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DISEASES OF CARROTS

BY J. G. BROWN

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF ARIZONA, TUCSON

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INTRODUCTION

Several diseases affect carrots, a crop that constitutes a small but important part of the vegetable acreage of Arizona. Certain diseases destroy the seedlings, or blight the mature plants, or decay the roots. Other diseases are less destructive but still affect the sale of the vegetable. Since about 90 per cent of the crop is marketed in bunches with tops attached, any disease that merely renders tops or roots unsightly detracts from the marketability of the crop, reduces the income, and thus becomes as important as the blights and rots. Some diseases of carrots mainly appear in the field; others develop in transit and storage; still others are limited to storage; a few may occur in any or all stages of production and marketing.

BACTERIAL BLIGHT AND SCAB
(Caused by *Xanthomonas carotae* (Kendrick) Dowson)

Bacterial blight of carrots, originally described (1)* from California, came to this laboratory in July, 1946, from the Salt River Valley—its first recognized appearance in Arizona. Shortly afterward carrots likewise infected came from Eloy and from a ranch in the upper Santa Cruz Valley. Later it was determined in numerous specimens from south Texas from a ranch that had reportedly sustained heavy loss from the blight. Samples of all lots of specimens, in different stages of growth from seedlings to mature plants, were cultured, the bacterial parasite isolated, healthy plants inoculated with the latter (Plate I), and the cause re-isolated from the carrot plants sickened with it.

SYMPTOMS

Bacterial blight of carrots may affect the plant in any stage of growth. On the seedlings (Plate II), the seed leaves (cotyledons) show yellow to white spots irregular in shape that appear on the margin or anywhere on the surface. The tips of the cotyledons often become yellow and later dark brown. Similar spots occur on the first true leaves. Yellow to brown spots that may eventually girdle the slender taproot result in the death of the root below the infected spot. In some cases the seedlings in an Arizona planting have been so extensively blighted that the entire field has been plowed under.

In mature plants bacterial blight affects the tops, flower clusters (2), and the roots (3). On the tops the bacterial parasite may attack a few leaf segments or the entire leaf. The infected parts turn brown to black (Plate I). When the infection originates

*Numbers in parentheses refer to literature affording further information and cited on the last page.

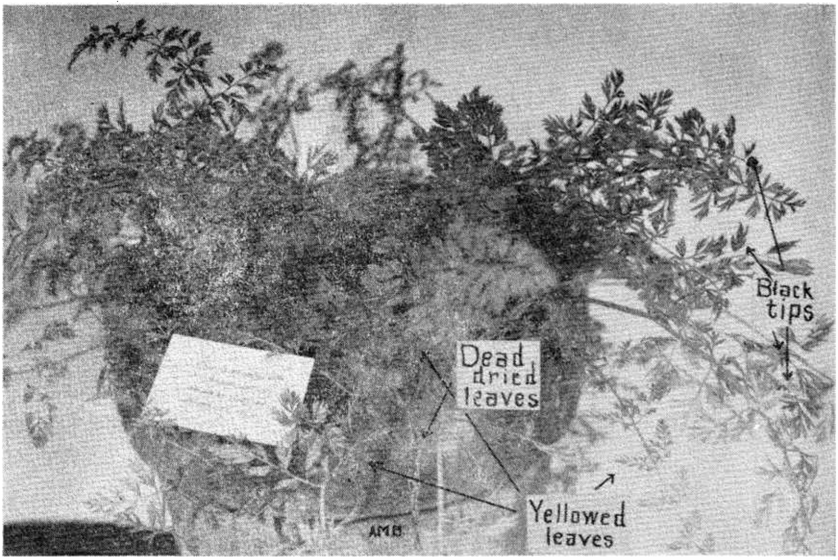

Plate I.—Carrot plants photographed forty-one days after inoculation with the bacterial blight parasite, *Xanthomonas carotae,* obtained from cultured carrot seed.

from the seed the outer leaves, next to be attacked after the seed leaves, are yellowed, darkened, and killed. A yellow bacterial ooze, flowing from the aerial infected parts of plants in the field in moister climates, usually is not present in the comparatively dry air of Arizona, but the ooze shows on lesions placed in a moist chamber. Injury to the plant results not only from the direct killing of the tops by the parasite, but also from the rapid evaporation of water from the infected parts. Girdling infection of the leaf stem (petiole) is followed by the death of the uninfected parts above. The same result follows girdling of the flower stalk (1, 2).

On the flower cluster, infection of the top may result in blasted seeds and seeds carrying the infection but still capable of germination. Killing of the central parts of the cluster in a seed-bearing stage and subsequent shrinkage may cause an inward bending or "cupping" of the cluster (2). Infected parts of the flower cluster show the same discolorations evident in infected leaf parts.

