Occurrence of rubbery brown rot of stored carrots in Alberta

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A Phytophthora disease of carrots (Daucus carota L. var. sativa DC.) occurred in a cooperative storage in southern Alberta in 1970 and 1971. The same disease was found in stored commercial carrots on a farm near Edmonton in 1975. The causal fungus was associated with a rubbery brown rot and proved to be pathogenic when inoculated into immature and mature carrots and unwounded roots at low temperature. Infection was obtained when the organism was inoculated into several other species of horticultural plants.

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En 1970 et 1971, le mildiou de la carotte (Daucus carota L. var. sativa DC.) s'est manifest6 dans un entrepôt du sud de l'Alberta. La maladie est reparue en 1975 dans un lot de carottes commerciales entreposées dans une ferme des environs d'Edmonton. Le champignon causal associé à une pourriture brune caoutchouteuse s'est révélé pathogène par inoculation sur des carottes mûres et non mûres. A basse température, il s'attaque également aux racines saines. D'autres espèces de plantes horticoles ont été infectées par inoculation.

Rubbery brown rot disease of carrot *(Daucus carota* L. var. *sativa* DC.) under natural conditions was first described by Dowson (1934) and resulted in serious losses of the vegetable in transit. Symptoms of 'the disease are initially a water-soaked appearance of affected taproot tissues which later become firm and dark brown but remain watery (Dowson 1934; White 1945; Rader 1952). In storage and in transit affected root portions may be covered by a dense white surface mycelium (Dowson 1934) overlaying the cortical tissues which generally contain oospores. Of the several *Phyfophfhora* spp. previously reported as attacking carrots, only *P. cactorum* (Leb. & Cohn) Schroet. and *P. megasperma* Drechs. caused decay under natural conditions (Rader 1952). This note deals with a Rubbery Brown Rot of carrots caused by a *Phyfophfhora* sp. which differs in several respects from those species previously reported to attack the crop.

Stored carrots of the cultivar Imperator II from 6 grower-members of a southern Alberta vegetable cooperative were affected with a rubbery type of brown rot (Henry et al. 1971), in early winter 1969-70. The following winter stored carrots of 5 growers in the same cooperative were similarly affected. All stored carrots involved in the disease outbreak were grown under irrigation. Losses, were heaviest the first year of the outbreak, reaching an estimated 20% by mid-January in several large storage pallets. No symptoms or signs of the disease were reported by handlers during digging and washing operations.

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The next reported Occurrence of the disease in commercial stored Imperator II carrots was near Edmonton, in December 1975. A grower had received bulk shipments of carrots for repacking from the southern Alberta cooperative carrot storage. Only 2 of his 4 affected fields had been irrigated. The soil, however, had received prolonged heavy rainfall during August of the growing season.

The Phytophthora-infected carrots in Alberta generally contained dark brown, firm, water-soaked areas sometimes in wide bands appearing anywhere on the root. The rot most commonly occurred near the middle and crown areas accompanied by a dense growth of white surface mycelium (Fig. 1A). Roots in advanced stages of decay were darker colored with a moist glistening surface, and tended to collapse readily. Interior rotted portions were usually brown, rubbery, and without noticeable leakage. Advanced stages of the rot were usually accompanied by fungi such as *Pyfhium* spp., *Botrytis* spp., *Fusarium* spp. and *Mucor* spp.

Materials and methods

To isolate the causal organism associated with the rubbery brown rot symptoms several procedures were used, the most successful being to break apart the edges of discolored tissues and aseptically transfer underlying darkened tissue to an antibiotic medium (Tsao 1970).

Pathogenicity tests were done at 20-0°C on surface-sterilized whole carrots and carrot slices. Five mm cork borer plugs of 14-day-old inoculum grown on cornmeal agar (CMA) were placed on freshly cut carrot slices. These surface-inoculated slices were incubated in sterile, moistened petri dishes. Inoculum plugs of a same size were placed at the bottom of 5 mm holes bored 10 mm deep at 3 positions along the length of whole carrots. Tissue plugs were replaced and inoculated areas

were tape-wrapped. The surface of inoculated whole carrots was moistened with sterile distilled water and placed inside tightly closed 1.5 mil polyethylene bags.

The potential pathogenicity of carrot isolates 980-1 and 1157 on alternate hosts was tested on selected tissues of 28 species of horticultural and legume plants. Inoculations involved inserting mycelium-bearing artificial media into plant tissue through toothpick and scalpel wounds. Inoculated host material was then incubated at 15°C and after 5 days results were recorded and reisolations attempted.

