UNIVERSITY OF IDAHO
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Department of Plant Pathology

A Survey of the

Diseases of the Carrot Seed Crop in Idaho

with Control Recommendations

by

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A good field of carrot seed.

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Summary of Disease Control Measures for the Carrot Seed Crop

1. CLEAN ROOTS: Raise your own roots. Do not introduce troubles at the start. Especially do not import roots from other states for planting here.
2. CLEAN SEED: Use hot-water treated seed.
3. ROTATION: At least a 4-year rotation, avoiding lettuce, beans, peas, or celery as the preceding crop.
4. LOCATION: Root crop as far distant as possible from any carrot, parsnip, or lettuce seed crop.
5. WEEDS: Clean up weeds along ditch banks and headlands.
6. IRRIGATION: Avoid flooding and excess irrigation.
7. SANITATION: Do not contaminate good roots with rotting ones. Clean out and spray cellars or use new pits. Store only sound roots free from tops and dirt.
8. BARRIERS to spread of rot: Use series of short, shallow pits, rather than one long one. In cellars store in small units rather than in large bins.
9. VENTILATION: Do not crowd storage. Leave spaces for air movement.
10. TEMPERATURE: Hold storage temperature near freezing.
11. CULLS: Bury them under at least 6 inches of soil.

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A Survey of the

Diseases of the Carrot Seed Crop in Idaho

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GLENN KENKNIGHT[1] and EARLE C. BLODGETT[2]

Introduction

ON the cover of this bulletin is a picture taken in 1941 of a good field of carrot seed in one of the older carrot-growing areas in Idaho. Carrot seed production in that area rapidly declined. There were very few carrot seed fields there in 1943 and almost none in 1944. The trend in yield has been steadily downward the longer carrot seed has been grown in an area. Where yields of 1,000 lb. per acre and even considerably higher were expected a few years ago, many growers now harvest 400 or 500 lb. per acre and sometimes obtain much less. Yields are still good in new areas but diseases soon become serious because no precautions have been taken to prevent their introduction nor to control them.

Carrot seed production is a relatively new industry in Idaho. It began on a contract basis about 1930. The industry expanded rapidly, reaching 803 acres with a yield of 356,935 lb. in 1942 and nearly 2,000 acres in 1943. Carrot seed is produced in nearly all the irrigated areas from Weiser to Hazelton and Twin Falls. Large acreages are located near Homedale, Caldwell, Nampa, Melba, King Hill, and Twin Falls. The fresh carrot market has become important in Long Valley (Valley County) and near Nampa (Ada County). About 500 acres were harvested in 1943.*

Growers, representatives of seed companies, and plant pathologists from the University alike have been deeply concerned over the disease situation. Much remains to be learned about disease control methods, but it is believed that recommendations made in this bulletin, if followed, will check the spread of diseases into new areas and greatly reduce losses from diseases in older areas. With lessening demand for carrot seed, the industry is becoming highly competitive and it will be necessary to obtain high yields of high-germinating seed in order to show a profit and keep a share of the industry in Idaho.

Surveys were made of diseases of the carrot seed crop in Idaho in 1943 and 1944 *(3.6)*†. Particular attention was paid to the major diseases: bacterial blight, aster yellows, and storage rots. In connection with the Emergency Plant Disease Prevention of the United States Department of Agriculture, the junior author visited numerous fields of carrots in all the carrot-producing areas and most of the principal carrot storages in Idaho. Some field-plot trials have been carried on in Canyon County, and in that area careful study

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*Courtesy the office of Richard C. Ross, Agricultural Statistician, Boise, Idaho.

†Numbers in parenthesis have reference to literature cited at the end of the bulletin.

has been made of the relation of the major diseases to location of carrot fields, crop histories of the land, sources of seed, and sources and manner of storage of roots. In collecting these data the authors have enjoyed the cooperation of field men of several seed companies and have profited by their observations and experiences.*

Diseases of Carrots in Relation to Diseases of Other Crops

In order to rotate crops to advantage as a disease control measure, the interrelations of the major diseases of carrots and other crops must be understood. So far as known, bacterial blight of carrots does not affect any other crop plants. Gray mold *(Botrytis)*, which causes a very destructive root rot of carrots, is important also on lettuce, beans, and peas. Sclerotinia, which is sometimes of importance as a root rot of carrots, is the cause of the worst disease of lettuce, and may cause severe damage to celery, cabbage and related crops, beans and peas. Bacterial soft rot affects not only carrots, but also potatoes and beets, and to a lesser extent other vegetable crops. Botrytis, Sclerotinia, and bacterial soft rot are soil-borne. All may be introduced into a field on rotting roots. Sclerotinia may be seed-borne in beans and possibly in other crops. Sclerotinia and Botrytis are spread also by air-borne spores which may be scattered far and wide by the wind from piles of susceptible, decaying vegetable refuse.

