

Review Article

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## Characterization and Identification of *Alternaria* spp. Causing Foliar Blight and Black Rot in Carrot

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### ABSTRACT

Carrot (*Daucus carota* L.) of plant family Apiaceae is a most popular and commonly used vegetable worldwide because of its multiple uses. This crop suffers greatly due to a number of diseases from seedling to maturity stage in which the diseases caused by *Alternaria* spp. are one of them. Two types of diseases occur in serious farm on this carrot crop, one is the *Alternaria* leaf (foliar) blight caused by *Alternaria dauci* and the other one, *Alternaria* black rot in which two species, *Alternaria radicina* and *A. carotiincultae* are involved in the causation of this disease. The symptomatology and etiology of both the diseases have been described and differences in symptoms of diseases and morphological characters of pathogens have been made critically. Based on the most distinguishing characteristic features of all the three causative species of *Alternaria*, a very simple and feasible key has been framed for their ready identification.

#### Keywords

Carrot, Leaf blight,  
Black rot,  
*Alternaria* spp.

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### Introduction

Carrot (*Daucus carota* L.) is one of the popular and commonly consumed tap root vegetables. It is a rich source of vitamin A (carotene). Carrot is grown all over India. It is taken raw as well as in coked form and is made into pickles and sweetmeat. Carrot juice is some times used for colouring butter

and other foods. The main constraint in increasing the production of this important vegetable is losses caused by diseases. Carrot suffers from many diseases (Walker, 1952; Chup and Sherf, 1960; Pryor, 2002). The leaf spot and blight and black rot of diseases caused by *Alternaria* spp. are very destructive and cause maximum losses in comparison to other major diseases of carrot

(Farrar *et al.*, 2004). Sometimes it becomes difficult to diagnose the disease in the field and to identify the associated causative *Alternaria* species correctly.

Three species of *Alternaria* viz., *A. dauci*, *A. radicina* and *A. carotiincultae* are responsible to cause leaf blight and black rot in carrot crop. Except the preliminary reports of the occurrence of species of *Alternaria* associated with carrot crop, detailed information is not available in India on clear and distinct symptomatology, etiology of the causative pathogens and their distinguishing characters for species differentiation and host-range of pathogens.

*Alternaria* leaf spot caused by *Alternaria dauci* (Kuhn) Groves and Skolko, is probably the most common and destructive disease of carrot world-wide (Pryor, 2002; Kumaret *al.*, 2013).

Meier *et al.*, (1922) and Lauritzen (1926) reported that the disease was mistakenly attributed to the fungus, *Sporidesmium exitiosum* (Kunh) v. *dauci* (Kuhn) (Syn. *Alternaria dauci*), the causal agent of *Alternaria* leaf blight. In the United States, the disease was first reported in 1918 on Long Island, NY, and in Washington, D.C., U.S.A. where it caused significant losses in carrot held in cold storage and in transit.

Meier *et al.*, (1922), Neergaard (1945) and Ellis and Holliday (1972) observed that black rot of carrot caused by *Alternaria radicina*, occurs in most carrot growing regions of the world.

### **Leaf blight**

The *Alternaria* disease of carrot was first reported in Germany in 1885 and later the leaf blight caused by *A. dauci* became a wide spread pathogen with a range that

extended from Israel (Netzer and Kenneth, 1970), Florida, USA (Strandberg, 1983), Canada (Arcelin and Kushalappa, 1991) to many parts of world (Farrar *et al.*, 2004) including India also (Roy, 1969; Kushwaha *et al.*, 2016) and other countries like Netherlands, New Zealand, Italy, Puerto Rico etc. (Woudenberg, 2014).

Symptoms begin on carrot leaflets and petioles as small necrotic lesions, which are often surrounded by a chlorotic halo (Walker, 1952). Under optimal conditions for *Alternaria* leaf blight, lesions can coalesce and blight the entire leaf. Typically *A. dauci* sporulates readily on diseased tissues (Strandberg, 1977 and Langenberg *et al.*, 1997; Farrar *et al.*, 2004; Kushwaha *et al.*, 2016) (Table 1).

