coarse, white stringy mycelium, which later turns gray and bears glistening, white spherical spore-filled heads (sporangia) that soon turn black. The coarse mycelium (whiskers) spreads from diseased to sound beans resulting in a nest of decayed pods.
Rhizopus fungi may cause decay at temperatures of 54° to 96° F., but most decay develops at 80° to 85°. Rhizopus rot therefore is not a problem if beans are maintained at the desired temperatures of 45° to 50° F. after harvest.

(See 86.)

**Russeting**

Russeting is a physiological disease of beans that should not be confused with the term “rust,” a universally accepted name for a fungus disease of beans. Russeting is characterized by the death of surface cells anywhere on the pod, which then become rusty brown to chestnut brown (pl. 7, E). Browned areas are irregular in shape and without definite margins, but they sometimes occur as short, narrow somewhat parallel areas suggesting streaks. The dead tissues are usually not sunken and are not highly subject to infection by decay organisms.

Russeting, as found during the marketing of beans, is basically a form of chilling injury; however, it is increased by keeping the beans wet. The disorder is brought on by holding beans for several days at 32° to 40° F. Different lots of beans vary somewhat in susceptibility to russeting. In general, however, beans held at 32° to 40° F. for 5 days or longer develop russeting when removed to temperatures of 70° to 80°. In one experiment with freshly harvested beans, russeting was not apparent on beans held 7 days at 36° to 40° as they were removed from storage, but was discernible on those held 9 days. After the beans were removed to room temperature, russetting developed in 24 hours on all lots held 5 days or longer at 36° to 40°. The severity of the disorder increased as the storage period at low temperatures was increased.

To be useful, the term “russeting” should be reserved for the condition caused by low but nonfreezing temperatures, as previously described. The term has been frequently misused to include conditions such as aging in the field, sunscald, wind and sand scarring, and scarring caused by the powdery mildew fungus. The similarity of some of these disorders makes an accurate use of the term “russeting” difficult. In general, however, the other disorders are either rare enough or different enough to make the restricted use of russeting practical.

For example, if pods are left attached to the plants well beyond the time of prime maturity, they may develop symptoms typical of russeting. Since such beans never reach the market no problem of identity is involved.

Another condition often mistakenly identified as russeting is sunscald, which has certain characteristics quite distinct from those of russeting. (See Sunscald, p. 30.) For example, sunscald occurs on only one side of the pod; the tissues are first watersoaked, then usually become sunken; and the color is a redder brown than that of russetting.

Beans are occasionally affected by wind and sand scarring. The damage occurs over the pod as in russeting, but the damaged area appears chafed and the brown tissues are a duller color than that in russeting.

Beans affected with powdery mildew become discolored and the disease is at times mistakenly identified as russeting. Where powdery mildew is common, some pods with early stages of the disease will be
found with the white powdery fungus on the surface of the pods overlying discolored tissues. When the white powdery fungus is rubbed away, a reddish-brown discoloration is exposed. In general, the pods show some sunken areas and are more speckled than pods affected with russetting.

The true russetting of beans can be controlled by holding them at the proper temperature. Beans should never be transported or stored at 40°F or below. The recommended transit temperature for snap beans is a range of 45°F to 50°F. After reaching the market, beans should not be held any longer than is necessary to get them through the wholesale and retail channels. And during that time they should be held at 45°F.

During retailing at temperatures of 45°F to 50°F, beans can be safely sprinkled with water without the hazard of russetting, unless they have been previously held for several days at temperatures below 45°F.

(See 91.)

Rust

_Uromyces phaseoli_ (Reben) Wint. var. typica Arth.

Rust is a fungus disease of beans that occurs throughout the world wherever weather conditions are favorable. The critical factor is moisture. A relative humidity of about 95 percent for a period of 8 to 10 hours or more is necessary for extensive infection. At times rust causes serious losses in the field, even crop failure. Although rust is a production problem at times, pods are so rarely affected that there is little chance of the disease reaching the market. Rust pustules on the pods are similar to those on the leaves. They start as small brown spots and later appear as rusty-brown pustules. The pustules are from $\frac{1}{16}$ to $\frac{3}{8}$ inch in diameter and show typical slits and feathering over the surface.

For field control, consult the State agricultural experiment station or extension service.

(See 189.)

Sclerotium Rot (Southern Blight)

_Sclerotium rolfsii_ Sacc. (Pellicularia rolfsii (Curzi) West)

Sclerotium rot or southern blight is a disease of vegetables in the southern tier of States. In general, the disease on snap beans is of minor importance after harvest. Sclerotium rot has at times, however, been observed on beans following periods of hot, wet weather. Pods mostly affected were those that had been in contact with the soil. The decayed area appears watersoaked without much change in color of the pod. Under warm, moist conditions, the coarse white mycelium makes characteristic fan-shaped patterns of growth over the decaying pods and causes a nest of decay. Typical mustard-seed-like sclerotia soon form in the mycelium. The sclerotia are spherical and in a few days turn brown. White fan-shaped patterns of mycelium and the sclerotia are striking symptoms of this disease.
At temperatures of 60° F. or above, the decay spreads rapidly from diseased pods to surrounding beans. Infection does not occur, however, at temperatures below 46°. Consequently, this disease can be held in check by quickly cooling beans to the desired temperatures of 45° to 50° and maintaining that range.

(See 86, 189.)

Soil Rot (Rhizoctonia Pod Rot)

Rhizoctonia solani Kuehn (Pellicularia filamentosa (Pat.) Rogers)

Occurrence, Symptoms, and Effects

Soil rot may occur on snap beans and lima beans wherever they are grown. The main losses from soil rot are during long distance shipment, especially beans shipped from the Gulf States during the warm spring and early summer months. The soil-rot fungus attacks various parts of the bean plant, including the pods, in the field. Initial infection usually occurs at the point where pods were in contact with the soil. Soil rot during marketing develops from incipient infections that were invisible when the beans were packed or from the inclusion of beans with active lesions that were overlooked during sorting and packing.

Soil rot starts as small rusty-brown to brown lesions anywhere on the bean pod. Lesions may be numerous or single in number. The decayed areas are irregular in shape and without definite margins. As the spots enlarge, the affected tissues may become soft and brown, or they may dry out and become roughtened and chocolate brown often surrounded by rust-colored tissues (pls. 6, C, and 8, E). Under some conditions, large lesions may show concentric zone markings. The above description is typical of the symptoms of soil rot as usually observed on beans during marketing. Under moist conditions with inadequate refrigeration, however, the surface mycelium is stimulated and grows over and infects healthy pods that are near the diseased beans. In a few days the mass of decayed pods may be bound together by the mycelium to form a nest of decay.

Causal Factors

Soil rot is caused by the fungus *Rhizoctonia solani* whose perfect stage is *Pellicularia filamentosa*. It is a common inhabitant of many soils. The fungus, which is parasitic on many vegetable crops, flourishes during warm wet weather. Although infection can occur at a wide range of temperatures, the fungus grows very slowly at temperatures of 45° to 50° F., the range recommended for transporting and holding beans.

Control Measures

Beans harvested from fields where the soil rot fungus is flourishing will probably develop some decay during marketing. Beans from affected soil should be carefully sorted to exclude pods with lesions from the pack. The beans should be dry when packed and should be
promptly cooled and maintained at temperatures of 45° to 50° F. This temperature range will prevent the development and spread of the disease during a normal transit period of 7 or 8 days, but will not necessarily prevent the development of some lesions on pods after they are unloaded and exposed to moist warm conditions. (See 86.)

**Sunscald**

Snap beans may develop sunscald during periods of intense sunlight following several days of cloudy weather if the beans are unduly exposed to the sun. Pods may become exposed because of changes in position of the plants or because of loss of some of the leaves. Heat is more penetrating under moist than under dry conditions, and beans develop more sunscald when the soil is wet or when the humidity is high.

Affected areas are first seen as tiny reddish-brown spots on the exposed surface of the pods. In slightly affected areas the reddish-brown spots become reddish-brown streaks running diagonally across the pod. Seriously damaged pods may develop a watersoaked condition followed by a complete death and browning of the affected tissues, which later lose moisture and become sunken.

In the early stages some of the watersoaked lesions resemble lesions of bacterial spot and bacterial blight but lack the greasy exudate that often is present in bacterial blight lesions.

The symptoms of beans slightly affected by sunscald and those with russetting are sometimes difficult to distinguish. Sunscald occurs only in the field and only on one side of the pod, but may be slightly delayed in producing symptoms. Russeting, as found on the market, occurs after the beans have been harvested, and may occur anywhere on the pod. (See Russeting, p. 27.) Pods seriously affected by sunscald have relatively large, sunken, dark, reddish-brown areas, which are not evident on those affected by russeting. (See 189.)

**Watery Soft Rot**

*Sclerotinia* spp.

The *Sclerotinia* fungi are soil-inhabiting organisms that are widely distributed. The watery soft rot disease produced by these fungi frequently cause serious losses in snap beans following cool, moist weather. The disease is most damaging in the fall crop of beans grown in the Middle Atlantic States, in the later winter and early spring crops in the Southern States, and in the crop grown in the moist areas of the Pacific Northwest.

Although infection may take place through wounds or through old or weakened tissues, wounds are not necessary. Badly diseased pods may be sorted out at harvest, but those with incipient infections carry the disease to beans packed for market. Incipient infections may develop into active decay. Under favorable conditions the mold spreads from pod to pod enmeshing the beans to produce the so-called nests of decay in containers during transit and during holding at the market.
One or more lesions of various shapes and sizes may occur anywhere on pods. Affected areas are first watersoaked but may later develop a pale tan color. Decay develops rapidly at room temperature. White mold, either cottony or somewhat appressed, usually accompanies decay (pl. 6, E). At a certain stage of development the fungus forms resting bodies known as sclerotia (pl. 6, F), which are the most important diagnostic feature in advanced decay. The sclerotia are white as they form, but at maturity they are black and hard.