From the standpoint of disease control, small grains, grasses, corn, alfalfa, and sweet clover are the most desirable crops for rotation with carrots. Potatoes and sugar beets are satisfactory, while lettuce, peas, beans, and celery are the most objectionable.

Infected carrots are one of the chief sources of the serious aster yellows disease of the lettuce seed crops. The disease is not soil-borne but, because infection spreads to weeds along the headlands and ditch banks, crop rotation is of some importance in its control.

Damping-Off

Poor stands of the root crop occasionally result from damping-off. The seeds may rot in the ground or the seedlings may be rotted off at the soil line. Under favorable conditions several fungi are capable of killing the young plants. Greatest damage occurs when the soil surface remains wet, especially in very cloudy weather. Usually the damage occurs in patches. Seed treatment with Spergon (1% by weight of the seed) may improve stand in some cases. However, probably more poor stands are obtained as a result of soil crusting than from damping-off.

Bacterial Blight

caused by *Xanthomonas carotae*

Bacterial blight of carrots was described by Kendrick *(3)* in California in 1934. The disease has been present in Idaho for several years. Blasting of carrot flowers and young ovules caused consid-

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*Acknowledgment is made of the cooperation of numerous carrot storage operators, of the State Seed Laboratory at Boise, and of D. F. Franklin and R. F. Johnson of the Parma and Caldwell Branch Experiment Stations respectively. Photographs for figures 8, 10, and 12 were made by W. J. Virgin, formerly Associate Plant Pathologist at the University of Idaho.

erable concern.* Seed company officials and field men noted bacterial blight as early as 1940. In the disease survey it was found present in all carrot seed fields examined in the vicinities of Caldwell, Nampa, Parma, Wilder, and King Hill, and was found in a field of carrots for roots at Georgetown. In 1943 the disease was not found in Twin Falls County even though careful examinations were made, but in 1944 a trace of infection was noted in several fields. The new area for carrot seed production around Melba was not surveyed in 1943, but in June, 1944, bacterial blight was prevalent in several fields. The disease was also found in a seed field near Craigmont, and in one at Moscow.

In an examination of seed samples special attention was directed to certain lots from fields where yields had been poor, clean-out heavy, and germination of seed unusually low. Close examination

Figure 1.—Bacterial blight on carrot leaves, southern Idaho, 1943.

of these seed samples disclosed traces to an abundance of the dried crystals of bacterial exudate resembling ground-up glass. In many samples individual seeds coated with the exudate were fairly common. The amount of exudate in seed samples from different areas could be roughly correlated with severity of bacterial blight in fields in those areas. It is not meant to imply that all loss in yield, heavy clean-out and low germination in these seed lots was necessarily due to bacterial blight. Other diseases, and perhaps other factors may have been involved. Nevertheless, bacterial blight appears to

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*Under the leadership of D. F. Franklin a project entitled "Factors Affecting Blasting of Seed in Onions and Carrots" (Hort. P-114D) was initiated in 1942.

be a limiting factor in carrot seed production where no measures are taken to combat it.

Symptoms of Bacterial Blight

The disease may affect any part of the plant, causing the infected tissues to turn dark brown or black. Bacterial exudate is not always conspicuous, but sometimes is present in great abundance giving affected leaves a glistening and later a glazed appearance. The sticky, yellowish exudate may flow down the stems from umbel and stem lesions, hardening in large drops.

On the leaves sometimes only the tips of a few segments are affected, turning dark brown or black. Sometimes the leaf blight phase is very conspicuous, giving the plants a scorched appearance. Stem and pedicel lesions may be so severe as to cause death of the portion of the plant above the lesion. Some flower umbels may be completely blasted as a result of more or less complete invasion by the bacteria or by girdling of the peduncle below the seed umbel. No root lesions definitely caused by bacterial blight were observed in the disease survey, but root infection in California has been described by Ark and Gardner *(1)*. The root lesions are small brown to maroon, scabby spots, usually with black centers, and sometimes showing a grayish bacterial exudate.

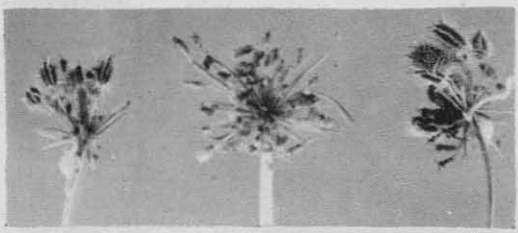

Figure 2.—Note bacterial blight exudate at base of severely blighted umblets. Danvers Half Long, Parma, Idaho, 1943.

In 1943 bacterial blight affected all, or nearly all, of the plants in many carrot seed fields, the majority of the plants showing only umbel injury. Usually only a portion of the florets in an umbel was blasted, and bacterial exudate from these accumulated on the lower side of the umbel. The disease was generally inconspicuous on the carrot root crop, but occasionally plants were found with leaf lesions or lesions on the leaf stem in the crown. In 1944 the disease was more widespread but generally less conspicuous. Cupping of the seed umbels due to blasting of the central flowers or seeds was very common.

