Review Article

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Diagnosis of foliar diseases of Brassicaceous hosts caused by *Alternaria* spp. in India

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Abstract

Brassicaceous hosts (crucifers) constitute the source of cooking oils, high quality of vegetables and ornamental plants. Twelve plants (hosts) of the family Brassicaceae were found to suffer from the attack of five species of genus *Alternaria.* The symptoms caused by different species of *Alternaria,* symptom differentiations, morphological characters of all the five causative fungi and their comparative differentiation and the simple key for their ready and correct identification have been given in this communication.

Keywords-*Alternaria alternata, A. brassicae, A. brassicicola, A. cheiranthi, A. raphani,* Brassicaceous hosts, diagnosis & disease.

Introduction

Oilseed crops and vegetables play an important role in the national economy owing to their oil content and nutritive value and virtually they form the essential contituents of human diet. Members of the family Brassicaceae are bestoved with their significant role in this regard. Oil yielding (oleiferous) crops like rapeseed, mustard, rai and raya are the main source of oil for cooking purposes. The Brassicas are the backbone of the vegetable garden. They include major cole crops like cauliflower, cabbage and knol khol which are commonly grown in India and European countries. Besides these, there are a number of vegetable crops included in family Brassicaceae like radish, turnip, broccoli, brussels, Chinese cabbage etc. apart from the ornamental plants *viz.,* candytuft, Chieranthus, stock and *Motthiola* species.

These 12 oilseed crops, vegetables and ornamewntal plants included in the family Brassicaceae commonly called as "Crucifers" (Table 1) suffer greatly due to attack of five species of *Alternaria viz., A. brassicae, A. brassicicola, A. raphani, A. alternata* and *A. cheiranthi* (Neergaard, 1945; Changsi and Weber, 1963, Rao, 1977 and Narain, 1986).

The disease is known by many names: Alternaria leaf spot, Alternaria pod spot, Alternaria blight, Alternaria dark leaf spot, block spot and in early stage as "damping off" (Sangwan and Mehta, 2007). The seed production of Brassicas has been reported to be greatly reduced by the attack of these diseases which invade the curds, heads and siliquae and the caustive

pathogens penetrate the seeds besides damaging the assimilatory tissues of the leaves and stems (Chahal *et al.,* 1977; Chahal, 1981; Kadian and Saharan, 1983, 1984; Prasad *et al.,* 2003; Prasad and Narain, 2007). Alternarioses often occur on older leaves, since they are closed to the soil and are more rapidly infected as a consequence of rain splash or wind blown rain (Chupp, 1925; Chupp and Sherf, 1960; Singh, 1999).

Among the four species of *Alternaria* infecting vegetables and oil yielding crops, *A. brassicae* is more destructive ones and occurs more frequently (Ansari *et al.,* 1990 and is the representative species infecting Brassicaceous hosts (Narain and Kant, 2008, Narain *et al.,* 2016). *A. brassicae* and *A. brassicicola* have been reported from every continent on Crucifers (Ellis, 1971; Verma and Saharan, 1994).

Table 1 -*Alternaria* spp. associated with Brassicaceous hosts

Hosts	*Alternaria* spp.
A. Vegetables: 1.Cabbage (*Brassica oleracea* var. *capitata* L.)	*Alternaria brassicae* *Alternaria brassicicola*
2 Cauliflower (Brassica oleracea var. botrytis L.)	*Alternaria brassicae* *Altern aria brassicicola* *Alternaria raphani*
3 Radish (*Raphanus sativus* L.)	*Alternaria brassicae* *Alternaria raphani* *Alternaria alternate*
4 Turnip (*Brassica rapa* L.)	*Alternaria brassicae* *Alternaria raphani*
5 Knolkhol (*Brassica oleracea* var. *caulorapa* L.)	*Alternaria brassicae* *Alternaria brassicicola*
6 Broccoli (*Brassica oleracca* var. *italica* L.)	*Alternaria brassicae* *Alternaria brassicicola* *Alternaria raphani* *Alternaria alternate*
B. Oilseed crops- 7. Rapeseed/mustard (*Brassica juncea*/*B.* campestris)	*Alternaria brassicae* *Alternaria brassicicola* *Alternaria raphani*
8. Raya (*Eruca sativa*)	*Alternaria brassicae*
C. Ornamental plants : 9. Candytuft (*Iberis amara* L.)	*Alternaria brassicae* *Alternaria raphani*
10. Wallflower (*Cheiranthus cheiri* L.)	*Alternaria brassicae* *Alternaria cheiranthi*
11. Matthiola (*Matthiola incana*)	*Alternaria brassicae* *Alternaria raphani*
12. Lepidium (*Lepidium sativum*)	*Alternaria raphani*