Tests showed that extensive development of watery soft rot on inoculated beans required temperatures of 70° to 80° F. for a short period or 42° to 51° for about 2 weeks. Infection required 9 days at 42°, 7 days at 47°, and 4 days at 54°. Spread of the rot to other beans required 5 days at 60° to 81° and 11 to 15 days at 42° to 51°. The rot develops slowly at moderately low temperatures. Beans that develop extensive watery soft rot during a 4- to 8-day transit period at recommended temperatures may have had active, but unapparent, lesions at time of harvest.

Snap beans are subject to chilling injury and should not be held below 45° F. Beans harvested from crops with active watery soft rot should be cooled quickly to the desired transit and holding temperatures of 45° to 50°. Although these temperatures will permit some development of watery soft rot during a period of 8 days or longer, the development of the fungus will be slowed and should prevent decay for periods up to 5 days. Beans should be dry when harvested. To hold losses to a minimum, they should be moved through the marketing channels without delay. Avoid slow cooling, long-distance shipping, and storage of beans after they reach the market.

(See 86, 121.)

**PEAS**

The common garden or green pea (*Pisum sativum* L.) is a member of the pulse family. The processing of green peas for canning and for freezing is a very important industry in a number of States. The acreage of green peas grown for the fresh market, however, has declined from 13,730 acres in 1954 to 4,550 acres in 1964. The marketability of peas depends chiefly upon the pods being fresh, green, well-filled, and free from blemishes and decay, as well as upon the tenderness and flavor of the seeds.

Many diseases and growing conditions affect the market quality of peas either directly or indirectly. Seedling diseases, root rots, and wilts, caused by various fungi, may kill plants outright or so reduce their vigor that both the quantity and the quality of marketable peas are affected. Similar effects may be caused in the field by root knot nematodes, *Meloidogyne* spp. Several diseases directly affect both the vines and pods, as pod spot (ascoscyta blight) and bacterial blight. Of lesser importance, but occasionally serious when seasonal conditions favor the growth of the pathogens, are septoria blight, powdery mildew, anthracnose, and downy mildew. The occurrence of mosaics and other virus diseases of peas is increasing; these diseases adversely affect the yield and quality of peas. On the market, bacterial soft rot, gray mold rot, rhizopus rot, and watery soft rot are the most serious diseases.
Anthracnose

*Colletotrichum pisi* Patterson

Anthracnose has been reported from Connecticut, Georgia, Iowa, Maine, Minnesota, Texas, Wisconsin, and Louisiana, but in general, it has not become a serious disease. Extensive losses have been reported only in Wisconsin in certain years.

This is a fungus disease that may attack the leaves, stems, and pods. Anthracnose has rarely been found on peas after harvest.

Anthracnose appears similar to “pod spot” caused by another fungus. The anthracnose spots on pea pods, however, are more circular in shape and larger than those caused by the “pod spot” fungus. Anthracnose spots also have pale centers with dark brown margins (pl. 9, F). Well-developed spots under moist conditions have yellow to salmon-color wet spore masses. Even if fungus spores are present, anthracnose will not develop on pods that are properly refrigerated to maintain the temperature as near 32° F. as possible.

(See 74, 112.)

Bacterial Blight

*Pseudomonas pisi* Sackett

Bacterial blight occurs in many States but is much more common east of the Continental Divide than west of it. At times it causes serious losses. Blight is most severe when humidity is high.

On pods the bacterial blight pathogen causes watersoaked, irregularly shaped, slightly sunken spots, which may be small to large (pl. 8, F). In some cases the bacteria may spread through the pods and infect and discolor the seeds. The high percentage of infected pods sometimes found on the market probably results from small lesions present at packing time, or from infections starting through wounds incurred during harvesting or packing. The lesions present at time of shipment may enlarge somewhat during transit, but it is not known whether any new infections take place.

Effective control measures are not known. The use of disease-free seed offers the best means to avoid bacterial blight. Peas should be held at a temperature as near to 32° F. as possible during marketing.

(See 184.)

Downy Mildew

*Peronospora pisi* Syd.

The downy mildew fungus requires cool, moist weather for serious disease development on peas. Such conditions occasionally prevail wherever peas are grown, but downy mildew is of economic importance only along the moist, foggy coastal areas of California, Washington, and Oregon. Under these favorable conditions the disease is often widely spread by the time the peas are blooming. Pod infection, which is the most serious feature of the disease, occasionally reaches 35 to 40 percent, and losses during marketing often range from 10 to 20 percent.

On the pods downy mildew is characterized by slightly raised, irregular patches that become yellowish then gradually change to
brown. The fungus, while not usually present on the surface of the pods, often grows on the interior of the pods. Immediately below the surface blotches the white mycelium flourishes and oospores are produced in the tissues. Under certain conditions, not understood, the disease appears to stimulate the proliferation of cells on the inner surface of the pods to form white tufts of feltlike tissues. The proliferation is usually, but not always, present in pods affected with downy mildew. It cannot be used as a diagnostic symptom, however, because proliferation is sometimes found in healthy pods.

Diseased pods that reach the market are those that were overlooked during sorting and packing. No control measures are effective after harvest.

(See 21, 142.)

Gray Mold Rot

*Botrytis cinerea* Pers. ex Fr.

Gray mold rot may occur wherever peas are successfully grown because conditions favorable for the production of peas are also highly favorable for the development of the *Botrytis* fungus. Pods carry the fungus spores on the surface at the time of harvest. More than a week is required for the disease to develop from spores on the surface of the pods at temperatures below 40°F. Gray mold rot is at times a problem on peas shipped long distances. Losses during transit in cars requiring inspection have averaged about 2.5 percent. Gray mold rot may develop also on peas held on the market at about 40°F. Most of the losses from gray mold rot occur during retailing, especially if peas have moved slowly through the marketing channels.

Gray mold rot starts as small, watersoaked spots, which gradually enlarge and become grayish buff in color. Under favorable conditions, a pale gray mycelium develops on the surface of the pods (pl. 8, D). Later, the mycelium becomes brownish and in time it is covered with small clusters of spores, which give the surface a strikingly distinct, granular appearance.

Gray mold rot is generally not a problem during transit or brief holdings if the temperature is maintained near 32°F. Only sound pods should be packed and shipped, and if the season is favorable for the *Botrytis* fungus to develop in the field, special precautions should be taken for prompt and adequate refrigeration and speedy marketing.

(See 170.)

Mosaics and Other Virus Diseases

Peas have a number of virus diseases, mostly classed as mosaics, that may greatly affect yield. Some viruses disfigure the pods, and a variety of symptoms occurs. Pods that are affected early fail to form seeds; those affected later form seeds but show symptoms on the surface of the pods. Viruses are of field origin and are found on pods during marketing only when overlooked during sorting and packing. In general, virus diseases are not important during marketing.

The following is a brief account of certain virus diseases that disfigure the pods.
**Enation Mosaic**

Enation mosaic is a widely distributed disease that can cause serious losses in peas. The most severely affected vines fail to set pods, but less affected plants produce pods that are rough, ridged, or variously distorted.

The common pea mosaic and bean yellow mosaic viruses also cause malformation of the pods but not to the extent of enation mosaic.

**Pea Streak**

Pods that are well formed before the plant is seriously affected by the pea streak virus become purplish-gray or brown. In general, pods are spotted, pitted, and seriously malformed.

**Spotted Wilt**

The spotted wilt virus has been reported on certain vegetable crops from widely separated areas in the United States. Although spotted wilt may occur on peas wherever there is a reservoir of the virus, there is probably little occurrence outside of California. Even there spotted wilt seems of little importance on peas grown for the fresh market.

On the pods spotted wilt is characterized by irregular brown patterns with concentric markings.

(See 24, 132, 184.)

**Pod Spot**

*Ascochyta* spp.

Pod spot (known on pea plants in the field as ascochyta blight), may occur throughout the commercial production areas in the eastern United States. Free moisture, in the form of rains and dew, is needed to promote the disease; consequently, peas grown in the arid Western States rarely develop pod spot. Occurrence of pod spot after harvest depends on the extent of the disease in the field, on favorable conditions for the disease to develop after harvest from incipient infections, and on the care in sorting out diseased pods during packing.

Three separate species of *Ascochyta* can cause the pod spot disease. *Ascochyta pisi* Lib. affects the leaves, stems, and pods; *A. pinodes* L. K. Jones, attacks leaves, stems, pods, and roots; and *A. pinodella* L. K. Jones, attacks mostly the roots, but does, at times, cause leaf and pod spots. The most striking difference in the life history of these three species is that the ascigerous (sexual) stage has been found for *A. pinodes* and is designated as *Mycosphaerella pinodes* (Berk. & Blox.) Vest. Although the symptoms on the pods produced by the different species are somewhat different, they are not sufficiently distinct to be treated as separate diseases.

Lesions typical of those commonly seen on pods grown along the east coast are more or less circular and range from ¼ to ⅜ inch in diameter. These spots are usually sharply depressed with a dark margin and a pale tan to pinkish center (pl. 9, E).

Spots caused by certain other of the *Ascochyta* fungi are usually not sunken; they are ⅛ inch or less in diameter and range from dark
brown to black. The fungus penetrates the pods and seeds. Affected pods held under moist conditions develop black pimplelike bodies that issue quantities of spores.

With the production of seed peas concentrated in the arid regions of the United States where pod spot rarely occurs, this disease on the market has probably been reduced from major to minor importance.

The development of lesions from incipient infections can readily be prevented by the prompt cooling of peas after harvest to 32° F. and the maintaining of that temperature during marketing.

(See 47, 51, 76, 184.)

Scab

\textit{Cladosporium pisicola} Synd.