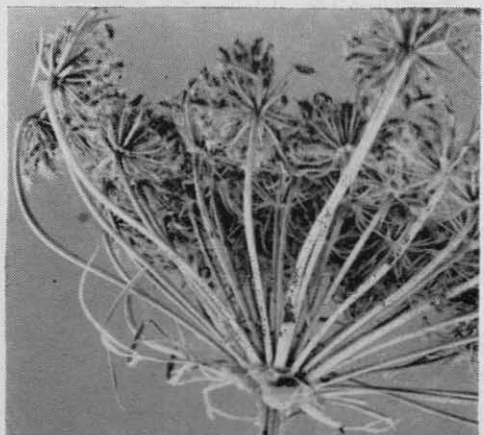

Figure 3.—A less damaged seed umbel with a conspicuous drop of bacterial exudate at its base. Danvers Half Long, Parma, Idaho, 1943.

Discussion of Bacterial Blight

Kendrick *(4)* demonstrated that the disease is seed-borne. So far as is known the disease affects only carrots. How long the bacteria that cause the disease can live in the soil in the absence of a carrot crop is not known. However, most bacterial blight diseases are not soil-borne more than 3 years, so it is thought that a 4-year crop rotation will control soil-borne bacterial blight. As shown by Kendrick *(4)* bacterial blight can be spread from plant to plant by spattering rain. Apparently only a small percentage of the plants develop bacterial blight from seed-borne infection, yet the disease has been found affecting most of the plants in seed fields on land never before planted to carrots. In view of the scant summer rainfall in southern Idaho, it seems probable that some method of spread other than in spattering rain is involved. When the bacterial exudate is liquid and sticky, any insect becoming contaminated with exudate, if capable of locomotion after the experience, probably can spread the disease. There is circumstantial evidence from greenhouse studies that insects, probably ants, do spread the disease organism. Another possible method of spread might be by means of irrigation water. This seems to be a probable method of spread in the root crop where blighted carrot leaves sometimes lap down into irrigation corrugates.

Bacterial blight may have been introduced into Idaho from California on infected seed or infected roots or both, and spread from one carrot seed-producing area in Idaho to others by the same means. Clean seed can be contaminated with bacterial blight in the threshing and cleaning process by equipment contaminated with bacterial exudate.

Recommendations for Control of Bacterial Blight

1. All carrot seed for planting in carrot seed-producing areas in Idaho should be treated by the hot-water method.

2. No field should be planted to either carrots for roots or carrots for seed oftener than once in 4 years.

3. Carrot fields for production of stecklings should be located as far away from carrot seed fields as practical.

Hot-Water Seed Treatment—Kendrick *(4)* showed that in water the bacteria which cause bacterial blight are killed at 120.2° F. in 10 minutes. Ark and Gardner *(1)* demonstrated that diseased seed could be disinfected by hot-water seed treatment at 125.6° for 10 minutes. Trials at the University of Idaho indicate that carrot seed will tolerate up to 136° F. for 10 minutes but is seriously damaged at 142° F.

The hot-water seed treatment requires great care. A thermostatically controlled hot-water seed treater has been designed at the Experiment Station and is loaned to seed companies with instructions for use.

Figure 4—Bacterial exudate in seed sample from southern Idaho. Shriveled seed with crystals of bacterial exudate at top; large seed with exudate in center. Seed from a healthy umbel below.

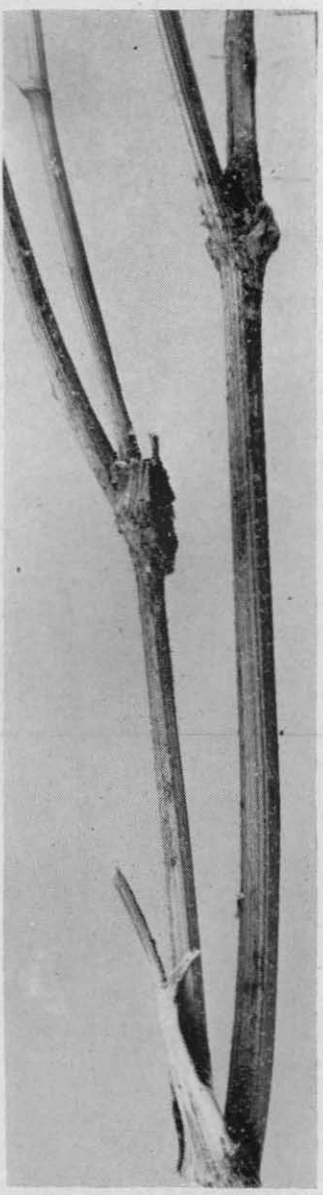

Figure 5—Bacterial blight cankers on stems. Note the abundant bacterial exudate at the joints. Red Cored Chantenay, Homedale, Idaho, 1943.