Symptomatology

The disease appears mainly from the seedling stage on Brassicaceous vegetables and oleiferous crops. Symptoms caused by *A. brassicae* initially start from margin of leaves or at the trip and spread inward. The dark brown irregular spots are accompanied by characteristic "yellow halo" appearance and have distinct or indistinct zonations, which increase in size in concentric manner. Two or more spots may coalesce to form bigger spots. In well-advanced stage, some of the spots are covered with dark olive green mass of the fungal spores (Changri and Weber 1963; Thomas, 1984; Narain, 1986; Singh, 1999; Gupta and Basuchaudhary, 1992).

The leaf spot disease of cauliflower, cabbage, knol khol and broccoli caused by *Alternaria brassicicola* are circular to elliptical and olivaceous in colour which vary from 4-10 mm in size. In case of severe infection, several lesions coalesce to cover larger area. Severely infected leaves show burning effect, which ultimately dry up and may fall prematurely (Chupp, 1925, Chupp and Sherf, 1960, Ellis, 1971; Singh, 1999).

The symptoms in case of Alternaria leaf spot of cauliflower, radish, turnip, broccoli, candytuft, Matthiola and Lepidium caused by *A. raphani* are brown to dark brown patches starting from margin of leaves, which develop inward in irregular fashion. The affected areas soon turn blighted and wither (Neergaard, 1945, Narain and Sakena, 1975; Narain *et al.,* 1982; Sharan *et al.,* 2002).

The symptoms of Alternaria leaf spot of radish and broccoli caused by *A. alternata,* initially appear as minute dark brown lesions which start from margin and centre of leaves and at later stage of disease development, a number of spots coalesce to form the irregular dark brown patches (Suhag *et al.,* 1985).

The leaf spots produced by *A. cheiranthi* only on wallflower (*Cheiranthus cheiri*) appear in the beginning as small dots, scattered on leaf surfaces. The mature spots are variable in size, 2-8 mm in diameter, dark brown with yellow margins and distinct zonations and abundant suppuration (Neergaard, 1945; Narain and Singh, 1981).

The symptoms caused by different species of *Alternaria* on different Brassicaceous hosts have close resemblance with that described by Chupp (1925), Chupp and Sherf (1960), Changsri and Weber (1963), Narain and Saksena (1975), Narain *et al.* (1982), Narain (1986), Gupta and Basuchaudhary (1992) and Chand *et al.* (2007).

Alternaria brassicicola has been reported to be pathogenic on white cabbage, cabbage, knol-khol and radish (Rao, 1977). Saharan, *et al.* (2002) reported that *A. raphani* isolated from radish was pathogenic to a number of Brassicaceous hosts and parasitized the vegetable crucifers as well as oil crops (Suhag *et al.,* 1985).

The comparative symptom differentiation of *Alternaria* spp. occurring on Brassicaceous hosts has been presented in Table 2.

Table 2.Comparative symptom differentiation of Alternaria diseases occurring on Brassicaceous hosts

Symptoms on	Alternaria brassicae	Alternaria brassicicola	Alternaria raphani	Alternaria alternata	Alternaria cheiranthi
Leaves	Spots dark brown to black with halo chlorotic tissues, 0.5 to 12 mm in diameter and in concentric circle	Numerous, dark brown to black spots, 4-10 mm in diameter, zonate, lesions with sooty black appearance.	Spots dark brown or black, 3-8 mm in size, raised with distinct or indistinct zonations.	Spots minute to large, dark brown in pathches, often coalescing to form irregular dark brown patches.	Spots minute to large, almost circular, scattered on the leaf surfaces, with distinct zonations and abundent sporutation.
Stems	Dot like linar or elongated lesions	Spots/lesions numerous, dark brown to black	Lesions dark brown to black, in linear manner	Lesions dark brown and elongated	Lesions variable in size, dark brown in colour
Siliquae	Linear, elongated or dot like lesions, without concentric rings.	Appearance of minute dark brown to black spots.	Irregular brown to black lesions.	Lesioins coalescing and splitting type.	-
Heads/ inflorensces	Dark brown spots in beginning which increase in size with sporulation.	Spots brown to black in colour with sooty appearance.	Spots dark brown to black in colour.	Cankers may form just below on nearly mature heads.	Spots dark brown to black in colour.