Contaminated field soil was suspected of being a possible source of inoculum for infection of immature carrots, particularly in low flooded areas. Experimental studies using pot-growing seedling carrots in inoculated soil were carried out in growth rooms at 20°C to test this hypothesis. In one experiment roots of seedlings up to 12 weeks of age were exposed to inoculated soil. Inoculum included blended sporangia-bearing cultures grown on CMA and introduced to pots through soil tubes. Other inoculum involved chopped infected carrot slices pushed into the soil near seedling roots. In another experiment 12 week-old seedlings were root-dipped in a slurry of sporangia-bearing inoculum before planting.

The possibility that feces from animals ingesting diseased carrots might spread inoculum was also investigated. Cattle manure and Richardson ground squirrel (*Spermophilus richardsonii* Sabine) fecal pellets were collected from animals fed Phytophthora-infected carrots. A slurry was prepared, using a 1:1 mix by volume, of feces and sterile sand covered in plastic dishes to a depth of 1-2 cm with sterile distilled water. Six day-old carrot and lettuce seedlings and leaf discs were floated as baits for 96 hours over the slurry incubated at room temperature.

The role of badly decayed carrots in disease transmission during storage was investigated. Affected carrots in commercial storage frequently produced sufficient aerial mycelium to bridge the space separating adjacent roots. During 2 trials each involving 6 replicates naturally-infected carrots from a commercial storage were bundled alongside healthy mature and immature roots. These were stored in moistened closed polyethylene bags and incubated at 5°C.

Fields of growers whose carrots were Phytophthora-infected in storage in 1970 and 1971 were sampled the following two growing seasons. Immature and mature carrots were lifted from the soil and placed in portable coolers for rapid transport to the laboratory. Following surface-sterilizing of underground parts, tissue was removed from taproots and rootlets then cultured on antibiotic media.

Results and discussion

Affected carrots from southern Alberta consistently yielded a slow-growing *Phytophthora* sp. on differential media. Edmonton area carrots yielded several isolates morphologically similar to those obtained from southern Alberta. Growth occurred readily on a variety of agar media on which non-septate mycelium with frequent knobby hyphal swellings was produced. Looping, skeining and a spidery mycelial growth often occurred. Sporangia formed abundantly on a variety of agar media without flooding. Sexual fruiting by oospores failed to occur on ordinary culture media. No Phytophthora oospores were found at any time in affected carrot tissue.

After 1 week incubation at 20°C inoculated carrot slices darkened slightly and became somewhat rubbery. Large liquid droplets appeared over the cut surface of core tissue. Three days later, infected carrot slices became quite soft and darkened noticeably. Within 1 week, whole inoculated carrots developed a soft water-soaked shiny appearance adjacent to cork borer plugs. A dense white weft of mycelium gradually developed over the darkened surface of infected tissue.

After 2 weeks incubation at 15°C inoculated slices and whole carrots developed symptoms similar to those which appeared within 1 week at 20°C.

Within 6 weeks at 5°C inoculated material (Fig. 1B) developed obvious rubbery brown rot symptoms. After 17 weeks incubation smaller carrot slices (Fig. 1C) were badly decomposed.

At 0°C noticeable darkening of affected tissue was visible within 7 weeks, following inoculation. Typical symptoms were well established after 13 weeks incubation but surface mycelium developed sparsely.

In each of the inoculation tests the fungus was recovered from darkened areas of affected tissue plated on an antibiotic medium.

Results of inoculating 28 other plant species indicated that the fungus has a wide host range. Positive results were obtained on ripe apples, green pears, bean pods, broccoli flower stalks, Brussels sprouts, cabbage stems, cauliflower curd and stems, cucumber fruits, pea pods, pepper fruits, potato .tubers, radish roots, turnip roots and tomato stems and fruits. No infection followed inoculation of clover seedlings, beet roots, parsnip roots, and celery stalks.

None of the growth room pot-soil inoculations resulted in infection, even when carrot seedlings were flooded for 96 hours, following soil or root inoculation.

The fungus was not recovered from any test animal fecal slurry baits nor from antibiotic media smeared with test animal feces. The fungus was recovered from control samples involving "seeded" sterilized feces used as apple plugs and as plate smears. It was also recovered from lettuce leaf discs floating in petri dishes over a "seeded" fecal slurry.

Forty percent of previously-healthy carrots placed in contact with diseased carrots in moistened closed bags appeared brown and glistening (Fig. 1D) within 6 weeks. Aerial mycelium, although sparser than that