Infection occurs initially on mature leaves, where lesions can merge, resulting in total leaf necrosis. Younger leaves are rarely affected. As the disease progresses, the lesions surrounding the infected areas exhibit chlorosis. Entire infected leaflets shrivel and die. The rapid loss of colour of carrot leaves following infection by *A. dauci* may be caused by toxins, known to be produced by *Alternaria* sp. (Kohmoto *et al.*, 1991).

Narain and Srivastava (2004), Narain *et al.*, (2020) reported that affected leaves first turn yellow then become brown or black and in severe infection the whole top is killed in infection with *Alternaria dauci*.

Although foliar symptoms are the most common, *A. dauci* can also infect the inflorescences, seeds and developing seedlings (Soteros, 1979 and Pryor, 2002). Lesions on the buds and flower parts can lead to infection of developing seeds (Soteros, 1979). Mohanty (1961), Roy (1969) and Singh *et al.*, (1975) recorded the

disease from India. The disease is seed borne in nature (Scott and Wenham, 1972; Puttoo, 1973; Lambat *et al.*, 1985; Strandberg, 1988).

*Alternaria* blight of carrot (*A. dauci*) normally appears severely in the month of February in India which increases or decreases with relative humidity and prevailing temperature (Kushwaha *et al.*, 2016). In the areas where carrot is grown sequentially, the disease causing pathogen survives saprophytically on diseased plant residues and forms the major source of primary inoculum (Pryor *et al.*, 2002).

### **Causal organism**

The disease was first described in Germany in 1855, when it was reported causing sporadic disease losses in several Northern European countries (Kuhn, 1885). At that time the causal agent was identified as *Sporidesmium exitiosum* var. *dauci* (Kuhn, 1885). It is well established that the blight of carrot is caused by *Alternaria dauci* (Kuhn) Groves and Skolko (1944).

The other possible synonyms were : *Polydesmus exitiosus* var. *dauci* (Kuhn) Kuhn, 1858; *Macrosporium dauci* (Kuhn) Rostrup, 1888; *Alternaria brassicae* var. *dauci* (Kuhn) Lindau, 1908; *Alternaria porri* f. sp. *dauci* (Kuhn) Neergaard, 1945; *Macrosporium carotae* Ellis & Langlois, 1890; *Alternaria carotae* (Ellis & Langl.) Stev. & Wellman, 1944; *Alternaria poonensis* Raghunath, 1963 (Woudenberg *et al.*, 2014).

### **Black rot**

Black rot of carrot is also an important disease of carrot roots. Black rot is characterized by dry, black, sunken lesions on carrot roots but under optimal disease

conditions, the causative agent spreads from crown to the canopy and may cause foliar blight also (Kumar *et al.*, 2013).

Black rot of carrot is caused by two species of *Alternaria* viz., *A. radicina* and *A. carottincultae*, which are closed to each other in causation of disease symptoms and in their morphological characters.

### **Symptoms produced by *A. radicina*.**

The black rot of carrot was reported by Meier *et al.*, (1922). Neergaard (1945) observed that *Alternaria radicina* infects carrot roots both in the field and in post harvest storage. The fungus produces large, black, sunken lesions along the root and under moist storage conditions, it spreads easily from carrot to carrot (Coles and Wicks, 2003).

The disease is characterized by black necrosis lesions on carrot leaf, petioles, crowns and tap root. In severe infections, foliage and roots may completely decay (Walker, 1952).

The decayed tissues become greyish black to jet black due to presence of masses of spores. On the stem, the fungus causes black sunken lesions of irregular to circular outline. Typically, the fungus infects the bases of petioles, resulting in a black ring of decay around the top of the tap root that reduces carrot quality.