Pea scab has been reported in California, Maine, Oregon, Texas, Utah, and Washington. This is caused by a fungus that may attack foliage, stems, and pods in the field. All varieties of \textit{Pisum sativum} L. are susceptible to infection. Moist weather and temperatures of 70° to 72° F. are optimum conditions for the spread of the disease in the field. Its presence after packing indicates the lack of thorough sorting.

The disease on the pods is characterized by dark brown or black, irregular, raised, scablike spots that may occur in large numbers. Seed infections appear as small blisters or brown and black lesions (pl. 9, G) that, in advanced stages, become sunken and covered with greenish-powdery spores.

(See 143.)

PARSLEY FAMILY

The parsley (\textit{Umbelliferae}) family includes several food plants eaten for their flavor and food value, such as the carrot (\textit{Daucus carota} L.), celery (\textit{Apium graveolens} var. \textit{dulce} (Mill.) Pers.), celeriac (\textit{A. graveolens} var. \textit{rapaceum} DC.), parsnip (\textit{Pastinaca sativa} L.), and finocchio (\textit{Foeniculum vulgare} var. \textit{dulce} (Mill.) Fiori). The seeds and leaves of certain other members of this family are used principally for flavoring and garnishing. These include anise (\textit{Pimpinella anisum} L.), caraway (\textit{Carum carvi} L.), parsley (\textit{Petroselinum crispum} (Mill.) \textit{Nym.}), and dill (\textit{Anethum graveolens} L.).

CARROT

For the most part the fresh market is supplied with carrots that are pulled before they are fully grown. Some of these are marketed with their tops on, but most carrots are topped and packaged in ventilated plastic bags. The incidence of diseases in packaged carrots depends upon the prevalence of organisms on the surface of the roots, upon relative humidities, and upon temperatures high enough to stimulate infection and decay. Carrots for processing and some others that are grown to a large size are stored either in refrigerated or common storage from 1 to 5 months.

In the field the aerial parts of the carrot plant are subject to a number of diseases. Among these are bacterial blight (\textit{Xanthomonas carotae}
Leaf blights caused by *Cercospora carotae* (Pass.) Solhi., and *Alternaria dauci* (Kuehn) Groves & Skolko, and mosaic and yellows virus diseases. (See Celery, Mosaics and Other Virus Diseases, p. 50.)

The principal diseases of carrot roots in the field are bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland), black rot (*Stemphylium radicinum* (Meier et al.) Neerg.), which attacks older leaves and under moist conditions may invade roots at the crowns, crown rot (*Pellicularia filamentosa* (Pat.) Rogers), root knot (*Meloidogyne* spp.), southern blight rot (*Pellicularia rolfsii* (Curzi) West), and watery soft rot (*Sclerotinia sclerotiorum* (Lib.) DBy.).

Scab (*Streptomyces scabies* (Thaxt.) Bergey et al.) rarely attacks carrot roots. In Canada, violet root rot (*Rhizoctonia crocom/m* (Pers.) DC.) has been reported on roots in the field. Roots may be injured in the field by several insect larvae, mainly wireworms (chiefly *Limonius* spp.) and the carrot rust fly (*Psila rosae* F.).

The most prevalent diseases of stored carrots are gray mold rot, watery soft rot, black rot, rhizoctonia rot, fusarium rot, rhizopus soft rot, and bacterial soft rot. Black mold and sour rot occur occasionally on prepackaged carrots. Fungus rots less frequently found in carrots stored under refrigeration than in common storage are licorice rot (*Oentrospora acerina* (Hartig) Newhall), brown crown rot (*Pellicularia filamentosa* (Pat.) Rogers), crater rot (*Rhizoctonia carotae* Rader), rubbery brown rot (*Phytophthora* spp.), rubbery slate rot (*Pythium* spp.).

Bitterness sometimes develops in stored carrots. Off-flavors result when carrots are stored with apples; the bitterness results from exposure of the carrots to ethylene given off by the apples. Bitterness also occurs in carrots affected with the aster yellows virus.

(See 6, 14, 16, 56, 104, 120, 152, 153, 165, 169.)

**Bacterial Soft Rot**

*Erwinia carotovora* (L. R. Jones) Holland

Bacterial soft rot was a serious problem when carrots were shipped with tops on, because the bacterial organism often caused decay of the foliage and the soft rot frequently spread to the roots. In the mid-1960's most carrots for the fresh market were topped, prepackaged, and handled under proper refrigeration. Bacterial soft rot rarely occurred under these conditions.

Stored carrots and parsnips, especially those held in common storage, may develop bacterial soft rot if temperatures are allowed to rise much above 40°F. The roots may become infected anywhere, but decay frequently develops at the crown and proceeds rapidly down the core. Lesions usually have a grayish to brownish color. Decayed tissues appear watersoaked (pls. 10, A, B, and 12, A) and are soft and watery. Later they become slimy and usually have a putrid odor.

Bacterial soft rot is not a problem in carrots or parsnips stored at temperatures of 32 to 36°F.

(See 16, 34, 104, 120.)
Black Mold

Thielaviopsis basicola (Berk. & Br.) Ferr.

Since the advent of prepackaging, a number of shipments of western-grown carrots with blemishes caused by a black surface mold have been received on eastern markets. The roots had black, irregular spots, which were scattered indiscriminately over the surface (pi. 11, A, B) and ranged in size from $\frac{1}{8}$ to $\frac{3}{4}$ inch. The mold usually affected only the skin, but some carrots had a dark-gray discoloration of the underlying tissues to a depth of less than $\frac{1}{16}$ inch. An apparently similar disease has been reported in Holland.

The evidence indicates the fungus Thielaviopsis basicola was able to develop on carrots because of the combination of high humidity within the polyethylene bags and the higher than desirable temperatures developed in transit and during marketing. Adequate precooling before carrots are bagged and good refrigeration in transit and during marketing will control black mold.

(See 13, 42.)

Black Rot

Stemphylium radicinum (Meier et al.) Neerg.

Occurrence, Symptoms, and Effects

The black rot fungus occurs in widely separated areas. The fungus attacks the older leaves of plants and at times the growing roots in the field. In general, however, the black rot disease occurs as a rot of topped, stored carrots. The disease is destructive in the North-eastern and North Central States where carrots are stored.

Black rot may occur anywhere on the fleshy roots. Lesions on the sides of the roots are circular to irregular with sharp margins (pi. 10, C). They are usually slightly depressed and shallow and have greenish-black to black, dry, mealy tissues. Under moist conditions, the decay penetrates deeper and affected tissues are soft and wet (pi. 10, D). Decay at the crown usually penetrates rather deeply into the core. Black mold produced by the fungus may or may not be present on the surface of decayed areas.

In storage, injuries caused by black rot open the way for more rapid decay-producing organisms such as Botrytis cinerea and Sclerotinia sclerotiorum.

Causal Factors

Black rot is caused by the fungus Stemphylium radicinum. The fungus is seed borne, but it may also overwinter in the soil on dead plant material. The fungus may infect roots directly from the soil, or infection may occur from infected tops. The prevalence of black rot lesions on the sides of the roots shows that the crown is not necessarily the pathway for infection from diseased leaves. Most carrots at harvest probably carry spores of this fungus on their surfaces.
Under favorable conditions these spores may infect the carrots mostly through broken root tips, dying rootlets, or other wounded tissues. The fungus can infect carrots at temperatures between 31° and 93° F.; the optimum is 82°. There is no relation, however, between this optimum and the occurrence of the disease during storage. Black rot is a serious storage problem because the fungus can grow at low temperatures; and although it is a moderately weak pathogen, it can cause decay during several months' cold storage.

Control Measures

Use care during harvesting and handling to hold mechanical injuries to a minimum. Store and cool carrots promptly and maintain the temperature as near 32° F. as possible. Avoid fluctuating temperatures and prolonged storage. (See 16, 54, 84, 100, 104, 109, 120.)

Crater Rot

*Rhizoctonia carotae* Rader

Crater rot has caused serious losses in cold storage houses in western New York and in Illinois. The decay is first evident as small pitted spots having a whitish mold. The pits later enlarge into brown sunken craters lined with a white to cream-colored mold. The brown craters vary from 1/4 to 1 inch in diameter and from 1/8 to 1/2 inch deep (pl. 11, D). Decayed tissues beneath the surface lesions are light brown, usually firm and dry. With high humidity the fungus may spread over entire root surfaces and cause a firm decay unlike the crater rot symptoms described above. During several months' moist storage the fungi causing gray mold rot and watery soft rot may invade old craters on the roots and cause secondary decay.

Crater rot does not appear until 1 to 2 months after storage. Once the disease starts it seems to progress rapidly and in 2 to 3 weeks at 32° F. may render carrots worthless. The fungus spreads from infected to healthy roots, and may even spread to roots in adjacent baskets. The fungus is apparently a soil inhabitant and infects only carrots. It has been found to cause most decay in cold storage houses where the relative humidities exceed 95 percent.

Measures to control crater rot are rigid sorting to cull out field-infected roots; use of new or disinfested storage containers; prompt cooling and maintenance of a temperature near 32° F. and a relative humidity near 95 percent, but avoiding surface moisture on the roots. (See 119, 120, 125.)

Fusarium Rot

*Fusarium* spp.

Various species of the fungus *Fusarium* cause a shallow, spongy, occasionally brownish decay of carrots in storage. Lesions occur at the crown or sides of roots, usually at the site of injuries. A sparse white mold may develop in infected tissues and on the surface.
Ordinarily, decayed roots are not found until after several months’ storage. The disease apparently seldom occurs if storage temperatures are below 46° F. Often fusarium rot is followed by bacterial soft rot or gray mold rot.

_Fusarium_ species have been isolated on the market from fresh table carrots having lesions typical of the scab complex.