On the roots of infected plants two kinds of symptoms may appear, constrictions and decayed spots. In plants with a healthy to slightly infected top, the roots are supplied with sufficient food for normal, or almost normal, growth. As infection spreads and more outer leaves are diseased, less food is available and the growth of the root becomes thinner. New leaves develop in the center of the top that work normally for a time before the in-

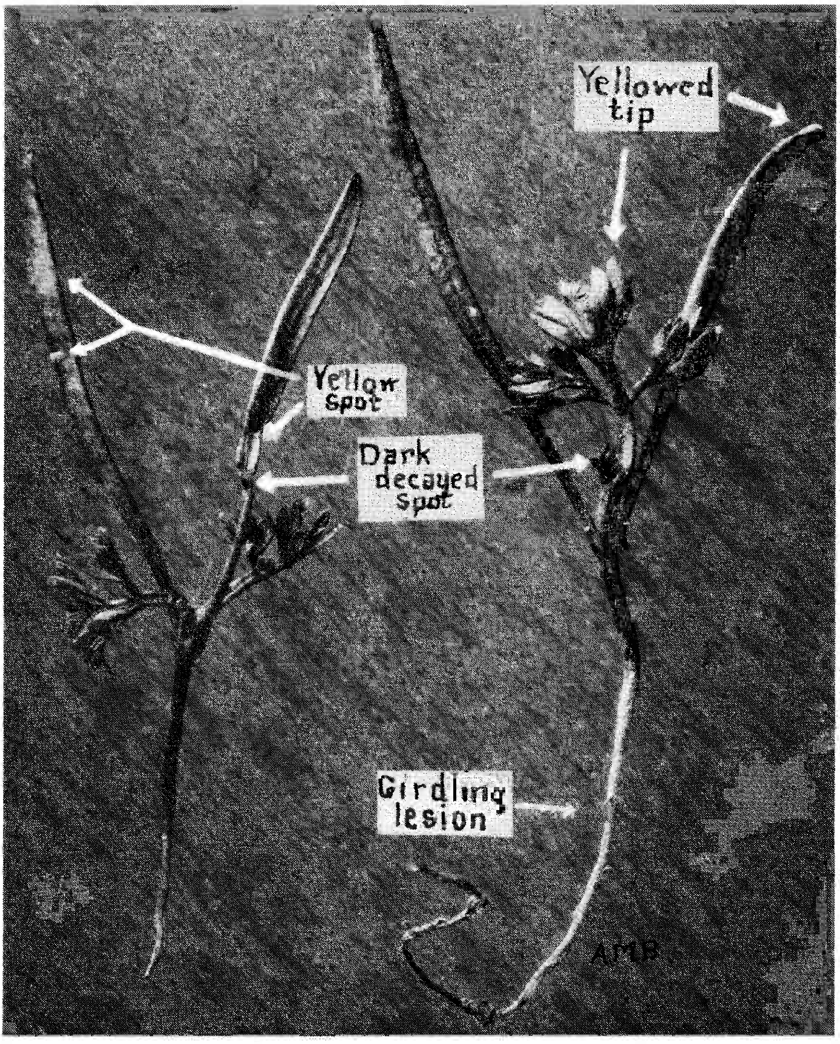

Plate II.—Bacterial blight of carrot seedlings. Older plant on right shows extension of infection from seed leaves (cotyledons) to developing true leaf above and between them.

fection reaches them and, during that time, more food for root growth is again available, resulting in a thicker growth of the root. The alternate variation in the area of healthy green leaf surface exposed to light and consequent variation in available food results in a root with thick parts alternating with slender parts, the so-called constrictions (Plate III). Even if such roots are dug without breaking at a constriction, they are not marketable.

The second root symptom is caused by direct infection. Minute brown spots appear anywhere on the root, increase in size, elongate crosswise of the root, often become scabby (Plate III) and render the root unfit for sale. The blight bacterium, liberated in the soil by the decay of the infected roots and in ooze flowing from the lesions, may live there for some time and infect the succeeding crop of carrots.

ORIGIN AND SPREAD

The carrot-blight bacterium is carried both on the surface and *inside* the seed. Carrot seed planted in Arizona is mainly supplied by growers in California. Seed-producing districts there and in Idaho are more or less infested with the bacterium of blight (1, 2, 3). Seed obtained from California and left over from planting Arizona fields that were later damaged by blight has been cultured in this laboratory and found to be infected. Once introduced into the field, the germ of blight may be spread by irrigation water, spattering rains, insects, and in other ways. Manure from livestock fed on cull carrots may also be an agency of dispersal.

CONTROL

To control bacterial blight of carrots, plant only seeds treated by the hot-water method, 126 degrees F. for ten minutes. There is no dust or other disinfectant that will kill the bacterium of blight *inside* the seed without injury to the embryo. Plant carrots in a given field only one year in four. Observe field sanitation.

BLACK ROT

(Caused by *Alternaria radicina* F. Meier, Drechsler and Eddy)

This fungus disease mainly affects carrot roots in transit, market, and storage (4), although infection may occur in the field. The disease has not been serious in Arizona.

SYMPTOMS

Black, somewhat depressed spots may appear on the lateral surface and crown of the root. The spots may or may not be covered with a black fungus growth. Spots on the side of the root are irregular in outline and shallow, but the rot at the crown may reach deeply into the core of the root (5). The decayed tissues are soft and black (Plate IV).

INFECTION

The fungus of black rot can penetrate a sound carrot root, but its entrance is made easier by bruises and wounds (4). It normally enters the root through broken rootlets. The temperature range for the growth of the fungus is 31 degrees F. to 93 degrees F., with the optimum at 82 degrees F.