Extensive petiole infection also results in excessive breakage of weakened, rotten petioles during mechanical harvesting, which may lead significant crop loss. The occurrence of disease, its effect on carrot and symptom variation were reported from different parts of the continents as the disease is considered very serious world wide. (Meier *et al.*, 1922; Laurantzen, 1926;

Neergaard, 1945; Grogan and Snyder, 1952; Maude, 1966; Scott and Wenham, 1972; Neergaard, 1977, Murtaza *et al.*, 1988; David, 1988; Saude and Housbeck, 2006). Since the fungus is seed borne, the disease cycle often begins with the planting of *A. radicina* infested seed (Soteris, 1979; Murtaza *et al.*, 1988). Pryor *et al.*, (1998) have established the fact that *A. radicina* is also soil borne pathogen being its occurrence in California (USA) carrot field.

### **Causal organism**

Black rot of carrot was first described in 1888 as a common disease of carrot in Denmark and other northern European countries (Rostrup, 1888). It is caused by *Alternaria radicina* Meier, Drechsler & Eddy 1922 (Syn. *Stemphylium radicinum* (Meier *et al.*, 1922) Neergaard 1939, *Pseudostemphylium radicinum* (Meier *et al.*, 1922; Subramanian 1961; Ellis and Holliday, 1972).

### **Symptoms produced by *A. carotiincultae***

*A. alternaria radicina*, *A. carotiincultae* cause similar disease symptoms in carrot and have nearly identical morphology. Similar to *A. radicina*, it has been reported strongly pathogenic on carrot, infecting crown, root and tissue and can be recovered from commercial lots of carrot (Park *et al.*, 2008).

Symptoms range from small lesions to large ones of blackened tissues covered with dense grey mycelial growth. Lesions on foliage may also be present. Infestation of the fungus on mature carrot suggests the pathogen is soil borne and widely prevalent. Infected cold storage carrots harbour the pathogen (Coles and Wicks, 1999).

### **Causal organism**

Blackrot is also caused by another species, *Alternaria carotiincultae*. As a new species, it was first isolated from wild carrot in Ohio, U.S.A. and was given the new name by Simmons in 1995. In many respects it resembles with *A. radicina* and differences have been made in Table 2.

### **Host-range**

#### **Host range of *A. dauci***

*A. dauci* has been reported of wide occurrence on many hosts of family Apiaceae (Umbelliferous plants) causing more or less similar symptoms as on carrot and wild carrots (Neergaard, 1945; 1977; Netzer and Kenneth, 1969; Soteris, 1970).

Ellis (1971) included a number of hosts of *A. dauci* restricted only to the family Apiaceae. In an extensive survey carried out by Kushwaha *et al.*, (2016) in Uttar Pradesh, India, dill or sowa, coriander and fennel were observed to be infected by *A. dauci* apart from carrot also. Cross infectivity of *A. dauci* isolates from these hosts was positive and produced similar type of symptoms as of *A. dauci* associated with carrot to cause the leaf spot and blight.

#### **Host-range of *A. radicina***

Ellis and Holliday (1972), Tahvonen (1978), Wearing (1980), Tylkowsa (1992) and Rotem (1994) opined that *Alternaria radicina* is known primarily as a pathogen of carrot, responsible for root and crown disease but causing foliar blight under certain conditions. However, the fungus also has been reported to cause foliar blight of parsley, stalk/root rot of celery (Ellis, 1971) and is pathogenic on caraway, dill, fennel and parsnip (Ellis and Holliday, 1972).

**Host range of *Alternaria carotiincultae***

It is the species of the *Radicina* section. Other plant pathogens included in this group, are *A. radicina* pathogenic on carrot and *Alternaria petroselini*, *A. smyrnii*, and *A. selini*, all pathogenic on parsley, celery and or other Umbelliferous plants (Lawrence *et al.*, 2016) but *A. carotiincultae* is restricted only to carrot crop (Simmons, 1995).