The control of _fusarium_ rot in storage depends upon avoidance of mechanical injuries during harvest and handling, rapid cooling, and storage at temperatures about 32° F.

(See 16, 85, 104, 120.)

**Gray Mold Rot**

_Botrytis cinerea_ Pers. ex Fr.

Gray mold rot may occur occasionally in the field following cold, wet weather or following frost injury. It is seen most frequently on carrots in cold or common storage. Gray mold rot is not a problem on bunched or topped prepackaged carrots.

Affected tissues are watersoaked, spongy, and light brown (pl. 10, G). Lesions occur anywhere on the roots, usually at the site of injuries. Whitish-gray, later grayish-brown, mold and granular spore masses, develop on the lesions. In long storage and especially under humid conditions sclerotia may develop (pl. 10, H). The rot spreads (nests) in storage. Gray mold may become serious on stored carrots in 3 to 4 months, especially if the carrots are wet and temperatures of 38° to 42° F. are maintained.

Gray mold can be reduced by careful handling, prompt cooling, storing of carrots at 32° F., maintaining a relative humidity near 95 percent, and preventing surface moisture.

(See 16, 85, 104, 120.)

**Rhizopus Soft Rot**

_Rhizopus spp._

_Rhizopus tritici_ K. Saito, _R. stolonifer_ (Ehr. ex Fr.) Lind, _R. arrhizus_ A. Fisch., and _R. oryzae_ Went & Geerl., cause soft rot of carrots. This disease is of minor importance, but can become a problem in common storage if the temperature rises above 40° F. frequently. The disease is unimportant on carrots marketed promptly for fresh use or on those held in refrigerated storage.

The lesions have a brownish, watersoaked appearance (pl. 11, C), and the decayed tissues are soft and watery. The early stages of decay are distinguished from those of bacterial soft rot by the presence of the fungus threads. These threads can readily be demonstrated by gently pulling apart the decayed tissues. In later stages of decay the coarse white mycelium (whiskers) of the pathogen can be found growing over the surface of the lesions.

(See 85, 120.)
Root Knot

*Meloidogyne* spp.

Root-knot nematodes cause knots or galls on many plants, including carrots and parsnips. Root knot occurs more frequently on plants grown on sandy soils than on heavy soils, and its development is favored by warm climates. Some species of root-knot nematode occur, however, in the Northern States so that losses may occur wherever carrots and parsnips are grown. The exact distribution of root knot on these crops is not known. The disease is of minor importance on the market because most affected roots are discarded during packing.

Early infestation may cause branched, poorly developed taproots. In later infestations the taproot is well developed, but has numerous galls over the surface, especially in the areas of secondary rootlets. This gives affected roots a rough, lumpy or knotty appearance (pl. 12, B).

For information on control measures, consult the State agricultural experiment station or extension service.

(See 16, 57.)

Scab Spot Complex

Scab spot of carrots is a physiological disease the cause of which appears to be related to climatic, nutritional, and genetic factors. The disease has caused considerable loss of carrots grown in California, Arizona, Texas, Massachusetts, and perhaps other States.

In the original description the cause of the disease was attributed to the bacterium *Xanthomonas carotae* (Kend.) Dows. and the disease was named bacterial blight. Some years later the same disease was studied by others, and the cause was found to be physiological. Although several bacterial and fungal organisms were isolated from the scab lesions, these organisms were not the cause of the disease. However, these organisms, as secondary invaders, contributed to the range of symptoms found on carrots affected by scab spot.

Carrots affected by scab spot at an early stage may later show one or more pockets of black necrotic tissues covered by normal tissues. They may also develop sharp constrictions encircling the roots at the point of damage. Lesions most frequently occur at or near the lateral rootlets (pl. 10, E, F). They may be few or numerous, separate or coalesced. In the early stages lesions are brown to maroon and may be raised. Later the lesions may crack and become sunken or contain fragments of soil and necrotic tissues and appear black and scablike. Practically all lesions are elongated laterally.

Recent investigators have found that varieties of carrots with abnormal oil production are apt to develop lesions. The abnormal physiology results from the interaction of a certain genotype with peculiar climatic conditions. The disease is also aggravated by low levels of nutrition.

(See 5, 52, 56, 58, 165.)
SOUR ROT

Geotrichum candidum Lk. ex Pers.

Sour rot, caused by the fungus *G. candidum*, occasionally develops in bulk and prepackaged carrots. The disease has been observed on carrots from the major producing areas that supply the fresh market. Infections occur under humid conditions, in wounds or weakened tissues, such as broken root tips and dying rootlets, of carrots that have not been adequately refrigerated. Carrots in film packages in which moisture has condensed after removal from refrigeration, often decay if held 2 or 3 days at 68° F. or above.

The decayed tissues are colorless, soft, and watery and have a pronounced vinegary odor.

Careful handling, precooling, and refrigeration at 32° F. after packing are recommended.

(See 778.)

WATERY SOFT ROT

Sclerotinia sclerotiorum (Lib.) DBy.

The *Sclerotinia* fungus is a widely distributed soil organism. The occurrence of watery soft rot after harvest is largely dependent upon the presence of the active disease at harvest.

The greatest hazard to carrots destined for storage exists if the weather at harvest is cool and rainy, making conditions favorable for the development of the fungus. Stored carrots may develop the rot even at recommended temperatures in refrigerated or common storage during a period of 3 to 5 months. Decay may make rapid progress in storage if moisture condenses on the carrots. The decay is ordinarily not important in carrots for fresh use.

The symptoms of watery soft rot of carrots are watersoaking and softening of decaying tissues. An important diagnostic characteristic in the advanced stages of decay is the presence of the white fluffy to appressed mold of the fungus (pl. 11, E). In later stages of decay sclerotia of the causal organism may be formed in the mold growth. Sclerotia are white at first, then bluish, and finally black.

Carrots from fields affected with watery soft rot should be carefully sorted at harvest and processed within 30 days of storage. Carrots should be stored at temperatures as near 32° F. as possible, and the relative humidity should be maintained at about 95 percent. Proper measures should be taken to avoid the condensation of moisture on carrots in storage.

(See 121.)

CELEY

Celery (*Apium graveolens* L.) is grown for its leafstalks. The celery plant consists of a short thickened stem or crown on which are borne the fibrous root system below and the succulent leafstalks above. Celeriac (*Apium graveolens* var. *rapeum* DC.) also known as turnip-rooted celery, is a form in which the leaves are borne on a thickened, turniplike crown that is the edible part of the plant.
The marketability of celery is determined primarily by tenderness, crispness, and color, and freedom from blemishes and decay. Tenderness is determined to a great extent by the variety, the local growing conditions, and the weather during the growing season. Lack of crispness is due to wilting because of shortage of moisture during the period of growth, harvest, transportation, or storage.

Most of the diseases affecting the celery plant not only occur in the field but are of direct importance on the market either as blemishes or as decays of the leaves or the leafstalks. These include bacterial soft rot \((Erwinia carotovora\ (L. R. Jones) Holland)\), early blight \((Cercospore apii Fres.)\), late blight \((Septoria apiicola\ Speg.)\), brown spot \((Cephalosporium apii\ M. A. Smith \& Ramsey)\), virus diseases, bacterial blight \((Pseudomonas apii Jagger)\), black heart, cracked stem, freezing injury, crater spot \((Pellicularia filamentosa\ (Pat.) Rogers)\), watery soft rot \((Sclerotinia spp.)\), gray mold rot \((Botrytis cinerea \ Fr.)\), and root rot \((Phoma apiicola Kleb.)\).

Bacterial soft rot and gray mold rot are primarily transit and storage diseases.

**Bacterial Blight**

*Pseudomonas apii Jagger*

Bacterial blight has been reported from New York and a number of other Northern States following periods of warm rainy weather. This disease occurs only on celery and, in general, is of minor importance as a market disease. The principal symptoms are the development of numerous irregular to circular spots on the leaflets. At first these are yellow, later turning to a rusty-brown with a yellow bordering halo around them. When the halo is not present the spots could be mistaken for early or late blight infections. However, celery plants with bacterial blight never show the ashen-gray mold typical of early blight nor the black fruiting bodies that eventually develop on late blight spots.

(See 35, 72.)

**Bacterial Soft Rot**

*Erwinia carotovora\ (L. R. Jones) Holland*

**Occurrence, Symptoms, and Effects**

Bacterial soft rot is a serious market disease that attacks a wide variety of vegetables. The disease may occur wherever vegetables are grown. It can be destructive both in the field and during marketing. Affected shipments of celery are always reduced in value and in some shipments heavy losses occur.

The first symptoms of decay are small spots of soft watersoaked tissues, which may occur on any part of the celery stalk. The decay usually progresses rapidly. On the leaflets the tissues may be completely destroyed, resulting in a soft wet rot that is usually not discolored. On the petioles the decay penetrates deeply as the spots enlarge, and there is a gradual change from the watersoaked appearance to a pale brown color. Decayed tissues are wet and mushy (pl.
Bacterial soft rot, of course, has none of the coarse mycelium in the decayed tissues such as that present in rhizopus soft rot nor any surface mold such as that usually accompanying watery soft rot. Ordinarily, bacterial soft rot of celery lacks the offensive odor that is associated with that rot on tomatoes and certain other vegetables.

Causal Factors

Bacterial soft rot of celery and other vegetables is caused by *E. carotovora*. The bacteria are soil borne and will live on plant debris or other organic matter. The disease is always more severe following rains and hot weather just before harvest. The organism requires wounded or dead tissues in order to establish decay. Under warm moist conditions bacterial soft rot readily develops following such diseases and injuries as early blight, late blight, brown spot, freezing injury, black heart, and mechanical injury. It is frequently destructive in celery that has not been refrigerated promptly after harvest or in storage. Contaminated tools or wash water are common sources of inoculum. Serious decay during transit and storage may result from early infections.