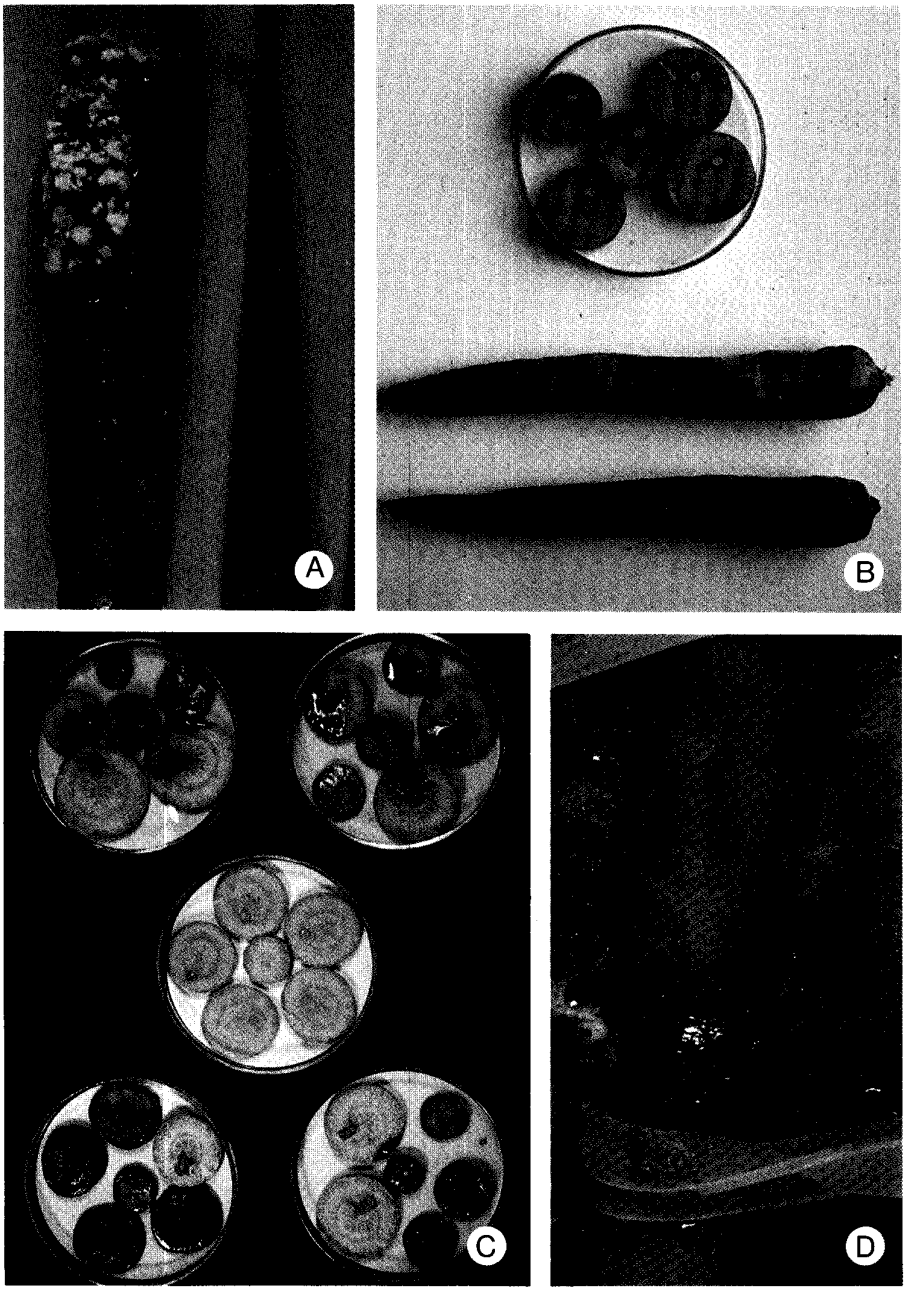

Figure 1. (A to D) Symptoms and signs of rubbery brown rot of stored carrots. (A) Dark brown discoloration is often accompanied by development of dense white mycelium. (B) Effects of artifical inoculation of whole carrots and slices. (C) A shiny liquid surface develops on infected carrot slices (control plate in centre). (D) Rot has spread from naturally-infected carrot (left) to immature and mature roots (right).

produced under natural storage conditions, nevertheless spread from carrot to carrot. The rubbery brown rot extended inward to a depth of 2-5 mm on newly-infected roots. isolates obtained from them were identical to those from the naturally-infected host. In some cases, a ***Pythium*** sp. was isolated from the original carrot and was transmitted singly or jointly to the adjacent host. When this occurred aerial mycelium was more dense and flocculent than with the carrot infected with ***Phytophthora*** alone.

Field-sampled carrots from which root tissue was plated in the laboratory yielded no ***Phytophthora.*** The pathogen was not detected during weekly sampling beginning August 15, 1971. Nor was infection found in roots examined during the growing season of 1972.

Symptoms associated with Rubbery Brown Rot of carrots in Alberta are similar to those reported for the disease involving ***P. cactorum*** or ***P. megasperma.*** The species involved in our isolates, however, differs from these 2 species in several respects. Most noticeable is the absence of oospore production by the Alberta carrot Phytophthora in infected tissue or in cultures on ordinary media. Other differences are growth patterns and growth rates, as well as the knobby appearance of mycelium in our isolates. Species identification may not be achieved until the fungus is induced to reproduce sexually.

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