Macrosporium Blight

caused by *Macrosporium carotae*

This disease is of importance to Idaho growers from the standpoint of production of disease-free seed of high germination. Macrosporium blight is more serious in areas with rainy summers. The fungus is seed-borne, and in addition to blighting of the leaves of older plants, it is capable of causing death of seedlings *(14)*. The seedling phase has not been noted in Idaho, but blighting of the foliage of carrots occurred in some fields in Canyon County in 1941. *(15)*. Although no leaf blighting has been noted since that time, in 1944 D. F. Franklin called attention to a conspicuous dark discoloration of the lower part of the stems of carrot seed plants on old carrot ground *(Figure 6.)*. Macrosporium was found producing spores in abundance on the scabby areas.* Even though there may have been little, if any, loss in yield from the disease, the seed from such fields may be heavily contaminated with the spores of the disease fungus.

Symptoms—Dark brownish discoloration of the lower part of stems of seed plants. Sometimes blighting of the leaves as irregular brown spots with yellow centers especially along margins of leaves. Entire leaves may turn yellow, then brown, and black. The affected leaves may be glossy as in the case of bacterial blight, but are never sticky.

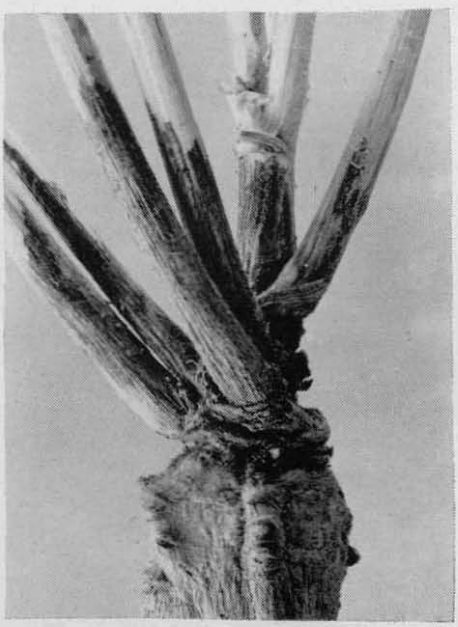

Figure 6—The Macrosporium blight fungus producing spores on carrot stems.

Control — Use hot-water treated seed together with a crop rotation of at least 3 years.

Diseases of the Roots

The full extent of losses by root rots of carrots is not easily estimated. In addition to some losses in the root crop before harvest, and rather frequent moderate to heavy losses in stand in the seed crop commonly amount to 10 to 20 percent of the roots planted and sometimes are so severe that the crop is abandoned. Part of the loss has resulted from shortage of labor at critical times and shortage of suitable storage space. A rather general belief that some loss from rots is unavoidable has led to much greater losses than need occur. Since storage rots have caused grave concern, there is a tendency to plant more carrots for steck-

*Identified as *Macrosporium carotae* by W. W. Ray.

lings than would seem adequate in order to have "enough." Frequently, flooded corners of fields have been planted to make space for more roots. Rotted roots have been sorted out and those contaminated with rot organisms placed in storage. The extra roots to take care of losses have overtaxed the storage space and so jeopardized the whole lot.

Symptoms of Diseases of the Roots

1. Black rot caused by *Alternaria radicina*, Figure 7.

Black, sunken, corky areas on the root; black spore masses of the fungus may be conspicuous. Sometimes a destructive rot in storage and the most serious root rot of the seed crop.

2. Sclerotinia or watery soft rot caused by *Sclerotinia sclerotiorum*. Figures 8 and 9.

A soft, watery decay caused by a white fungus which produces rather round-edged sclerotia embedded in the mycelium and appearing as dark humps under the fungus mats. Apparently the most commonly destructive rot in storage and sometimes serious in the following seed crop. Especially common when the root crop was planted after beans, peas, or lettuce that had been heavily damaged by the disease.

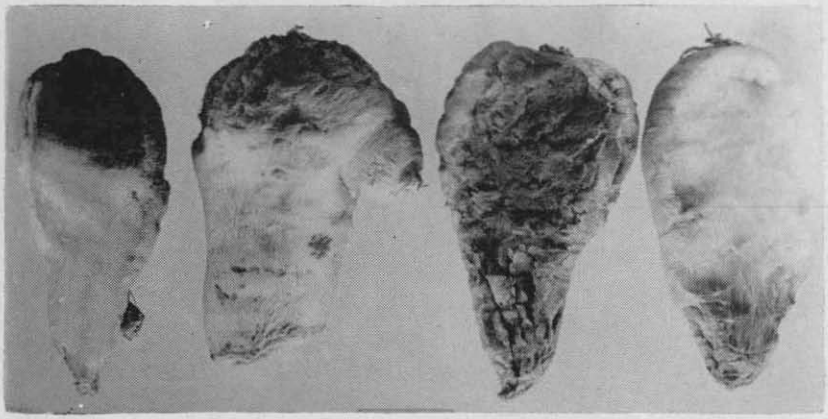

Figure 7—Black rot on Chantenay from a pit at Caldwell. 1944.