**Morphological characters of isolates of *Alternaria* and their identification**

The genus *Alternaria*, the alternarioid hyphomycetes, comprises of a biologically,

ecologically and morphologically rich group of fungi, consisting of more than 200 species and these fascinating fungi have been divided into 27 sections.

The causative pathogen of *Alternaria* leaf blight of carrot (*A. dauci*) is included in largest Section of *Porri* which has larged conidia and longer beaks, 63 species *A. radicina* and *A. carotiincultae* are included in a small section *Radicina* consisting of only five species, all isolated from host family Apiaceae (Simmons, 2007; Lawrence *et al.*, 2016).

**Table.1** Comparative symptom differentiation of *Alternaria* spp. occurring carrot

On symptoms	<i>Alternaria dauci</i>	<i>Alternaria radicina</i>	<i>Alternaria carotiincultae</i>
Root	-	Dry, black sunken lesions on carrot root	Infecting crown, root with blackened tissue
Seedlings	-	Black, necrosis of seedlings, post emergence damping off occurs near the soil lines	Post emergence damping off of seedlings
Leaves	Infected tissue becomes dark brown to black surrounded by a chlorotic halo, lesions common on the leaflets	Small necrotic spots surrounded by a chlorotic margin may appear in severe attack	Lesions on foliage are not of common occurrence and if infected, leaf tissues are damaged
Petioles	Similar to lesions on leafblades	Black ring and decay at the point of petiole attachment	-
Flowers	Infection early produces non-viable seed due to flower infection	-	The disease becomes serious at flowering stage
Nature of disease	Both seed and soil borne	Seed and soil borne	Soil borne

The comparative study of carrot black rot and blight has been made by Hooker (1944) and Kushwaha *et al.* (2016).

**Table.2** Comparative differentiation in *Alternaria* spp. occurring on carrot

Morphological characters	<i>Alternaria dauci</i>	<i>Alternaria radicina</i>	<i>Alternaria carotiincultae</i>
<b>Conidiophores</b>	Olive brown, straight, erect septate with one or two geniculations	Simple or occasionally branched, straight, cylindrical, septate, pale to mid-brown or olivaceous brown	<b>Simple or occasionally branched, straight, mid-brown or olivaceous brown</b>
<b>Length</b>	Up to 80 $\mu$ m	Up to 200 $\mu$ m	<b>Upto 150 <math>\mu</math> m</b>
<b>Width</b>	6-10 $\mu$ m	3-9 $\mu$ m	<b>4-10 <math>\mu</math> m</b>
<b>Conidia :</b>			
<b>Conidia formation</b>	Solitary occasionally in chain of 2	2 or rarely 3 in chain	<b>Chains of 2 to 4</b>
<b>Shape</b>	Ellipsoid to obclavate	Ellipsoidal, obclavate or obpyriform	<b>Broadly oval or ellipsoid</b>
<b>Colour</b>	Dark olive brown	Dark olive brown to natal brown	<b>Dark olive brown</b>
<b>Cross-septa</b>	7 to 11	2 to 5	<b>5-11</b>
<b>Longi-septs</b>	1 to 5	1 to several	<b>1-3</b>
<b>Length</b>	60-100 $\mu$ m	27-57 $\mu$ m	<b>Ellipsoid-60-80 <math>\mu</math> m, oval-40-60 <math>\mu</math> m</b>
<b>Width</b>	15-25 $\mu$ m	9-27 $\mu$ m	<b>Ellipsoid-15-20 <math>\mu</math> m, oval-20-23 <math>\mu</math> m</b>
<b>Beak :</b>			
<b>Length</b>	80-250 $\mu$ m	-	-
<b>Width</b>	5-7 $\mu$ m	-	-
<b>Cross septa</b>	4-8	-	-
<b>Growth rate on PDA</b>	<b>Moderate</b>	<b>Moderate</b>	<b>Greater</b>

The morphological characters of the species of *Alternaria* causing leaf-spot and blight (*A. dauci*) and black rot (*A. radicina* and *A. carotiincultae*) are as under:

### Section - Porri

#### *Alternaria dauci* (Kuhn) Groves and Skolko

Conidia are produced in abundance on erect conidiophores. In culture, hyphae are subhyaline to olive brown and septate.