Control Measures

Control measures include the adoption of general sanitary practices around storage houses and during harvesting and packing operations. Care should be taken to avoid contamination by soft rot bacteria. The most important measure for the control of bacterial soft rot is that of temperature control during transit and storage. Celery should be cooled quickly after harvest and maintained at a temperature of 32° to 36° F. during marketing.

(See 20, 77, 87, 129.)

Black Heart

Occurrence, Symptoms, and Effects

Black heart, a physiological disease of celery, occurs wherever the crop is grown commercially. The occurrence of black heart varies from season to season, but the greatest losses are reported in California and Florida.

Because of new control measures, black heart has been less prevalent since about 1953. The disease continues to occur, however, and is considered fairly important during marketing.

Typical black heart affects only the heart leaves of celery. In the field the first symptoms may appear suddenly as brown watersoaked lesions along the margins of the young heart leaves. This condition may spread to the entire heart leaves or may become arrested. Affected tissues become dry and turn black, which gives rise to the name “black heart.” Under favorable growing conditions young plants may recover from a slight condition, but the affected tissues do not recover. In general, plants are most susceptible as they reach maturity.
Typical symptoms of black heart during marketing are dead black tips, or entire leaflets of the heart leaves (pl. 15, A). In severe cases the petioles of the heart leaves may also be discolored. Black heart may be detected readily in stalks with sparse or spreading petioles. In tightly formed stalks, however, the petioles must be forced apart to locate diseased leaves. Occasionally, the outer leaves develop yellowed or chlorotic areas before the first symptoms of black heart appear. Undoubtedly, most celery that has black heart when it was packed. Black heart may become more serious during transit or on the market.

Bacterial soft rot organisms readily invade dead black heart leaves and under favorable conditions may cause soft rot both in the field and during marketing. (See Bacterial Soft Rot, p. 42.) Bacterial soft rot is entirely a secondary disease and is in no way connected with the cause of black heart.

Causal Factors

Through the years investigators have associated the development of black heart in celery with such factors as hot dry weather or unbalanced water relationships; heavy fertilization, excess nitrogen or potassium, or high soluble salts; low calcium; rapid growth; and over-maturity. Recently, lack of calcium has been shown to cause black heart.

Control Measures

Black heart is a field disease that may become more severe during marketing, but is in no way induced by postharvest treatment. The disease can be controlled by timely spraying in the heart leaves with calcium chloride or calcium nitrate at weekly intervals starting when the celery begins making rapid growth about 5 weeks before harvest.

Special care should be taken to avoid packing celery affected with black heart, for it is practically certain to develop bacterial soft rot in transit or after reaching the market.

Brown Spot

Cephalosporium apii (M. A. Smith & Ramsey)

The brown spot disease was first observed on celery from Colorado, and later from New York, Connecticut, Ohio, Canada, and England. In seasons when the average temperatures are high the brown spot disease is more severe and may cause severe spotting and streaking of stalks in the fields. These infections often open the way for secondary bacterial soft rot infections in storage and on the market.

The brown spot disease is characterized by irregular, tan to brown, shallow lesions one-eighth to three-fourths inch in diameter occurring on the inside and outside of petioles and on leaflets (pl. 14, C, D). Lesions are often so numerous that they coalesce to form areas one-half inch to one and one-half inches in length. Infection may also result in a curling or distorting of mature petioles.
The causal organism *C. apii* is a weak pathogen that is present in seedbeds and celery fields. The disease is generally more severe in the fields when the average temperature is about 75°F. The fungus grows in temperatures of 40° to 90° with the optimum at 75°.

Some plants bear incipient infections that may develop during transit or in storage. It is recommended that celery destined for the market be quickly cooled and maintained at about 32° F. during marketing. The use of resistant varieties has been shown to be effective in the control of the disease.

(See 89, 128, 133, 140.)

**Cracked Stem**

**Occurrence, Symptoms, and Effects**

Cracked stem, also known in another symptom phase as “brown checking” or “adaxial crack stem,” is a complex physiological disease of celery relating to boron deficiency. The disease has at times caused serious losses in Florida since 1924 and was first observed to be a problem in California in 1945. Cracked stem has also been reported along the eastern coast of the United States and Canada and in Michigan, Minnesota, and Oregon.

Cracked stem detracts from the appearance of celery, and if the disease is severe, greatly reduces the value of the celery or even makes it unmarketable.

In Florida in 1924 and in 1937, the term “cracked stem” was used for a severe condition on celery that occurred on the convex side of the petioles. In California the affected area was largely confined to the inside or concave side of the petioles and was called “adaxial crack stem” by some and “brown checking” by others. Both symptoms, however, occur in California and in Florida. At this time each of these symptoms is known to be caused by a boron deficiency or imbalance in relation to certain other nutrients. Therefore, the nomenclature can be simplified by using the original name of “cracked stem” to include both types of symptoms.

Cracked stem is a field disease and any symptoms that are found during marketing were present at harvest.

Symptoms of cracked stem may occur on the front or back side of celery petioles, separately or simultaneously, as well as on the branchlets. The inner petioles are more often affected than the outer ones. The first signs of cracked stem in the field are similar irrespective of the location on the petiole. These symptoms appear as small white flecks immediately below the epidermis. The affected tissues collapse and become light yellow. Healing then occurs between the dead and growing tissue forming a corky layer which is light brown to brown. Sometimes this condition remains unchanged, but generally the affected petioles elongate and transverse cracks develop through the corked areas giving them a distinct appearance. In cases of severe cracking on the back of the petioles, special elongated cells adjacent to the ribs are involved, and the cracked tissues curl back and turn brown (pl. 17, D). This characteristic is confined to cracks on the back of the petioles. Such obviously and seriously blemished
stalks would be culled in packing. Most of the cracked stem condition found on the market occurs as slight visible blemishes or as more serious blemishes obscured on the inside of the petioles.

The cracked stem condition in the suture or on the front of the petiole is a common type of symptom and is usually severe enough to be objectionable. In some cases the corked area has not become cracked. Generally, however, the petioles continue to elongate after the damaged tissues are corked over as described above, and transverse cracks develop in the corked area (pl. 15, B). Only corked, cracked lesions are found on celery after harvest.

**Causal Factors**

The complex of causal factors relating to cracked stem of celery involves the plant’s ability to obtain and utilize boron. The disorder can be induced by a direct deficiency of boron or by an imbalance between boron and certain other nutrient elements such as nitrogen, potassium, calcium, and sodium. Cracked stem has been reported on celery grown on a wide range of soil types, but is worst in celery grown on muck soil.

Cracked stem is much worse on celery that has received heavy fertilization. Low boron or high nitrogen and high potassium with low boron causes an increase in cracked stem. A threefold increase in potassium with a normal level of boron increased the incidence of cracked stem in California on the front of the petioles, but did not increase cracking on the back. In Florida the cracked and curled condition on the convex side of the petioles has been found to be related to an imbalance between calcium and boron. The “brown check” phase in the suture of the petioles, however, appears to be related to an imbalance involving nitrogen, potassium, sodium, and boron.

There is some indication that resistant varieties absorb more boron than susceptible ones.

**Control Measures**

Control measures for cracked stem must be applied during the planting and growing of the crop. General control measures include use of resistant varieties, reduction of nitrogen and potash applications, and application of boron either to the soil or as a foliar spray. Recommendations of the State agricultural experiment station or extension service should be followed.

(See 9, 40, 80, 82, 101, 118, 179, 180.)

**Crater Spot**

*Rhizoctonia solani* Kuehn (*Pellicularia filamentosa* (Pat.) Rogers)

A petiole spot disease known as crater spot caused by the *Rhizoctonia* fungus (*Pellicularia filamentosa*) has been reported on celery from California and Florida. In both localities the disease appears

---

*From correspondence and unpublished data of Howard W. Burdine, Florida Agricultural Experiment Station, Belle Glade, Fla.*
to be associated with excessive water in peat soil. Losses result when the outer petioles become so severely infected that they must be removed before marketing. The fungus appears to be of relatively little importance as the cause of storage decay.

The first evidence of the disease is seen on petioles that are in contact with the soil. The lesions first appear as tan to brown, ovoid, sharply delimited sunken areas on inner and outer surfaces of the fleshy petioles (pl. 14, E, F). The sunken nature of the lesions has given rise to the term “crater spot.”

The bacterial soft rot organism _E. carotovora_ often follows crater spot and has at times been considered to be the cause. Careful inoculation studies by Houston and Kendrick demonstrated _R. solani_ to be the pathogen. (See 68.)

**Early Blight**

_Cercospora aphii_ Fres.

Early blight, a foliage disease of celery, occurs in celery-growing areas all over the world. The disease detracts from the appearance of the celery and the lesions caused by it facilitate infection by soft rot bacteria. It frequently causes serious losses in California, Florida, New York, and Michigan, especially during periods of high temperature and abundant moisture. Severe blight may necessitate extensive stripping at harvest time.

The disease is caused by the fungus _C. aphii_, which is maintained between crop seasons on plant debris. Under favorable conditions spores carried by air currents, rain, or on the clothing of field workers may spread the disease to healthy plants.

The disease on the leaves appears as circular, pale-yellow spots, which enlarge rapidly and become brown (pl. 16, B). In moist weather the centers of old spots assume a gray cast due to the growth of the fungus. When present on petioles, lesions run lengthwise of the stalk. The lesions can generally be distinguished from those of late blight by the yellowish-gray color and by the absence of black fruiting bodies found in late blight lesions. The most favorable conditions for spore germination are moisture on the leaf surface and a temperature of 81° to 84° F. The optimum temperature for growth of the fungus is 77° to 86°, although it grows well between 73° and 86°.

When early blight is serious at harvest time, some stalks bearing disease lesions may be overlooked during packing and appear on the market. If infected celery is marketed, it should be cooled promptly to 32° F. and moved through the channels of trade as rapidly as possible. (See 81, 106, 150, 163.)