Etiology

Morphological characters of *Alternaria* spp.

***1. Alternaria brassicae* (Berk.) Sacc.** (*Michelia*,**2**: 129, 1880)-*Colonies* fast growing, amphigenous, usually in beginning pale olive and later turn into dark olivaceous in colour with abundant sporulation; *Mycelium* septate, branched, yellowish brown, smooth, 4-8 µm thick; *Conidiophores* arising in groups of 2-10 or more from hyphae, emerge through stomata, usually simple, erect, geniculate, septate, grayish to olive in colour, swelling at its base, measuring 15-150 x 5-10 µm in size, bearing one to several small but distinct conidial scars; *Conidia* solitary or occasionally in chains of 3-4, straight or slightly curved, obclavate, rostrate with 5-10 transverse and 0-8 longitudinal or oblique septa, olive or grayish olive in colour and 40-150 x 15-30 µm in size; *Beak* usually pale brown, short, cylindrical, 10-130 µm in length and 3-8 µm in width.

***2. Alternaria brassicicola* (Schw.) Wiltshire** (*Mycol. pap.*, **20**: 8, 1947)-*Colonies* growing as dark olivaceous to dark blackish brown, velvety; *Mycelium* septate, branched, hyaline at first, later brown or olivaceous brown, inter and intracellular, smooth, 25-75x1.5-7.5 µm in size; *Conidiophores* produced either singly or in groups of 2-12, emerging through stomata, usually simple, erect or curved, occasionally geniculate, more or less cylindrical but often slightly swollen at the base, septate, pale to mild olivaceous brown, smooth, 20-75 µm long and 4-8 µm thick; *Conidia* mostly in chains of upto 20 or more, usually tapering slightly towards apex, obclavote, basal cell round, the apical cell being more or less rectangular or resembling a truncate cone with 2-10 cross and 0-6 longitudinal septa, often constricted at the septa, pale to dark olivacecous brown, smooth or becoming slightly verriculose with age and measuring 20-120 µm in length and 7-25 µm in width; *Beak* usually non-existent.

3.*Alternaria raphani* Groves and Skolko (*Can. J. Res., Sect. C.* **22**:227, 1944)-*Colonies* grow faster, centre sometimes raised and light brown to dark brown in colour; *Mycelium* septate, branched, hyaline at first later become olive buff in colour, 2-7 µm thick, some times swollen to form chlamydospores in chains or in groups; *Conidiophores* simple or occasionally branched, septate, olivaceous brown, 2.5-8.0x25-150 µm in size some times swollen slightly at tip and usually with a single conidial scar; *Conidia* commonly in chains consisting of 3-4, obclavate or ellipsoidal in shape, dark golden brown to olivaceous brown, smooth or some times minutely verruculose with 3-7 transverse and often a number of longitudinal or oblique septa, constricted at septa and 20-60 µm long and 10-30 µm thick; *Beaks* of conidium smaller than that of *A. brassicae*, but longer than that of *A. alternata*.

4.*Alternaria alternata* (Fr.) Keissler (*Beih. Bot. Zbl.,* **29**: 434, 1912) - *Colonies* fast growing, usually black or olivaceous black with abundant sporulation; *Mycelium* septate, branched, olive buff in colour, 2.5-9.5 µm in width; *Conidiophores* usually arise singly or sometimes in groups, mostly simple, septate, straight, brown or variously curved and geniculate, pale to mid olivaceous brown, measure 24.5-68.5 µm in length and 3.50-7.25 µm in width; *Conidia* formed in long and often branched chains, varying in shape and sizes, dark brown in colour, smooth to verruculose and 8.50-53.50 x 5.0-21.50 µm in size, *Beaks* of conidia usually short, conical or cylindrical but never equal in the length of conidium, often one third or half of the spore body, usually lighter in colour, 10-45.5 µm in length and 1.5-6.5 µm in width and 0-3 septate.