CONTROL

The fungus of black rot can live in the soil on decaying plant parts, therefore rotation of carrots with other crops is advisable. Bruised and broken roots should be culled out before the crop is shipped or stored. Storage rooms should be thoroughcleaned and disinfested before use.

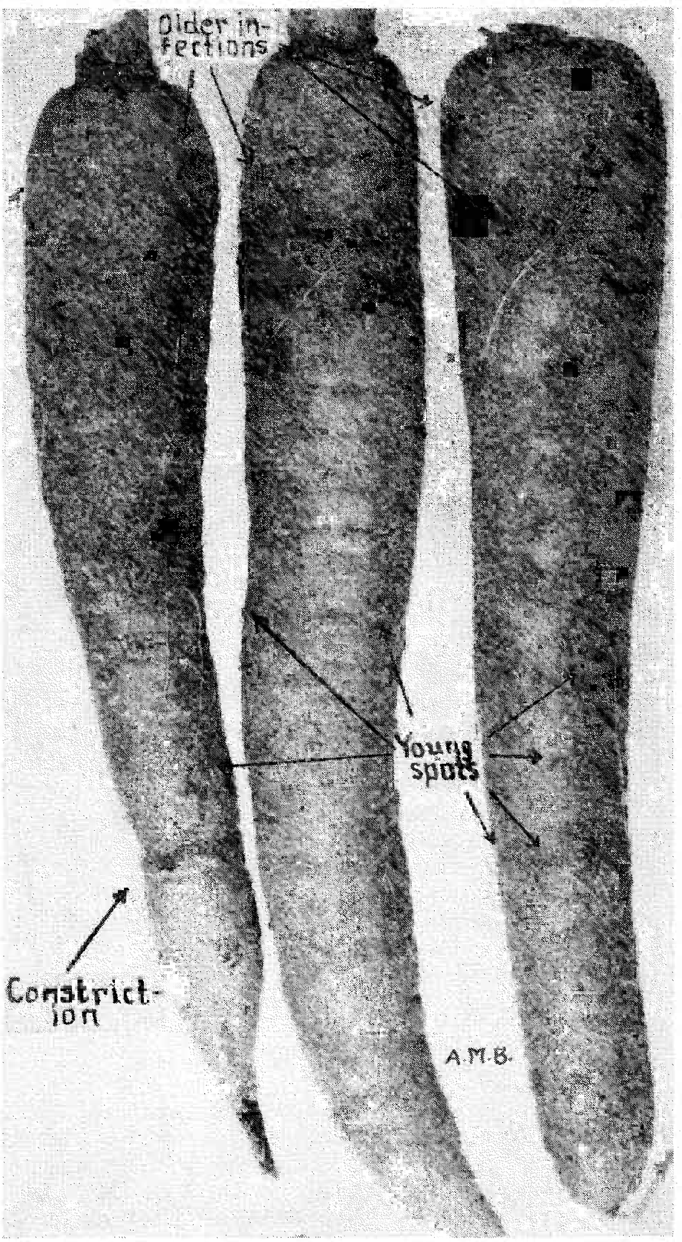

Plate III.—Arizona carrot roots with small, young, brown infected spots that elongate crosswise of the root and may become scabby. Result of infection with the bacterium of blight.

CERCOSPORA LEAF SPOT

Caused by *Cercospora carotae* (Passerini) Solheim)

Cercospora leaf spot of carrots, although widely distributed, is one of the less serious diseases of that crop. This fungus disease can affect both wild and cultivated carrots. All kinds of carrots tested are too susceptible to afford a start toward breeding for resistance to this leaf-spot disease (6).

SYMPTOMS

Any part of the leaf may show spots of diseased tissue, but primary lesions are located on the edge of the segments. There the spots are elongated. Spots back of the margin are very small, roundish and chlorotic. They may enlarge and unite until the whole leaf is killed. Fungus growth over the spots in moist weather gives them a gray to silvery appearance in contrast to the black color of the Macrosporium leaf spot under like conditions. Cercospora spots also differ from spots caused by Macrosporium in being roundish with a light center (Plate V). Elongated black to silvery lesions that may girdle the petiole and thus kill parts above the lesion may also be present.

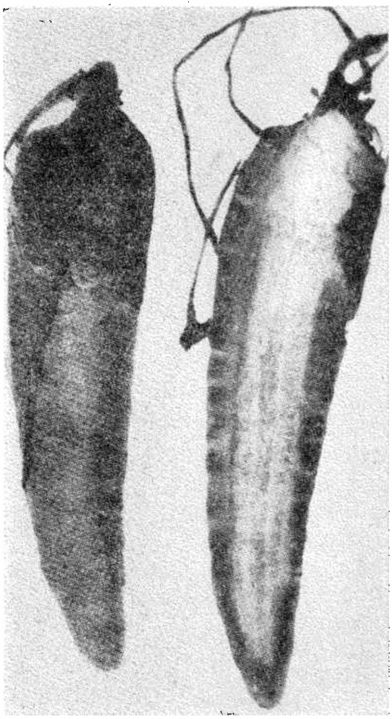

Plate IV.—Black rot of carrot root caused by the fungus, *Alternaria radicina*. At left, external appearance; at right, internal rot. —From Ramsey and Wiant.