3. Botrytis or gray mold caused by *Botrytis cineria*, Figure 10.

A slightly watery rot of the roots commonly starting at the base of the leaf stalks, caused by a conspicuous gray fungus which in cool storage produces abundant, black, naked, rather rough surfaced sclerotia. In warmer storage the affected roots appear to be covered with a gray fur and sclerotia may be absent. Roots rotted by Botrytis tend to mummify. Commonly destructive in storage, and sometimes serious in the seed crop.

4. Bacterial soft rot caused by *Erwinia carotovera.*

A soft, watery rot accompanied by a foul odor. Frequently serious in areas that have been flooded in the root crop. Can be serious in storage.

5. Neck constriction or heat injury. Figure 11.

Roots severely constricted at the crown with the result that the tops snap off easily. Has been noted as serious in the root crop at King Hill on white sandy soil and in late-planted carrots at Moscow. Believed to be due to heat injury.

Figure 8—Sclerotinia rot spreading by contact in a cellar at Caldwell, Idaho. 1941.

6. Giant roots or vegetation in the seed crop.

Roots continue to grow after setting out and may reach 6 or even 8 inches in diameter. The plants either set no seed or set seed late and out of season with the rest of the crop. Has been noted as serious in fields planted with roots shipped in from California, and as troublesome in a few other instances where the roots were not stored at a low enough temperature.

7. Root-knot nematode, *Heterodera maroni,* Figure 12.

Swellings on the fine lateral roots and sometimes enlargements on the tap root. Plants stunted, roots much forked, stubby, and rough. Noted on carrots at Caldwell and at Hammett, on lettuce at Nampa, and troublesome on potatoes in eastern Idaho.

Control of Root Diseases

1. Grow roots in clean soil.

The remarkably good keeping quality of roots grown on land new to vegetable crops has been noted in several instances. On the other

hand, careful attention to storage conditions appears to be necessary to prevent losses in roots grown on land regularly used for row crops. A rotation of at least 4 years is advisable. Lettuce, beans, and peas are probably the least desirable crops to precede carrots in the rotation because they are all susceptible to Botrytis and Sclerotinia.

2. Avoid flooding during irrigation.

Land new to vegetable crops may be nearly free from most carrot root rotting fungi, but the bacterial soft rot organism seems to be present everywhere and to rot carrots whenever they are flooded for long. Field corners that tend to flood should not be planted to carrots. The roots grown there may be a source of infection and cause heavy damage by rotting of all the carrots in storage.

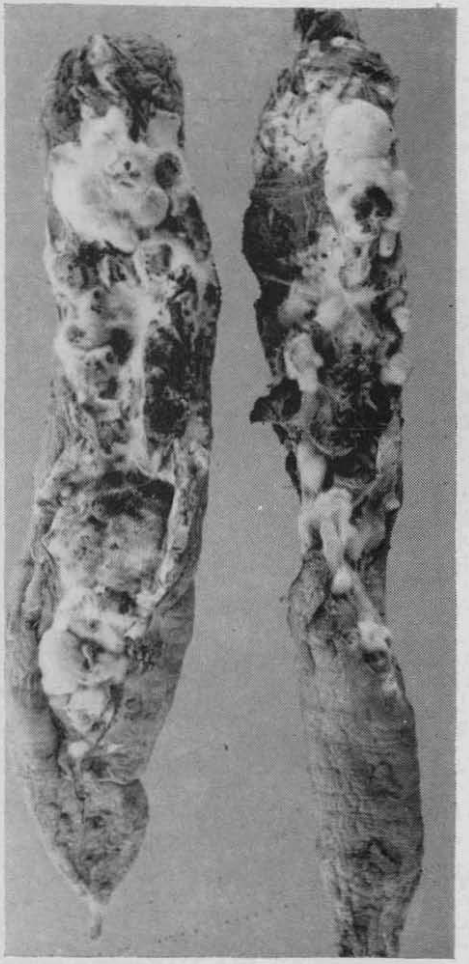

Figure 9—Sclerotinia rot on Imperator roots. From a pit at Moscow. 1944.

3. Store only clean roots.

If there are spots in the field where many roots are rotted, do not harvest those areas. Do not endanger all the roots to save a few. Roots covered with fungus spores or bacterial slime, even though they may look sound at harvest time, are hard to keep.

4. Provide clean storage.

Storage cellars should be given a thorough cleaning. Spraying the floor and bins with copper sulphate; 1 pound to 10 gallons is advised. Pits should be dug in clean soil, and certainly not in carrot fields.

5. Provide barriers to spread of rots in storage.

Rots starting at one point may spread for great distances. Much of the spread could be prevented by separating the roots into smaller units. In this respect a series of short pits, has an advantage over one long pit, and, in cellars, roots in crates or small bins have an advantage over those that are in large bins.

6. Store roots free from soil.

Soil or sand mixed with carrot roots interferes with proper ventilation and reduces the chance of the roots keeping. Recommendations for storing a box or two of carrots in a basement should not be confused with those for large scale storage. It is true that where the air is too dry for carrots, as is the case in many basements, the roots may keep better in sand.