**Freezing Injury**

Freezing injury of celery can be readily recognized at harvest time by the flabby watersoaked condition of the leaves and leaf stalks. Frozen leaves, if not attacked by bacteria, dry out and become papery.
A second type of freezing symptom is the appearance of isolated sunken lesions on the leafstalks. The lesions are elliptical on the convex side and circular on the concave side of the stalk. The affected tissues soon turn brown, so that the lesions are very conspicuous. These types of injury are most often apparent at harvesttime and of little importance on the market.

Celery that has been only mildly or partially frozen and that has recovered without markedly conspicuous effects of the injury may be seen occasionally on the market. This slight injury may be recognized by a loosening of the epidermis, which can be detected by twisting the affected leafstalks. Then, as the epidermal layer rises in irregular corrugations, it will be seen that it has separated from the underlying tissues.

(See 167, 177.)

Gray Mold Rot

Botrytis cinerea Pers. ex Fr.

Although the Botrytis fungus occurs wherever celery is grown, gray mold rot is usually not a problem during the marketing of freshly harvested celery. In some years the disease has caused considerable loss of Florida-grown celery when cool, rainy weather occurred before and during harvest. In general, however, gray mold rot is confined to stored celery and is probably the principal cause of loss of celery stored longer than 4 weeks.

In tests at the recommended temperature of 32° F., gray mold rot caused about 2 percent loss in 3 to 4 weeks, 5 percent loss in 5 to 6 weeks, and 15 percent loss in 7 to 8 weeks. Gray mold rot caused nearly twice as much loss during the same periods at 38° as at 32°.  

Decay develops slowly at temperatures of 32° to 38° F. Lesions are first watersoaked and relatively firm. Although decay may develop in an irregular pattern, it tends to progress lengthwise along the petioles faster than across them. In advanced stages of decay, the skin becomes quite tender and slippery. The decayed tissues remain watersoaked for a long time at low temperature, but eventually change to grayish-buff (pl. 13, B). Under conditions favorable to the disease, masses of grayish-brown spores form, which give the surface a granular appearance.

Gray mold rot can be controlled on fresh celery by careful handling and prompt cooling to at least 40° F. after harvest. Transit temperatures should be 32° to 36°, and storage temperatures as near to 32° as possible. Gray mold rot may eventually develop in celery stored 4 weeks or longer, but the disease is greatly delayed at these temperatures. Only celery grown and harvested under conditions that favor its keeping should be stored.

*Unpublished data of Chester Parsons, Market Quality Research Division, Agricultural Research Service.*
Late Blight

*Septoria apiicola* Speg.

**Occurrence, Symptoms, and Effects**

Late blight is one of the serious diseases of celery; it also occurs on celeriac. The disease occurs wherever celery is grown. Although primarily a field disease, some new lesions may appear and old lesions change after harvest. After harvest the dead tissues afford a ready entrance for bacterial soft rot and watery soft rot organisms. Market losses also result from the greater amount of trimming required and in the less attractive appearance of the marketed product.

The first symptom on the leaflets is the formation of small yellowish or chlorotic spots. These change to brownish, grayish, or sometimes black. They may be few or numerous. If numerous, the spots may coalesce to form large areas of dead tissues. The shiny black pycnidia occur both on the dead tissues of the spots and also on green tissues surrounding the spots. The pycnidia develop abundantly and are scattered, although occasionally two or three may coalesce. On the petioles the spots are elongated and parallel to the petioles (pl. 14, A). The spots are without definite margins and are brown; they frequently coalesce to form larger areas. The pycnidia are mostly located on the older spots, but are occasionally found on tissues showing little discoloration (pl. 14, B).

**Causal Factors**

Following research published in 1932 the view was held that two types of late blight of celery existed: A small-spot form caused by *S. apiicola-graveolentis* and a large-spot form caused by *S. apiicola*. Of these the small-spot form was considered to be the more common in this country. *S. apiicola-graveolentis* was reported to differ from *S. apiicola* not only in the production of smaller spots but also in the production of diffusable pigment in culture media, production of spots with definite outlines, pathogenicity on petioles, and shape and size of pycnidia and spores.

Recent extensive studies of a worldwide collection of *Septoria* isolates from celery indicated, however, that only one species is pathogenic on celery. Fungus characteristics, such as ability to attack petioles and to produce pigment in agar, were found to be only of secondary importance. Pycnidial and spore shapes were found to be similar. Their dimensions varied, but the differences between individual isolates were small. The occurrence of the large-spot type of late blight of celery probably is largely dependent upon recurrent mutations of small-spot fungus types. Since *S. apiicola* has priority over other named species it probably should be accepted as the correct name.

**Control Measures**

Transportation, storage, and market losses can be reduced by the control of the disease in the field. However, if infected celery is mar-
keted it should be cooled promptly to 32° F. and moved through mar-
keting channels as rapidly as possible.
(See 26, 27, 29, 43, 43a, 93, 172.)

Mosaics and Other Virus Diseases

Cucumber mosaic, calico caused by either cucumber or alfalfa mosaic
virus, western celery mosaic, spotted wilt, and aster yellows are virus
diseases of celery that are prevalent in certain geographical locations.
In addition, there are several other virus diseases that occur less
frequently.

Since virus diseases develop in the field and most of the symptoms
have developed by harvest, affected plants are usually eliminated dur-
ing sorting and packing. Some symptoms of moderate degree may
escape the sorter, however, and get into the commercial pack. There
are also some symptoms that may either develop or become more pro-
nounced during transit or on the market.

Cucumber Mosaic

Cucumber mosaic occurs throughout the United States on a wide
range of unrelated plants. The virus is extremely variable. Three
strains of cucumber mosaic on celery have been named. The common
cucumber mosaic is probably found wherever celery is grown. The
southern celery strain of cucumber mosaic occurs mostly in Florida,
Cuba, and Puerto Rico, but has also been reported in New York. In
California a strain of cucumber mosaic virus that causes a more bril-
liant yellowing of affected leaflets than other strains is known as calico.
The yellow-mottle symptom of calico, however, may also be produced
on celery by the alfalfa mosaic virus.

The cucumber mosaic virus attacks the young plants in the field and
may produce a range of symptoms. The symptoms included here,
however, are those that may be found during marketing. Leaflets
may or may not be mottled, depending on the strain of the virus and
the time of infection. If mottled, the yellowed areas may be moder-
ately or brilliantly colored. Affected leaflets may be grayish green
and may be narrow and twisted. Some may have dark-green blister-
like areas. In severe cases of common cucumber mosaic, the petioles
show elongated brown areas. Petioles affected by southern celery
mosaic develop buff to smoky-brown sunken spots (pls. 15, C, and
17, C). The spots appear somewhat translucent and irregular in
shape, and may occur sparsely or in abundance. The vascular tissues
may also be discolored.

Western Celery Mosaic

Western celery mosaic is the most prevalent virus disease of celery
in California; it also occurs in Colorado. Apparently, the disease is
restricted to members of the Umbelliferae (parsley) family.

On the Utah types of celery the virus causes a green-light-green
mottling or vein banding with cupping and distortion of leaflets. If
plants are seriously enough affected, the petioles may lose moisture
and become flabby during transit or after reaching the market. Some stunting and horizontal spreading of petioles occur in seriously affected plants, but these would not be marketed.

**Spotted Wilt**

Spotted wilt may occur wherever celery is grown, but it is not a serious problem in any locality at this time.

The symptoms are mainly confined to the outer petioles. The older leaflets are the first to show signs of the disease. They develop numerous small yellow spots, which become necrotic. Areas of dead, brown tissues occur in the petioles and appear as sunken brown patches. Seriously affected plants are stunted and are not marketable.

**California Aster Yellows**

In the study of aster yellows in New York, the virus did not infect celery, although it was transmitted to related plants such as dill and anise. In later studies with the aster yellows strain in California, celery was found to be susceptible to the virus. The New York strain, however, infected only a small percentage of plants, which indicates that some strains are more infective than others. The disease is a problem in the production of celery in California; it also occurs in the Middle West.

Affected inner petioles are shortened and chlorotic and are bent and twisted as they intertwine giving the plant a contorted appearance (pi. 15, D). Outer stems are prematurely blanched, brittle, and often cracked. Affected leaflets are yellow.

**Control Measures**

Virus diseases are important on the market only when an attempt is made to market affected plants. For details on the control of virus diseases, consult the State agricultural experiment station or extension service.

*(See 41, 44, 117, 134, 135, 136, 144, 151, 164, 181,)*

**Pencil Stripe**

Pencil stripe of celery is a physiological disease that apparently occurs only in Florida. It is not a new disease, but little has been known about it until recently. Recent severe occurrences of pencil stripe probably coincide with the introduction of the celery selection Utah 52-70 into commercial production in Florida.

The narrow brown lines that characterize the disorder occur both on the petioles and their branchlets. The disorder, when present on the branchlets has been erroneously called “rust” by some growers, a term which should be reserved for the disease caused by the rust fungus.

---

7 From correspondence and unpublished data of Howard W. Burdine, Florida Everglade Experiment Station, Belle Glade, Fla.
Pencil stripe may start while the plants are in the seedbed, but usually the disorder develops during the last 3 weeks before harvest and is most pronounced during the last week that the plants are maturing.

Affected plants develop a brown pigment, which penetrates the tissues to the surface cells, along the vascular bundles. Long, narrow, brown lines parallel to the petioles form the basic characteristics of the pencil stripe disorder (pl. 16, C, D). Closely spaced horizontal checks composed of corky tissues may form across the brown lines as in certain symptoms of boron deficiency. This phase is not typical of the disorder, however. Although more research is needed to determine the complex cause of pencil stripe, present studies indicate that the disorder may be associated with high phosphate content of the soil. The disorder is most prevalent during December and January, but has been observed in June.