INFECTION

The Cercospora fungus spreads by means of spores carried by the wind and on the surface of the seed. A film of moisture is necessary for germination of the spores. The fungus cannot grow directly into the leaf but enters through the "breathing pores" (stomata). Temperature relations of the fungus are, minimum 45 degrees F.; optimum, 66 degrees to 83 degrees F.; maximum, 99 degrees F. Leaf spots are fewer and shorter on nitrogen-deficient plants (6).

In the Santa Maria Valley of California where Cercospora leaf spot has caused considerable loss, the average minimum

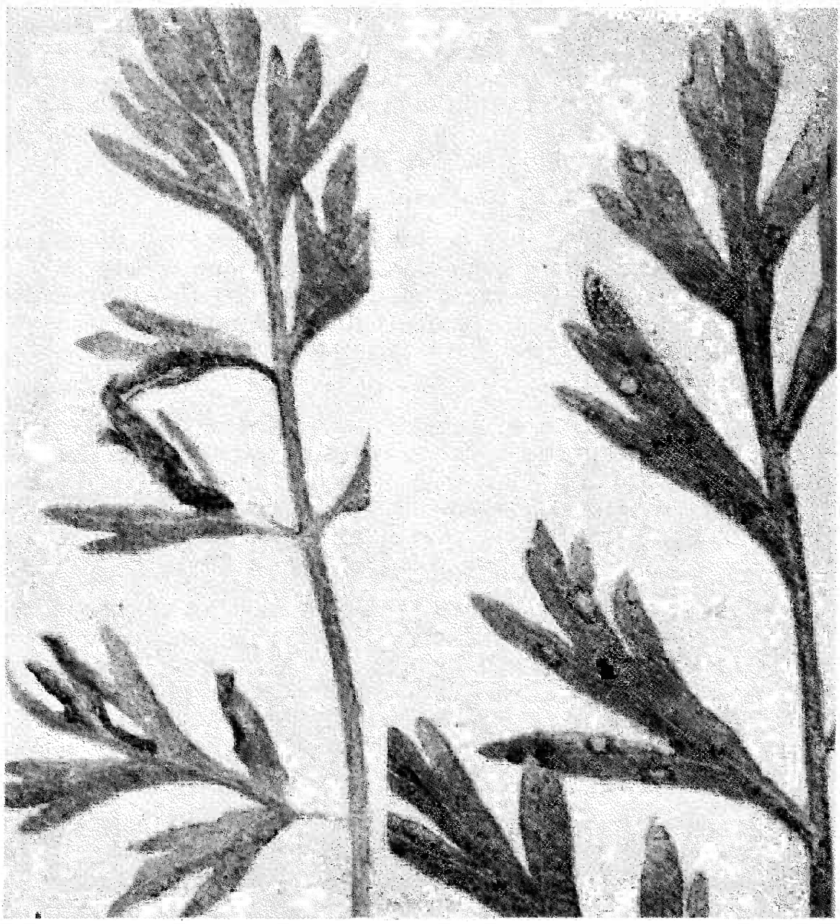

Plate V.—Parts of two carrot leaves, on left with segments showing irregular dark infections of Macrosporium leaf blight; on right, roundish Cercospora spots with light centers and dark margins.—After Hooker

temperature was 40-50 degrees F. and average maximum temperature 70-81 degrees F., considerably like winter temperatures in southern Arizona during the carrot-growing season.

CONTROL

Since the spores of Cercospora are carried on the surface of the seed, numerous disinfestants are reported (6) as successful in seed treatment. Among them are copper sulphate, 2 ounces per gallon of water, two hours; mercuric chloride, 1 to 1,000, five minutes; Spergon, 1 to 1,200, five minutes; ethyl mercury phosphate, 5 per cent dust, but injured germination; ethyl mercury phosphate, 1 to 24,000, wet treatment, did not injure germination;

cuprous oxide dust, 47 per cent. Spraying the foliage of growing carrots with Bordeaux mixture is suggested for the control of Cercospora and other carrot leaf spots. Since the fungus can live on organic matter in the soil, field sanitation and crop rotation are advisable.

CROWN ROT

(Caused by *Rhizoctonia solani* Kühn)

Infection in the field may be followed by crown rot there and in roots in transit and storage (4). Although the disease is unreported in Arizona, the cause of it is common throughout the agricultural districts of the state. Crown rot may appear when conditions particularly favor the disease.

SYMPTOMS

The leaves are killed by fungus attack on the petioles where they are attached in the crown. From the leaf bases the fungus grows downward into the root. Decayed tissues are soft and brown. Small, irregularly shaped, brown resting bodies of the fungus may appear on the surface of the decayed roots.

INFECTION

The fungus, *Rhizoctonia solani,* may or may not be present in virgin soil. It is almost invariably present in soils that have been cropped for a time. It lives in acid soils as well as highly alkaline soils. Temperature relations of the fungus are: minimum, 36 degrees; optimum, 73 degrees; maximum, 94 degrees F. At storage temperatures of 50 degrees and lower, its rotting action is retarded. The fungus can penetrate sound carrot plants.