7. Store carrots free from tops.

Much of the rotting in storage starts with the tops. Frequently the topping of carrots has been carelessly done. There is no question about its being a big job to top them cleanly. One instance was noted where sheep were employed to top the carrots neatly and cleanly before harvest. Recently, topping machines built on the principle of a clothes wringer have come into use and seem satisfactory.

Figure 10—Botrytis or gray mold frequently begins on sprouts. The tissues are blackened in advance of the grayish fungus. Moscow, Idaho. 1941.

8. Provide adequate ventilation.

Carrots stored properly need not be moved. Sometimes in carrot cellars the roots are piled 6 or even 12 feet deep. Some growers have the idea that roots have to be spread out once in a while to cool them off. It should be remembered that fungi and bacteria that cause rotting are living plants which make very little growth at 32° to 34° F., but that their growth rate increases rapidly with rise in temperature. Carrot roots, too, are alive and respire, and in so doing give off heat. If carrots are piled deeply, heat accumulates in the pile until the roots "sweat" and may be damaged even if they do not rot. They will rot if any rot-producing fungi are present. The most ideal system of storage in cellars noted on the survey was that of placing the roots 2 to 2½ feet deep on slatted decks about 3 feet wide and 16 feet long. The decks may be placed one above another leaving a foot or so clearance between the roots on the one deck and the floor of the deck above. For pit storage irrigation ditches have been used satisfactorily. It is advisable to support the weight of the soil for covering with poles laid across the ditch.

9. Keep the temperature near freezing.

If the ceiling of the storage is high, fans may be necessary to provide a uniform temperature. The cooler the roots are kept without freezing, the better they will keep. The storage should be well insulated against becoming too warm in the spring. If the roots sprout long before planting time some damage from rots is certain even under the most sanitary conditions attainable. Common molds that do no damage under field conditions are capable of attacking the tender sprouts, and the rot may extend down into the crowns of the carrots and kill the buds.

10. Store carrots by themselves.

Ideal carrot storage is too cold for potatoes and too moist for onions.

11. Precautions in sorting.

Frequently carrots are sorted during storage to remove the rotting ones, and in so doing all the carrots are contaminated with

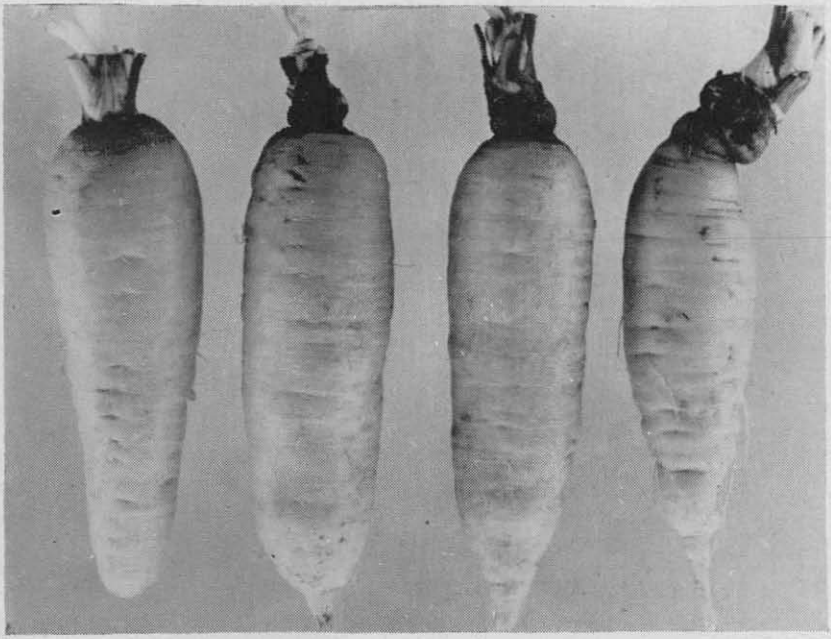

Figure 11—Neck constriction probably due to heat injury. Normal root at left. Red Cored Chantenay, Moscow, Idaho. 1944.

spores of rot-producing fungi. When a pocket of rot develops, the temperature rises in that area favoring the rooting of neighboring roots. As rotting continues, the temperature continues to rise and the speed of rooting increases. The hot spots should be removed along with all contaminated roots near them. However, when there are many points of infection, it is rather hopeless to attempt to sort all the roots to save the sound ones. Roots heavily contami-

Figure 12—Root-knot nematode. Caldwell, Idaho, 1941.

nated with spores of rot-producing fungi are not worth planting. Even if they survive storage as a result of keeping the temperature low, they may still rot after being planted.

12. Plant only sound roots.

Late in the season most roots of the carrot seed crop in some fields are somewhat rotted even where the yield of seed is good. However, root rots early in the season are very destructive to both stand and yield. Some growers plant many more roots per acre than others, and a loss of 20 or 30 percent of the roots often may still leave enough plants, but not enough healthy plants. If many plants die as a result of root rots, it is certain that many more have been weakened in vigor and productiveness.