The original Utah strains are more homozygous than Utah 52–70 in their susceptibility to pencil stripe. Selected strains that appear to be resistant to the disorder are being tested.

**Phoma Root Rot**

*Phoma apiicola* Kleb.

Phoma root rot occurs in northern celery-growing areas in the United States. Celery and celeriac are the major hosts. Losses from phoma rot are sporadic and largely confined to the field. In several shipments, however, the disease has been responsible for approximately a 50-percent loss either in storage or on the market.

This decay is confined chiefly to the tissues of the crown, which are first bluish-green and later black. When the disease is severe, the affected tissues are usually completely disintegrated by secondary soft rot organisms. This rot is easily distinguished by its greenish color and less watery consistency from that caused by *Sclerotinia* sp.

Phoma root rot is caused by the fungus *P. apiicola*. The black fruiting bodies (pycnidia) of the fungus are formed in abundance over the decayed areas of the crown. Spores released from the fruiting bodies may be carried to healthy plants during washing and packing.

The optimum temperature for growth of the pathogen is within the approximate range of 61° to 68° F. The maximum temperature for growth is around 82°.

Although there is often no evidence of disease at harvesttime, the celery may bear incipient infections that will bring about decay in transit and storage. Celery from fields in which phoma rot has appeared should be cooled to 32° F. and marketed as promptly as possible. (See 10, 11, 107.)

**Pithiness (Hollow Stem)**

*Occurrence, Symptoms, and Effects*

Pithiness or "hollow stem" is a nonparasitic disease of celery that occurs wherever the crop is grown. Affected plants show no signs of the disorder on the surface, but the petioles readily collapse if pressed.
Pithiness may be characterized by the central tissues of the leaf stems being soft and spongy. This is caused by the death of large thin-walled cells in the central area of the petioles. Affected tissues dry out and become pithy, or the pithy tissues may collapse and result in a hollow stem (pl. 16, A).

Two types of pithiness are known. Hereditary pithiness affects all petioles and is present from an early stage of plant development. The other type of pithiness affects only the outer petioles. Plants affected by hereditary pithiness are a total loss. Those with only the outer petioles affected may be trimmed and marketed.

**Causal Factors**

Genetic pithiness is a dominant factor, and a few affected plants in the field of celery grown for seed can readily perpetuate that type of pithiness.

Physiological pithiness seems to follow if plant growth is temporarily arrested or if plants are allowed to become overmature before harvest or are held for a long period in cold storage.

The actual cause of pithiness is believed to be due to the translocation of carbohydrates from the outer petioles to the crown petioles. Moisture loss accompanies the loss of carbohydrates and causes the death of certain of the parenchyma cells in the center of the affected petioles.

**Control Measures**

The genetic type of pithiness can be readily controlled because the normal or nonpithy factor is recessive and pure recessive seed lines can be easily developed.

The physiological type of pithiness can be controlled by maintaining uniform growing conditions and by harvesting celery before it becomes overmature. The continued development of physiological pithiness in susceptible celery can be further controlled after harvest by proper refrigeration, to slow senescence of the plant, for a reasonable time during marketing. Prolonged storage at 32° F., however, should be avoided.

(See 38, 40, 59, 168.)

**Watery Soft Rot**

*Sclerotinia* spp.

**Occurrence, Symptoms, and Effects**

Watery soft rot of celery, also known as pink rot, attacks most of the vegetables crops and many other succulent plants. It is destructive not only in the field, but also in storage and transit.

The organisms are soil borne and may attack seedlings in the seedbed. The disease often appears as a basal crown rot in plants invaded in later stages of growth.

The symptoms of watery soft rot of celery on the market or in storage are watersoaking and softening of decaying tissues, which are
generally light-brown with a pinkish-brown border. There is no characteristic odor. An important diagnostic characteristic in the advanced stages of decay is the white more or less appressed growth of the fungus (pl. 13, C). In later stages of decay the resting bodies or sclerotia of the causal fungus are formed either over the surface or in cavities within the affected commodity. These are white at first, then bluish, and finally black.

**Causal Factors**

Watery soft rot may be caused by *Sclerotinia sclerotiorum* (Lib.) DBy., *S. intermedia* Ramsey or *S. minor* Jagger, but *S. sclerotiorum* is the species generally responsible.

Watery soft rot may be expected to develop in transit or storage in celery harvested from fields in which the *Sclerotinia* disease was prevalent, even though the crop appeared to be free of decay at harvesttime.

Wounds are not necessary for the entrance of the pathogen, but fresh wounds favor immediate infection and may result in an increased amount of decay. Each of the species of *Sclerotinia* has a wide temperature range for growth and for production of decay. Infection may occur at temperatures as low as 32° F. and as high as 82°. The optimum for infection is between 60° and 70°. Low temperature will retard the development and spread of decay in transit and storage but will not completely control it. During long storage periods, severe losses are frequently noted at temperatures between 32° and 45°.

**Control Measures**

Celery harvested from fields where the disease is serious should be cooled quickly and maintained at about 32° F. during marketing. For field control follow the recommendations of the State agricultural experiment station or extension service.

(See 23, 71, 116, 121, 146.)

**FINOCCHIO**

Finocchio (*Foeniculum vulgare* Mill.) frequently, but erroneously, called “anise” or “sweet anise” on the market is grown and marketed for the edible bulblike enlargement found at the base of the above-ground portion of the plant. The enlargement is formed by the compact and overlapping arrangement of the thickened leafstalk bases and appears as a well-branched fairly solid structure.

Few diseases have been reported on finocchio. On the market it has occasionally been found affected with bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland) and watery soft rot (*Sclerotinia sclerotiorum* (Lib.) DBy.).

**Bacterial Soft Rot**

(See Celery, Bacterial Soft Rot.)
PARSLEY

Fresh parsley consists of the leaves of the parsley plant (*Petroselimnum Crispmum* (Mill.) Nym.). The most common types appearing on the market are the "moss" or the "triple curl," marketed in bunches and used primarily for garnishing foods, and the rooted or turnip-rooted parsley, which is marketed as a long thin taproot with leaves attached. This latter type is used primarily for flavoring.

Diseases of parsley in the field include downy mildew (*Plasmopara nivea* (Ung.) Schroet.), root knot (*Meloidogyne* spp.), septoria blight (*Septoria petroselini* Desm.), leaf blight (*Stemphylium* sp.), and watery soft rot (*Sclerotinia sclerotionirum* (Lib.) DBy.). Bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland) and watery soft rot are the most serious transit and market disease of parsley. To keep parsley in a fresh, sound condition it should be cooled quickly after harvest and maintained at 32° to 40° F. and a relative humidity of 90 percent.

(See 90, 99.)

PARSNIP

The parsnip (*Pastinaca sativa* L.), like the carrot, is grown for its edible, fleshy taproot. The plants are allowed to mature in the field, and afterwards they are pulled and topped, and the roots usually stored before they are marketed.

Diseases that affect the foliage in the field include, among others, *Ramularia pastinacae* (Karst.) Lindr. & West, downy mildew (*Plasmopara nivea* (Ung.) Schroet.), *Cercosporas pastinacae* (Sacc.) Pk., and powdery mildew (*Erysiphe umbiliferarum* (Lin.) DBy.).

Field diseases of parsnip roots include parsnip canker (*Itersonilia perplexans* Derx), root rot (*Phoma* spp.), scab (*Streptomyces scabies* (Thaxt.) Waks. & Henrici), and watery soft rot (*Sclerotinia sclerotiorum* (Lib.) DBy.). Diseases of importance during transit, storage, and marketing are parsnip canker (*I. perplexans*), gray mold rot (*Botrytis cinerea* Pers. ex Fr.), bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland), bacterial brown rot (*Pseudomonas pastinacae* Burkh.), watery soft rot (*S. sclerotionirum*), and rots caused by *Fusarium* spp.

(See 19, 57, 58.)

Bacterial Soft Rot

(Pl. 12, A.) See Carrot, Bacterial Soft Rot.

Gray Mold Rot

(Pl. 12, D.) See Carrot, Gray Mold Rot.
**Parsnip Canker**

*Itersonilia perplexans* Derx

The fungus that causes parsnip canker has been found in a number of countries on various crops and weeds. It occurs naturally on parsnip, hollyhock, and sunflower. The fungus enters through broken rootlets into the edible roots or through wounds and injuries caused by insects. Infection of roots exposed in the field may also take place by airborne spores.

Greatest losses follow seasons with heavy rainfall. Parsnip canker may be one of the most destructive diseases of long-stored parsnips.

The lesions, which at first are slightly depressed and rust colored, later turn black. The affected area may consist of a few small lesions, which often enlarge until much of the root surface is covered. Infections occasionally are characterized by dark-brown to black ringlike areas on various portions of the roots (pl. 12, C). The disease has recently been observed on roots stored in polyethylene bags.

Careful handling and prompt storage at 32°F. are the best methods of controlling parsnip canker after harvest.

(See 22, 111, 145, 171.)

**Root Knot**

(Pl. 12, B.) See Carrot, Root Knot.

**LITERATURE CITED**

(1) Altstatt, G. E., and Smith, H. P.

(2) Anderson, P. J.

(3) Angell, H. R.

(4) Ark, P. A., and Barrett, J. T.


(6) Atkin, J. D., and Shallenberger, R. S.

(7) Baggett, J. R., and Fragill, W. A.

(8) Bain, D. C.

(9) Bardin, Roy.


(20) and Smith, W. L., Jr. 1949. Erwinia atroseptica and Erwinia carotovora. Phytopathology 39: 887–897.


(30) Cox, R. S., and Hyre, R. A.

(31) Davis, G. N., and Henderson, W. J.

(32) Drechsler, Charles.