CONTROL

Carrots should not immediately follow a crop that has been seriously damaged by *Rhizoctonia solani.* Susceptible crops in Arizona include cotton (sore shin); peas, beans, cantaloupes (root rot, damping off); potatoes (black scurf), and root crops (scab). It has also caused root cankers on alfalfa, particularly in Yuma County. Repeated dry working of the soil with an occasional irrigation, before planting, should reduce the fungus population.

It is interesting to know that soil inoculation with the fungus, *Trichoderma lignorum,* reduced damping off caused by *Rhizoctonia solani* (7) and also killed the Texas root-rot fungus (8).

FUSARIUM ROTS

(Caused by *Fusarium spp.*)

There are many species of Fusarium fungus. Some species can cause a spongy rot of carrot roots that are stored at temperatures above 45 degrees F. The rot fungi enter through wounds and bruises in the root that may also admit secondary rot organisms like the vegetable soft-rot bacterium. Another disease besides the spongy Fusarium rot affects the roots of bunched carrots produced in the West. A symptom of this Fusarium disease is the presence of shallow, scabby spots on the taproot (Plate X) that extend crosswise of the root like the lesions of bacterial carrot blight (Plate III). The two diseases can be distinguished by placing an infected root in a closed jar: then a cottony fungus growth appears on the surface of the Fusarium-decayed spots in contrast to a yellow bacterial ooze in the case of bacterial blight.

CONTROL

The following methods of control are recommended: Crop rotations omitting root crops; care to avoid injury to the roots at harvest; disinfestation of storage rooms; storage at approximately 32 degrees F.

HEAT INJURY

Carrot root growth is normal at 60-70 degrees F. (16). Unusually high temperatures may injure or kill young carrot plants. For example, such unseasonable temperatures resulted in injury to carrots over a 160-acre field in Pinal County in the late autumn of 1939. The crop eventually outgrew the injury.

SYMPTOMS

The crown presents a more or less slender, straight or curved "neck" (Plate VI). The plant as a whole is temporarily checked in growth.

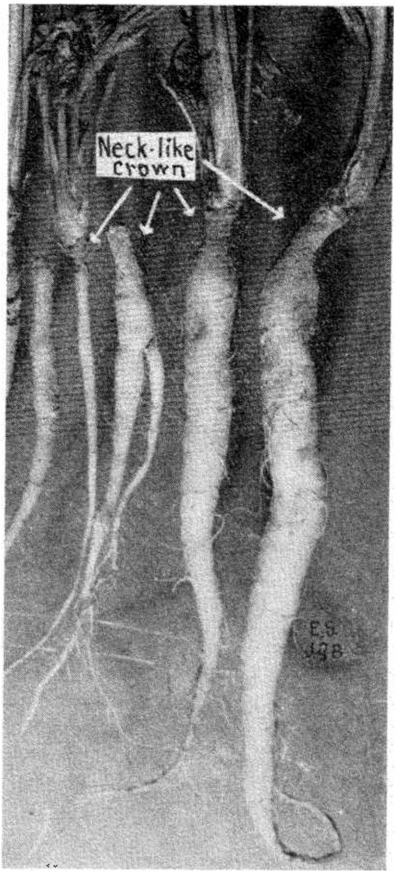

Plate VI.—Arizona carrots deformed by high soil temperatures.

CONTROL

No method of control is practical except later planting. Mulching with straw could be practiced on small areas.

MACROSPORIUM LEAF BLIGHT

(Caused by *Macrosporium carotae* Ellis and Langlois)

This fungus leaf blight is widespread geographically. It causes damage by slowing growth, increasing water loss from the tops in the field, and by rendering the tops of bunched carrots unsightly on the market. It has long been present in Arizona fields.

SYMPTOMS

The older leaves are attacked by the fungus (9). Irregular spots elongate on the margins of leaf segments and on the petioles, and tissue around the spots becomes yellowed. Spots do not have the light-colored center that is present in Cercospora leaf spot (Plate V). Severe infection makes a field conspicuous.

INFECTION

The spores of Macrosporium may be spread by wind, showers of rain, by seed, and in other ways. Temperature relations for the germination of the spores are like those for Cercospora.

CONTROL

Diseased tops may be removed and destroyed after the crop is well established. Spraying with Bordeaux mixture is also a helpful control measure.

Spraying carrots in the field with a fungicide may be particularly important here. That the carrot Macrosporium can attack cotton as well as tomatoes was demonstrated by Butler* (Plate VII). If the reverse is true, the prevalence of Macrosporium-infected carrots would be expected. Carrots are often grown near cotton fields.

RHIZOPUS SOFT ROT

(Caused by *Rhizopus tritici* Saito and *R.nigricans* Ehrenberg)

The Rhizopus group of fungi includes not only the two listed species but also several other species. Based upon a study (10) of more than 200 carlots of carrots, the conclusion was reached that harvested carrots are always contaminated with *R.tritici* and *R.nigricans;* also that sources of contamination include not only the field but also the storage room. These two fungi cause losses in storage that are almost as extensive as those due to watery soft rot. Of the two fungi, *R.tritici* is more important than *R.nigricans* in rotting carrots (4).