13. Do not attempt to dry out rots.

Some growers assume that half-rotten roots can be made satisfactory by drying out the rot before planting. This practice is undesirable. Fungi do require moisture and will become inactive when the roots are dried out, but the fungi will get moisture and become active again when the roots are planted. In the meantime, drying weakens the vitality of the roots.

14. Bury the culls.

Frequently large piles of what looks like charcoal have been noted near pits, cellars, and carrot fields in the summer. On closer inspection, these have turned out to be dumped, discarded carrot roots left there to rot, and were black mummies covered with sclerotia and with billions of spores of the black rot and gray mold fungi. The wind carries the spores far and wide to infect carrots and other susceptible crops wherever and whenever conditions favor infection. Bury the rots in a waste place and cover with at least 6 inches of soil.

15. Do not tolerate the root-knot nematodes.

This pest is such a great potential danger to the vegetable industry in Idaho that it should be eradicated in all new areas of infestation. The disease is readily recognized by the fact that it produces swelling from the size of legume nodules up to the size of pea seeds or even much larger on the roots or tubers of susceptible hosts.

Avoid introducing the nematodes (1) on seed potatoes, plants, or roots purchased for setting out in the field; (2) on cull potatoes used for livestock feed (if the culls contain any nematodes, cook them before feeding); or (3) on farm implements that may have been used on land infested with the nematode. Complete washing of equipment will lessen the danger. Plant the infested areas for at least 4 or 5 years with only non-susceptible crops such as small grains, grasses, and corn.

Aster Yellows

To a large extent the decline of carrot and lettuce seed production on the Wilder Bench has resulted from the seriousness of aster yellows in that area. In 1943 aster yellows occurred throughout the carrot seed-producing areas, but was worst in the older areas. Losses noted in the carrot seed crop varied from a trace to 40 percent of the plants killed and averaged between 10 and 15 percent. Losses in the lettuce seed crop were slightly greater. It was then thought that all recognized aster yellows in the carrot seed crop arises from roots that had been infected the previous season. In 1944 there was considerable evidence of some current season spread in the seed crop. Similar observations have been reported from California *(2)*. Aster yellows did relatively little damage in 1944. It was entirely absent from many lettuce fields indicating little spread. Presumably, as in the case of the sugar beet curly top disease, there will be years when aster yellows is a scourge and others when it is of little consequence, depending on the population of insects carrying the virus and of diseased plants serving as a source of infection.

Aster yellows is neither seed-borne nor soil-borne. Like curly top, it is spread only by leafhoppers, but the beet leafhopper that spreads curly top cannot spread aster yellows. Instead, the aster or six-spotted leafhopper appears to be the principal carrier of aster yellows *(7, 10)*, although some other leafhoppers can transmit at least the California strain *(13)*. When leafhoppers transmit the virus from diseased to healthy plants, two to several weeks elapse before the latter plants show any signs of the disease *(11)*. Spread of aster yellows is most rapid during cool weather in spring and fall *(11)*. There is good field evidence that many carrots infected in the fall show no symptoms until they have made considerable growth the next season and so serve as a reservoir of infection for healthy plants in neighboring fields of lettuce and carrots for roots.

There are two or more strains of aster yellows that differ slightly in their host ranges. In experimental plots at Caldwell there has

been no natural spread of aster yellows to zinnias and celery which are affected by the California but not the New York strain of the virus *(9, 13)*. Both strains have a very wide host range of crop plants and weeds *(7, 11)*. However, the virus apparently overwinters only in the roots of biennial and perennial plants.

Figure 13—Aster yellows on Oxheart roots from storage. Wilder, Idaho. 1944. The roots at the extreme right and extreme left are normal. Note the numerous, slender, twisted sprouts and tufts of fibrous roots on the affected tap roots.

Symptoms of Aster Yellows

Plants severely dwarfed and pale green to yellowish, or occasionally with a reddish to purplish cast; usually with many slender twisted leaf stems arising from the crown. Seed stalks develop abnormally early. Flower umbels small and pale green with small greenish white flowers on long, slender pedicels. Frequently only a part of a plant is affected early in the season, resulting in uneven growth; but later the entire plant is diseased and no seed is set. On the root crop, aster yellows causes a "bunchy top" with slender, twisted leaf stems and wooly roots. Sometimes the leaves are off-color: yellowish, reddish, or purplish.

Control of Aster Yellows

1. Plant the root crop at a distance from any seed field of either carrots, lettuce, or parsnip, or from commercial fall lettuce. Possibly the roots should be grown at a distance from any onion field, but as yet there is no field evidence that aster yellows in carrots has come from onions. Linn in New York *(6)* recommended that lettuce should be planted at least 200 feet from a source of infection. However, surveys in Idaho indicate that a greater distance is advisable. It appears that the farther the carrot root crop is from a susceptible crop or weed patch that may serve as a source of

infection, the better. This recommendation as to location of the carrot root crop applies only to roots intended for seed production. Evidently, the disease does so little damage to the root crop in Idaho that special control measures are unnecessary when the roots are intended for table stock.