(33) ———

(34) Dye, D. W.

(35) Dye, H. W., and Newhall, A. G.

(36) Elliot, Charlotte.
1930. MANUAL OF BACTERIAL PLANT PATHOGENS. 349 pp.

(37) Ellison, J. H.

(38) Emsweller, S. L.

(39) Evans, R. I.

(40) Foster, A. C, and Weber, G. F.

(41) Freitag, J. H., Aldrich, T. M., and Drake, R. M.

(42) Friedman, B. A., Barger, W. R., and Radspinner, W. A.

(43) Gabrielsson, R. L.

(43a) ——— and Grogan, R. G.

(44) George, J. A., and Richardson, J. K.

(45) Geraldson, C. M.

(46) ———

(47) Gilpatrick, J. D., and Busch, L. V.


(49) ——— Walker, J. C, and Larson, R. H.
(50) Goss, R. W.  
1940. THE RELATION OF TEMPERATURE TO COMMON AND HALO BLIGHT OF BEANS. Phytopathology 30: 258-264.

(51) Gould, C. J.  


(53) ——— and Kimble, K. A.  

(54) ——— and Snyder, W.C.  

(55) ——— and Walker, J.C.  

(56) ——— Zink, F. W., and Kimble, K. A.  

(57) Guba, E. F.  

(58) ——— and Young, R. E.  

(59) Hall, C. B., and Burdine, H. W.  

(60) Hancock, J. G., and Lorbeer, J. W.  

(61) Hanna, G. C.  

(62) Harrison, A. L.  

(63) Hart, L. L.  

(64) ——— and Whitney, W. A.  

(65) Hatfield, W. C., Walker, J. C., and Owen, J. H.  

(66) Hedges, Florence.  

(67) Heuberger, J. W., Cox, R. S., and Hyre, R. A.  

(68) Houston, H. R., and Kendrick, J. B.  

(69) Hungerford, C. W., and Dean, L.  

(70) Hyre, R. A., and Cox, R. S.  
1953. FACTORS AFFECTING VIABILITY AND GROWTH OF PHYTOPHTHORA PHASEOLL. Phytopathology 43: 419-425.
(71) Jagger, I. C.  

(72) ———  

(73) Johnson, J. C.  

(74) Jones, F. R., and Vaughn, R. E.  


(76) Jones, L. K.  

(77) Jones, L. R.  

(78) Kaufman, J., and Ceponis, M. J.  

(79) Kendrick, J. B., and Stevenson, E. E.  

(80) ———  

(81) Klotz, L. J.  

(82) Knott, J. E.  

(83) Krout, W. S.  

(84) Lauritzen, J. I.  

(85) ———  

(86) Hart, L. L., and Whitney, W. A.  

(87) Leach, J. G.  

(88) Lewis, G. D.  

(89) ———  

(90) ———  

(91) Lewis, W. E.  
MARKET DISEASES OF VEGETABLES

(92) LINK, G. K. K., and Bailey, A. A.

(93) LINN, M. B.

(94) LIPTON, W. J.

(95) LUTZ, J. M.

(96) MACHACEK, J. E.

(97) MANN, L. K., and LITTLE, T. M.

(98) MARLATT, R. B.

(99) McCLEINTOCK, J. A.

(100) MEIER, F. C, DRECHSLER, C, and EDDY, E. D.

(101) MIDDLETON, J. T., HALL, B. J., WEDDING, R. T., and KENDRICK, J. B.

(102) MILLER, P. R., and O'BRIEN, MURIEL.

(103) MOORE, W. D.

(104) MUKULA, J.

(105) MUNN, M. T.

(106) NELSON, R.

(107) NEWHALL, A. G.

(108) ———

(109) ———

(110) OGLIVIE, L., and HICKMAN, C. J.

(111) OLIVE, L. S.

(112) OU, S. H., and WALKER, J. C.

(113) PALO, M. A.

PERRY, B. A., and JONES, H. A.  

POOLE, R. F.  

PRICE, W. C.  

PURVIS, E. R., and RUPRECHT, R. W.  

RADER, W. E.  
1948. RHIZOCTONIA CAROTAE N. SP. AND GLOIOCLADIUM AUREUM N. SP., TWO NEW ROOT PATHOGENS OF CARROTS IN COLD STORAGE. Phytopathology 38: 440-452.

—-  

RAMSEY, G. B.  

—-  

—- and BUTLER, L. F.  

—- and HEIBERG, B. C, and WIANT, J. S.  
1946. DIPLODIA ROT OF ONIONS. Phytopathology 36: 245-251.

—- and SMITH, M. A.  

REDIT, W. H., and HAMER, A. A.  

RICH, A. E.  

RICH, SAUL.  

RICHARDSON, J. K.  

RIEMAN, G. H.  

ROSBURG, D. W., and JOHNSON, H. B.  

SCHROEDER, W. T.  

SEGALL, RALPH.  
MARKET DISEASES OF VEGETABLES

(142) SNYDER, W. C. 1934. PERONOSPORA Viciae and INTERNAL PROLIFERATION IN PEA PODS. Phytopathology 24: 1358–1365.
(144) ——— and RICH, SAUL. 1942. MOSAIC OF CELERY CAUSED BY THE VIRUS OF ALFALFA MOSAIC. Phytopathology 32: 537–539.
(155) ——— 1924. WHITE ROT OF ALLIUM IN EUROPE AND AMERICA. Phytopathology 14: 315–322.
(156) ——— 1925. TWO UNDESCRIBED SPECIES OF BOTRYTIS ASSOCIATED WITH NECK-ROT DISEASES OF ONION BULBS. Phytopathology 15: 708–713.
(158) WALKER, J. C.  

(159) ______  

(160) ______ and LARSON, R. H.  

(161) ______ and LINDEGREN, C. C.  

(162) ______ and MURPHY, A.  

(163) WELLMAN, F. L.  

(164) ______  
1934. Identification of celery virus 1, the cause of southern celery mosaic. Phytopathology 24: 695–725.

(165) WHITAKER, T. W., MacGILLIVRAY, J. H., MIDDLETON, J. T., and LANGE, W. H.  

(166) WHITEMAN, T. M.  

(167) WHITE-STEVENS, R. H.  

(168) ______  

(169) WHITNEY, N. J.  

(170) WLIANT, J. S., and BRATLEY, C. O.  

(171) WILKINSON, R. E.  

(172) WILSON, J. D.  

(173) WINGARD, S. A.  

(174) ______  

(175) WRIGHT, R. C.  

(176) ______ and LAURITZEN, J. I., and WHITEMAN, T. M.  
(177) ——— Rose, D. H., and Whiteman, T. M.

(178) Wright, W. R., Smith, M.A., and Beraha, L.

(179) Yamaguchi, M., Howard, F. D., and Minges, P. A.

(180) ——— and Minges, P. A.

(181) ——— and Welch, J. E.

(182) Yarwood, C. E.
1926. THE TOLERANCE OF Erysiphe polygoni AND CERTAIN OTHER POWDERY MILDEWS TO LOW HUMIDITY. Phytopathology 26 : 845–859.

(183) Zaumeyer, W. J.

(184) ———

(185) ——— and Goth, R.W.

(186) ——— and Harter, L. L.

(187) ——— and Thomas, H. R.

(188) ——— and Thomas, H. R.
1949. SHINY POD (GREASY POD) VIRUS AND ITS IDENTITY WITH THE BLACK ROOT VIRUS. Phytopathology 38 : 29.

(189) ——— and Thomas, H. R.
PLATE 1.—Asparagus diseases: A, Bacterial soft rot; B, fusarium rot; C, phytophthora rot; D, gray mold rot.
Plate 2.—Onion disease: A and B, Gray mold rot (Botrytis allii type); C and D, smudge; E, bacterial soft rot; F, purple blotch; G, smut.
PLATE 3.—Onion diseases: A, White rot; B, black mold rot; C, diplodia stain.
Plate 4.—Onion gray mold rot: A and B, *Botrytis allii* type; C, *Botrytis byssoida* type; D, *Botrytis squamosa* type.
PLATE 5.—Onion diseases: A, Ammonia injury; B, sour skin; E, translucent scales. Garlic diseases: C and D, Waxy breakdown; F, blue mold rot; G, black mold rot.
PLATE 6.—Bean diseases: A, Anthracnose; B, bacterial blight; C, soil rot; D, gray mold rot; E and F, watery soft rot; G, cottony leak.
Plate 7.—Bean diseases: A, A strain of common bean mosaic; B, southern bean mosaic; C and D, pod mottle; E, russetting.
PLATE 8.—Lima bean diseases: A, Downy mildew; B, halo blight; C, bacterial spot; E, soil rot. Pea diseases: D, Gray mold rot; F, bacterial blight.
PLATE 9.—Lima bean diseases. A and B, Pod blight; C, seed spotting; D, yeast spot. Pea diseases: E, Pod spot; F, anthracnose; G, scab.
PLATE 10.—Carrot diseases: A and B, Bacterial soft rot; C and D, black rot; E and F, scab spot complex; G, typical gray mold rot; H, advanced stage of gray mold rot showing surface mold and black sclerotia.
Plate II.—Carrot diseases: A and B, Black mold; C, rhizopus soft rot; D, crater rot; E, watery soft rot.
PLATE 12.—Parsnip diseases: A, Bacterial soft rot; B, root knot; C, parsnip canker; D, gray mold rot.
PLATE 13.—Celery diseases: A, Bacterial soft rot; B, gray mold rot; C, watery soft rot.
PLATE 14.—Celery diseases: A and B, Late blight; C and D, brown spot; E and F, crater spot.
Plate 15.—Celery diseases: A, Black heart; B, cracked stem; C, southern-celery mosaic; D, aster yellows.
Plate 16.—Celery diseases: A, Pithiness; B, early blight on foliage; C and D, pencil stripe.