SYMPTOMS AND SIGNS

Infected tissues are water soaked, soft and brownish and, when picked apart, show threads of the parasites. Signs of the disease are abundant grayish threads of the fungi that grow out and cover infected spots. Finally, the fungus threads on the surface of the rotting carrot develop numerous small white globules that later become black (Plate VIII). These globules are the fruiting bodies filled with spores. The fungus threads of *R.tritici* are finer, more delicate than the filaments of *R.nigricans* that are

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*Unpublished experiments of Karl D. Butler, at that time research assistant in this department.

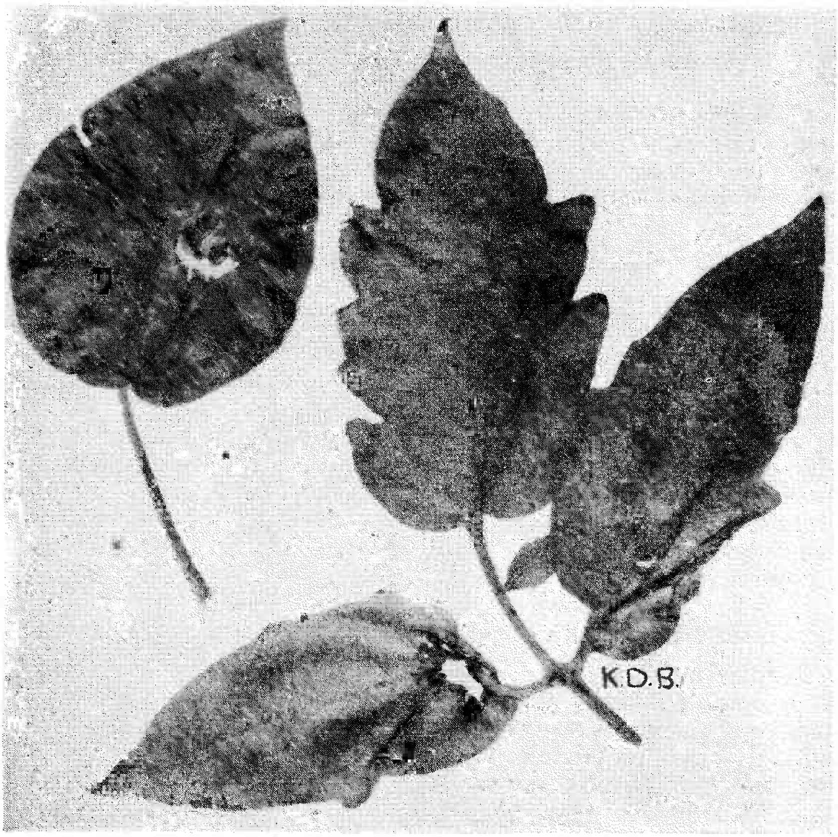

Plate VII.—Carrot Macrosporium fungus attacks cotton leaf (left) and tomato leaflet (right).

coarse and "whiskery." The latter species is the common bread-mold fungus.

INFECTION

Carrots directly from the field and stored at high temperatures, or at first stored at low temperatures and subsequently changed to high temperatures, may become infected with Rhizopus. At 86 degrees F. and above, decay is rapid; on the other hand there is little decay below 68 degrees F. (10).

CONTROL

Carrots should be handled carefully to avoid wounds and bruises; the roots should be promptly stored at harvest, at approximately 32 degrees F. and held at that temperature in order to check Rhizopus rot and other storage rots. The storage room should be cleaned and disinfested before use.

ROOT KNOT

(Caused by *Heterodera marioni* (Cornu) Goodey)

Root knot stimulated by the common nematode or eelworm is increasing in importance as a cause of loss, not only in carrots but also in other crops. The cause is not native to Arizona. It is commonly brought to the farm on rooted plants (11).

SYMPTOMS

Small knots or galls, pinhead size or larger, form on the lateral roots and rootlets. Small, pimple-like swellings in the taproot enlarge (Plate IX) and roughen the surface. Plants are often stunted and chlorotic, but the knots are the only dependable symptom.

CONTROL

Eradication of the root-knot nematode from the soil by chemical means, the only quick method, is expensive. Numerous chemicals have been tried for the purpose and some of them are quite satisfactory. Among them are chloropicrin, DD mixture, carbon disulphide, ethylene dichloride, and methyl bromide. Active stages of the nematode are easily killed but the eggs are very resistant. Chloropicrin (trade name Larvacide) is regarded as best for small areas, for it kills not only nematodes and their eggs but also harmful fungi in the soil. It is as yet too expensive for large areas. Several types of apparatus and machines have

Plate VIII.—Natural infection of Arizona carrot roots caused by *Rhizopus tritici*, a bread-mold-like fungus. Note the very numerous black dots that are spore sacs (sporangia) of the fungus.

been devised for applying chemical disinfectants to the soil.

Rotation of carrots with nematode-resistant crops is complicated by the lack of an available "money" crop. Small grains, hegari, resistant cowpeas and velvet beans, grown for three or four seasons, sufficiently reduce the nematode population of the soil so that at least one crop of carrots may be successfully grown. In an experiment with strongly infested Arizona soil some years ago, in which resistant crops and green manuring were used, the root-knot nematode was all but eradicated. With expensive land, chemical disinfestation may prove more economical in the long run.