2. Eradicate weeds along the headlands and ditch banks. Field evidence has shown that aster yellows in lettuce or carrots for roots often has spread from seed carrots where in turn it has arisen from overwintering virus in infected roots. However, in the Wilder area there has been no relation between the amount of aster yellows in lettuce and the location of the field with respect to carrot seed fields. There the principal source of overwintering virus must be

Figure 14

Figure 15

Aster yellows. Plants severely stunted, usually with numerous twisted shoots from the crown. Leaves pale green or yellowish, flowers abnormal and sterile. Nampa, Idaho. 1944.

susceptible weeds that survive the winter. The only weed known to be important as a source of the virus is a perennial blue aster occasionally found along ditch banks. This and common plantain, which is susceptible *(7)*, should be eradicated where found. Wild lettuce may overwinter occasionally, but in spite of its abundance, few infected plants have been found. Dandelions are reported to be susceptible *(7)* and land infested with them should be avoided until they have been eradicated. Sow thistles are supposed to be

susceptible *(7)* but none has been noted in Idaho showing symptoms of aster yellows. Obviously there are other weeds that carry the virus but on which the symptoms of aster yellows have not yet been recognized. So far as known, all plants of the grass family are immune. It is recommended that the weeds along ditch banks, on headlands, and in waste places near fields be replaced by grasses. This can be accomplished gradually by burning the areas with a weed burner.

3. Do not import carrot roots from other states for planting here. By so doing, other strains of aster yellows may be introduced.

4. Other measures that may be of some value:

Pulling of infected plants in the seed crop may be of some value in protecting neighboring fields of lettuce or carrots for roots, but

Figure 16

Figure 17

Green dwarf. Plants stunted, erect, and rigid, with very dark green, thick leaves, and few and late seed stalks. Plant in Figure 17 appears to have made considerable growth before it became affected. Melba, Idaho. 1944.

it is far more advisable to surround susceptible crops with non-susceptible crops such as legumes, cereal crops, or grasses. When pulling plants infected with aster yellows, it is not necessary to remove them from the field.

Any aster yellows found in the root crop should be sorted out. An excessive number of first-season leaf stems is a fairly reliable

s. However, multiple sprouts or hairy
e sometimes occur in abundance in the

Green Dwarf

rmined cause, but probably a virus, is of
ughout the carrot seed producing areas.
ffected and the degree of damage done to
arly so great as in the case of aster yellows.
oted in the root crop in the fall and it seems
ory, method of spread, and methods of con-
very similar to those of aster yellows. Since
affected plants in a seed field is somewhat
e of the field than elsewhere, it is believed
spread in the seed crop from infected weeds
s and headlands. The host range of green

Dwarf

stiff, late in flowering and seeding, and with
en leaves. Seeds may be twisted and many fail
tly only one side of a plant is affected. Not easily
root crop, but affected plants have thick, very

Dwarf

mended for the control of aster yellows will prob-
disease also.

Mosaic*

affected plants are distorted and twisted, frequently
rom drought. A mosaic pattern of light and dark
sometimes apparent on the lower surfaces of the
18). Some affected plants appear to be stunted. It
low much damage the disease does, but is common
ot and seed crops. The disease is probably spread by
ssibly by knives in topping the roots. Location of
ot fields at a considerable distance from carrot seed
ommended for the control of aster yellows may help
saic. At the present time no special control measures
nded.

Stunt

al plants have been noted in carrot seed fields with the
ched in a tight cluster at the top of the plant. Affected
erally are pale in color and severely stunted. The cause
able is not known, but the symptoms suggest that it is
sease. Probably measures recommended for the control
ellows will reduce the amount of stunt *(Figure 19)*.

to our attention by Donald M. Murphy of the Cornelli Seed Company.

Fasciation

Occasional plants have been noted in the seed crop with
and leaf petioles very flat, thin, and weak. Sometimes o
a plant is affected and the color of the leaves is quite nor
times the entire plant is affected, the leaves are pale and
and no flowers are produced. The cause of fasciation is n
but the trouble is too rare to give cause for concern.

Dodder, *Cuscuta* sp.

This yellowish, twining, parasitic, flowering plant has b
several times in carrot seed fields in Canyon County and
become very troublesome if control measures are neglected

Figure 18—Mosaic. Leaves distorted, twisted, drooping, sometimes with a mosaic pattern of light and dark green. Twin Falls, Idaho. 1944.

Figure 19—Stunt. Plants se
ly dwarfed with the pale gre
yellowish foliage clustered a
top. Melba, Idaho. 1944.

in addition to being a parasite, is capable of transmitting ce
virus diseases. Pull and remove dodder from the field before it
duces seed. Avoid planting seed of the parasite as a mixtu
seed of crop plants.

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