*Conidiophores* are olive brown and straight to flexuous with a single terminal or one to two geniculate conidiogenous sites. *Conidia* are typically borne singly, but occasionally a secondary conidium is produced.

Conidia are medium to dark olive-brown, long ellipsoid to obclavate, 60-100 x 15-25  $\mu$  m (spore body), with 7 to 11 trans-septa and 1-5 longi-septa. Mature conidia are rostrate with a terminal *filamentous beak*, 80-250 x 5-7  $\mu$  m, tapering distally, occasionally with a single lateral branch up to 100  $\mu$  min length.

## Section - *Radicina*

### *Alternaria radicina* (Meier) Drechsler and Eddy

The colonies growing as dark blackish brown to black in colour. *Conidiophores* arising usually singly from hyphae, simple or occasionally branched, straight, cylindrical, septate, pale to mid brown or olivaceous brown, up to 200  $\mu$ m long, 3-9  $\mu$ m thick, with 1 or several conidial scars. *Conidia* solitary or in chains of 2 or rarely 3, and are typically dark olive-brown to natal brown, very variable in shape, often ellipsoidal, obclavate or obpyriform with 1 or several longitudinal or oblique septa, sometimes constricted at the septa, 27-57 (39)  $\mu$ m long, 9-27 (19)  $\mu$ m thick in the broadest part.

Two to five trans-septa and one to three longi-septa in any or all segments, except basal and optical segments, which usually are free of septa. *Beaks* are almost lacking.

### *Alternaria carotiincultae* Simmons

*Colonies* growing as dark brown to black in colour. *Conidiophores* arising usually singly, simple or occasionally branched, straight, septate mid-brown or olivaceous brown, upto 150  $\mu$ m long, 4-10  $\mu$ m thick with scars. *Conidia* are formed in chains of 2 to 4, they are smooth, broadly oval; 40-60 x 20-23  $\mu$ m or ellipsoid, 60-80 x 15-20  $\mu$ m with 5-11 transverse septa and 1-3 longitudinal septa. *Conidia* are without beak. Greater growth rate in culture (PDA).

A comparative morphological characters of all the three species of *Alternaria* associated with carrot has been presented in Table 2.

*Alternaria dauci* is quite different from *A. radicina* and *A. carotiincultae* in

morphological features because of larger size of conidial length and having long filamentous beak (upto 250  $\mu$ m) but differentiation between *A. radicina* and *A. carotiincultae* is particularly difficult because of their resemblance and being both the carrot pathogens.

*A. carotiincultae* differs slightly from *A. radicina* in having

A greater average conidium length;

A lower percentage of obovoid and sub-spherical conidia; and (iii) a greater number of conidia formed in chains of two, and sometimes three (Simmons, 1995, 2007). It is more aggressive pathogen on carrot than is *A. radicina* (Pryor and Gilbertson, 2002). *A. dauci* and *A. radicina* have been reported to cause foliar blight of many hosts of family Apiaceae while *A. carotiincultae* being restricted only to cause black rot of carrot.

Based on the most distinguishing characteristic features simple and feasible key has been framed for ready and correct identification of *Alternaria* spp. associated with carrot crop.

### Key to *Alternaria* species parasitic on carrot

#### Conidia without beaks (unbeaked)

Conidia variable in shape with many cross and longitudinal septa *A. radicina*

Conidia broadly oval or ellipsoid with more number of cross septa and greater growth rate on PDA *A. carotiincultae*

#### Conidia having beaks (beaked)

Conidia larger, ellipsoid to obclavate with longer and branched beaks *A. dauci*

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