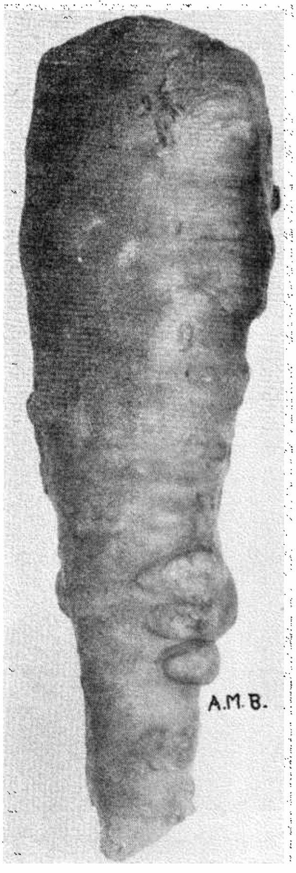

Plate IX.—Root knot on carrot, caused by the common nematode (*Heterodera marioni*).

SOUTHERN SCLEROTIAL ROT

(Caused by *Sclerotium rolfsii* Saccardo)

This fungus disease is present in Arizona mainly on sugar beets (12) and cotton (13), although carrots, cabbage, eggplant, melons, peppers, potatoes, pumpkins, radishes, squashes, sweet potatoes, tomatoes, and other economic plants as well as certain weeds are susceptible. Sclerotial rot is a field, transit, and storage disease.

SYMPTOMS AND SIGNS

On carrots in the field, sclerotial rot starts slightly below the surface of the soil. The tops of the infected plants may become yellowed and killed. The best sign of this rot is the appearance of a white fungus growth on the soil around the infected plant, in which many resting bodies are formed that are about the size and color of bird shot. A similar growth of the fungus may show on the infected stored roots (Plate X). The rotted carrot root is soft at first but may later dry out and become hard.

CONTROL

Carrots should not follow a crop that has been damaged by southern sclerotial rot. Frequent cultivation to dry and aerate the surface layers of soil, long rotations with non-susceptible crops, and field sanitation are recommended control measures in the field.

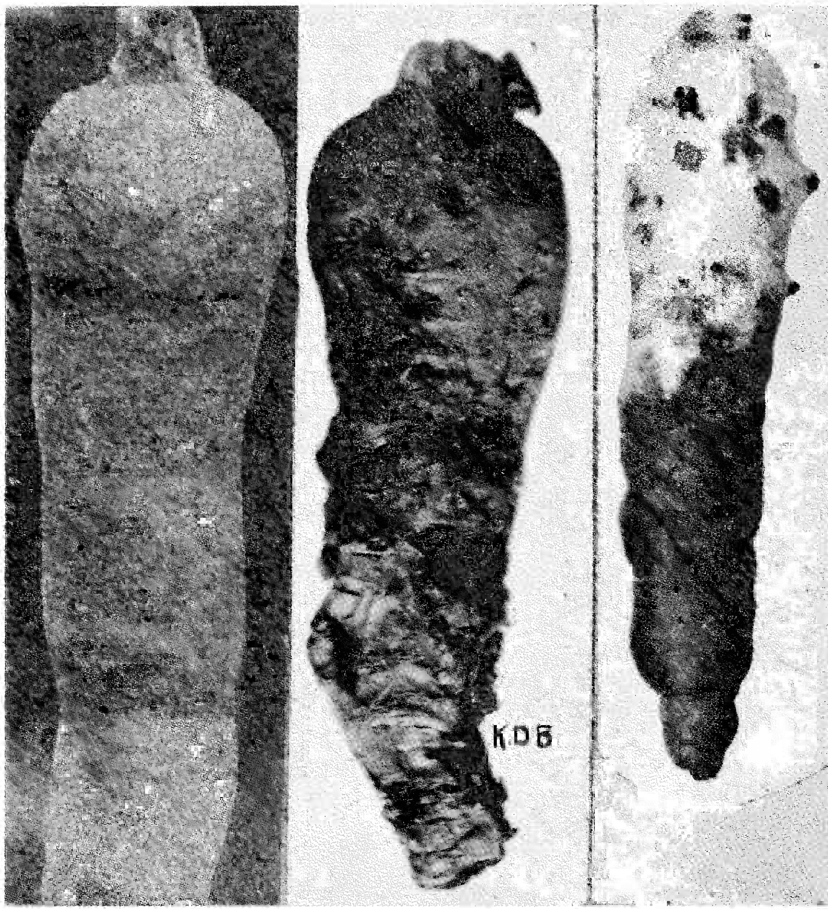

Plate X.—*Left:* Western Fusarium rot that may blemish bunched carrots (after Ramsey and Wiant). *Middle:* Rot and scab resulting from mixed infection with Fusarium sp. and Actinomyces scabies. *Right:* Southern sclerotial rot showing white cottony growth of causal fungus with dark resulting bodies in it (after Ramsey and Wiant).