5.*Alternaria cheiranthi* (Libert) Wiltshire (*Trans. Br. mycol. Soc.,*18:135-160, 1933)-*Colonies* growing fast, light grayish, olive to dark grayish olive with abundant sporulation; *Mycelium* septate branched, whitish to greenish gray, ageing to dark olive, septate, 2-8µm wide; *Conidiophores* dark olive-buff to buffy brown, septate, produced singly or in groups, mostly simple but sometimes branched also with prominent scars at apex, 3.5-8.0x25-153 µm in size; *Conidia* formed singly, sometimes in chain of 3-4, smooth, light olive to golden brown, oval to ellipsoidal or elongated, ovoid to pyriform often with rounded base, provided wth 4-12 transverse and 2-10 longitudinal septa, 10.5-25.0x15-95 µm in size; *Beaks* often of same colour of spore body, 4.5-45 µm in length and 3.0-7.5 µm in width with 0-3 cross septa and prominent scars. Based on the cultural and morphological characters of all the five species of *Alternaria,* a very simple and feasible key has been framed for ready identification of *Alternaria* spp. associated with Brassicaceous oilseed, vegetables and ornamental plants.

Key to *Alternaria* spp. parasitic on Brassicaceous hosts

I.Conidia solitary or occasionally 3-4 in chains, obclavate, rostrate, tapering gradually into thick cylindric beaks..... *A. brassicae.*

II.Conidia in long chains, consisting of twenty or even more:

Conidia usually cylindrical, basal cells rounded and apical cell more or less rectangular and beaks usually almost non-existent .... *A. brassicicola*

Conidia usually polymorphic, often with short conical or cylindrical short beaks..... *A. alternata*

III.Conidia 3-4 in chains straight or curved, obelavate or ellipsoidal generally with short beaks:

(a) Conidia with limited number of cross & longi-septa, chlamydospores formed abundantly in culture .....*A. raphani*

(b) Conidia with numerous cross and longitudinal septa without chlamydospore formation culture .....*A. cheiranthi*

Table3. Comparative differentiation in *Alternaria* spp. occurring on Brassicaceous hosts

Morphological characters	***Alternaria brassicae***	***Alternaria brassicicola***	***Alternaria raphani***	***Alternaria alternate***	***Alternaria cheiranthi***
Conidiophores	Mild-pale grayish to olive, simple erect, swelling at base, geniuculate, septate.	Pale mild olivaceous brown, simple, septate, erect or curved.	Olivaceous brown, simple or occasionally branched, septate.	Olive brown erect, simple and septate.	Pale olive with scars, produced singly on in groups.
Length	15-150 µm	20-75 µm	25-150 µm	24.5-68.5 µm	25-153 µm
Width	5-10 µm	4-8 µm	2.5-8 µm	3.50-7.25 µm	3.5-8 µm
Conidia					
Conidial chain	Solitary or occasionally upto 4	Upto 20 or more	Upto 3-4	Upto 20 or more	Solitary or 2-3 in chains.
Shape	Obclavate rostrate	Obclavate	Obclavate or ellipsoidal	Polymorphic	Oval to ellipsoidal
Colour	Olive or grayish olive	Pale to dark olivacious brown	Golden brown to olivaceous	Dark brown	Dark brown
Cross septa	5-10	2-10	3-7	3-10	4-12
Longitudinal septa	0-8	0-6	0-5	0-8	2-10
Length	40-150 µm	20-120 µm	20-60 µm	8.5-35.5 µm	15-95 µm
Width	15-30 µm	7-25 µm	10-30 µm	5.0-21.50 µm	10.5-25 µm
Beak					
Length	10-130 µm	Non-existent	5-75 µm	10-45.5 µm	4.5-45 µm
Width	3-8 µm	-	2.5-6.0 µm	1.5-6.5 µm	3.0-7.5 µm
Cross septa	0-5	-	0-3	0-3	0-3

Morphological observations of all the five species of *Alternaria* made in culture (PDA) and in nature (host) with their comparative differentiation has been presented in Table 3.

All the five species of the genus *Alternaria* observed to be parasitic on 12 Brasicaceous hosts differ from each other on the basis of their mode of formation of spores (Groves and Skolko, 1994, Neergaard, 1945) and conidial morphology (Ellis, 1971; Khalid *et al.*, 2004; Chand *et al.,* 2007). In *A. alternata* and *A. brassicicola* long chains of conidia are formed but latter is without beaks (Ellis, 1968b). In *brassicae,* conidia are solitary or seldom in chains with comparatively larger conidia and beaks (Ellis, 1968a) but in *A. raphani* conidia are produced in short chains (3-4) and there is frequent formation of chlamydospores in culture (Atkinson, 1950; Narain and Saksena, 1975; Verma and Saharan, 1994). Conidia of *A.*

cheiranthi are quite different from other four species as they possess several cross and longi-septa (Neergaard, 1945).

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