VEGETABLE SOFT ROT
(Caused by *Erwinia carotovora* (Jones) Holland)

Vegetable soft rot is a long-known bacterial disease affecting numerous kinds of vegetables and causing heavy losses. The greatest damage due to the soft-rot bacterium in Arizona has occurred in head lettuce in which a strain of the parasite induces slime (14). Both bunched and topped carrots may be rotted by the bacterium, although losses are heavier in the topped roots.

SYMPTOMS

The disease is characterized by a soft, slimy, foul-smelling rot in which the infected tissues are discolored gray to brown.

INFECTION

Infection in the field often accompanies the attacks of other parasites such as *Actinomyces* (scab), *Fusarium spp.*, and *Rhizoctonia.* Roots in the field may also show the soft rot either in the tender lower end or in the crown. Leaves may become wilted and yellowed in late stages of the disease. Optimum temperature for the growth and increase of the soft-rot bacterium is 85 degrees F.; minimum, approximately 39 degrees F.; maximum, 100-102 degrees F.

CONTROL

Rotate carrots with immune small grains, hegari, cotton, or other crop, particularly avoiding vegetable crops. Proper rotations preceding carrot planting should result in winter carrots little, if any, affected by vegetable soft rot. Storage rooms should be thoroughly cleaned and disinfested. Bruised and otherwise damaged roots should be discarded at harvest. Sound, dry roots stored in a small quantity of clean straw, at approximately 32°F., should escape damage from vegetable soft rot in the absence of moist air.

WATERY SOFT ROT

(Caused by *Sclerotinia sclerotiorum* (Libert) De Bary)

The watery soft rot of carrots in Arizona was first observed in 1935 in the Salt River Valley. The roots concerned were stored in a pit and most of them were destroyed by the disease. The causal fungus first appeared in this state on head lettuce in 1925 (found on only one head), was most destructive in 1935 (15), and still takes an annual toll in lettuce.

SIGNS AND SYMPTOMS

Usually the first sign of the watery soft rot disease noticed by the grower on carrots is a fine cottony fungus growth on the surface. After a time the fungus threads form dense, white, cottony bunches that become black and hard. These are the resting bodies of the fungus. They are irregular to roundish, from the size of a pea to 1½ inches long. The larger resting bodies resemble coal clinkers. They can produce the watery rot directly (15) by sending out fine threads into the carrot plant, or indirectly by producing one to several mushroom cups (apothecia) containing millions of spores that, in turn, sprout fungus threads that can enter the carrot plant and cause disease. The resting bodies have been kept in a glass dish in this laboratory for eleven years, without added moisture, and have still retained the power to cause disease. Carrot roots affected with watery soft rot finally dry and harden.

INFECTION

Watery soft rot is a winter disease in southern Arizona. Favorable conditions for its development in the field prevail from mid-November to April. Minimum night temperatures of 40-55 degrees F. have resulted in heavy infections (lettuce) with Sclerotinia, even when the maximum (midday) temperatures reached 80 degrees F. or higher (15). In stored roots, temperatures of 32-40 degrees F. merely slow infection (4).

CONTROL

Carrots should not be planted in Sclerotinia-infested soil. Roots grown in such soil may be rotted in transit and storage, even when they show no visible infection at harvest. Rotation of carrots with most other root crops and with lettuce, cabbage, and other leafy vegetables, is bad practice. Small grains and sorghums are safe crops to rotate with carrots.

By applying calcium cyanamide to the soil at the rate of 900-1,000 pounds per acre before planting, Dr. Keener of this Department has materially reduced damage caused by Sclerotinia in heavily infested plots.

Carrots should be stored at 32 degrees F. and a relative humidity of 90-95 per cent after bruised and otherwise injured roots have been discarded (10).

DISINFESTATION OF STORAGE ROOMS

Most winter carrots grown in Arizona are immediately shipped at harvest, but grocers and other vegetable retailers store the vegetable for varying periods of time. Storage rooms for carrots and other vegetables should be kept clean and should be disinfested occasionally. Rooms with smooth floor, walls, and ceiling can be disinfested by burning sulphur candles, or by burning sulphur (⅓ pound per 1,000 cubic feet), or by spraying the surfaces with a weak 2-3 per cent) solution of formaldehyde.

For disinfesting rooms with uneven surfaces such as cracks, knotholes, and broken cement and plaster, there is no better method than fumigation with potassium permanganate—formaldehyde. Procedure follows:

1. Determine the volume (length x width x height) of the room in cubic feet.
2. Seal windows and other openings and outlets, excepting one door.
3. Place a tub containing 2-4 inches of water in the middle of the room (large storerooms may require two or more tubs).
4. For each 1,000 cubic feet of space in the room, 23 ounces of potassium permanganate and 3 pints of formaldehyde will be needed. Place the permanganate in a bowl resting in the water in the tub. There should be plenty of space left in the bowl for the formaldehyde to be added later.
5. From a wide-mouth vessel, pour the required quantity of formaldehyde (3 pints to 23 ounces of the permanganate for each 1,000 cubic feet of room space) on the permanganate. Leave the room immediately to avoid breathing the fumes; close and seal the door on the outside. Leave the room closed for at least twenty-four hours.

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