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Morpho-physiological and Pathogenic variability among *Alternaria lini* and *A. linicola* causing Seedling and Leaf Blight of Linseed

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ABSTRACT: A total of 19 isolates including four *Alternaria linicola* and 15 *Alternaria lini* collected from different agro-ecological zones of Bihar were studied for morpho-physiological and pathogenic variability. In *A. linicola,* colony colour was found to be greyish-black to grey-white with smooth colony margin. The maximum spore size was found in ALC-2 (40.2-44.6 × 9.5-10µm) with up to 9-12 horizontal and 3-4 vertical septation. Days taken to sporulation was found maximum in ALC-1 (14 days) and minimum in ALC-4 (10days). Similarly, colony colour in *A. lini* was white or whitish grey to greyish black with smooth margin. Maximum spore size was found in ALN-14 (21.4-23.6 X 12.3-12.9µm) with a septation of 5-7 × 2-3. Days taken to sporulation was found maximum in ALN-1, 6 & 15 (16 days) and minimum in ALN-3 & 12 (11days). Maximum growth on potato dextrose agar (PDA) was achieved after two weeks of incubation. The mean mycelial dry weight of six isolates measured at different temperature conditions revealed that 25 °C was the most favorable condition for mycelium production (57.2mg). Among the different isolates, ALN 15 (44.2mg) was found to be performing better at all temperatures. Interestingly, the *A. linicola* isolates performed better at lower temperatures (15 °C). Similarly, the Relative Humidity (RH) of 90 per cent was found better for all the isolates tested except ALN-4 where maximum radial growth (37.3) was found at 80 per cent RH. The Detached leaf technique was found useful in differentiating the isolates and may be employed for screening of germplasm. Among the different isolates, ALN-4 isolated from lower leaves from the oil seed field of BAU farm was found more aggressive than other isolates.

Keywords: *Alternaria lini, A. linicola,* seedling blight, Linseed, Detached leaf assay.

INTRODUCTION

Linseed also referred to as flax (*Linum usitatissimum* L.), belongs to the family *Linaceae* and is an annual self-pollinated crop widely adapted to temperate climates of the world (Biradar *et al*., 2016). Flax seeds are a rich source of both edible and non-edible oil. It contains alpha-linolenic acid (ALA), a polyunsaturated fatty acid that has nutritional and other health benefits (Neil and Alister 2003). Apart from ALA, it is widely used as nutritional as well as functional food across the world due to its high content of 'omega- 3'fatty acid (Covington, 2004). Linseed is cultivated in over 2.2 million ha as a commercial or subsistence crop across 30 countries for industrial, food and feed purposes. India ranks third in the world in respect of acreage accounting for 14.8 per cent of the world production area and fourth in production contributing 6.57 per cent of the world production (Anon., 2014). Linseed is a *Rabi* season oilseed crop grown in India which is next in importance to rapeseed and mustard in area as well as production (Verma and Singh 2017). Bihar is an important state for linseed production, covering an area of 18,700ha and a production of 15,900 tons (Anon, 2014). The lower productivity of linseed is attributed to several biotic and abiotic stresses. Among them, seedling and leaf blight caused by *Alternaria lini* Dey and *A. linicola* Grooves and Skolko respectively, are considered serious threats to linseed production under hot and humid climate causing an estimated yield loss of 28-60 per cent (Singh and Singh, 2005, 2014; Reddy *et al*., 2009; Singh and Kerkhi 2010). *Alternaria linicola* causing seedling blight is known to be seed borne (David, 1991; Corlett and Corlett 1999) whereas, *A. lini*, known to infect all the aerial parts of plant producing air-born conidia is considered a more serious threat (Verma and Singh 2017). Bearing in mind, the involvement of seed borne and air-borne inoculum the use of resistant cultivar is considered as best management strategy. Understanding the variability of

the pathogen population is a prerequisite for the identification of stable sources of resistance. Considering the importance of the disease and lack of literature on pathogen variability the present study was conducted to elucidate the variability of *Alternaria* spp. causing seedling and foliar blight of linseed in Bihar.

MATERIALS AND METHOD

Isolation of fungi and pathogenicity test: Pathogen was isolated from seeds of Alternaria blight infected linseed crop of the previous year collected from Mokama, Bihar using the agar plate technique. Similarly, the infected plant tissues (cotyledonary leaves, true leaves, stems and buds) showing typical symptoms of alternaria blight collected from three agro-climatic zones of Bihar *viz*., Zone II, Zone IIIA and Zone IIIB were used for isolation of fungi using tissue isolation technique. Fungi were identified based on conidial morphology and pure cultures were obtained using single spore isolation method (Table 1).

The pathogenicity was proved on thirty days old plants grown in sterilized soil in pro trays covered with polythene bags by spraying with a spore suspension having a concentration of 1×10^3 spores/ml. The plants sprayed with sterile distilled water alone served as control. The observations were taken for the appearance and development of symptoms. The fungus was isolated from infected parts.

Morphological variability of *A. lini* & *A. linicola.*: Morphological characters *viz.*, colony colour, type of margin, colour of margin, mycelial growth and sporulation were measured. The length, breadth, colour and number of septa were recorded. Further, the morphological data *viz*., spore dimensions, septation, radial growth and days taken to sporulation, etc. were subjected to phylogenic analysis in 'R' statistical software and a dendrogram depicting the relationship based on similarity was developed.

Physiological variability of *A. lini* & *A. linicola.* Physiological studies were carried out on six representative isolates including one isolate of *A. linicola* and five isolates of *A. lini* at various degrees of temperature and relative humidity on potato dextrose broth (PDB) as a basal media. The growth of six isolates of *Alternaria* spp. was tested at 15°C, 20°C, 25°C, 30°C and 35°C for three weeks. After an ++incubation period, the dry mycelial weight and sporulation were recorded. *Alternaria* spp. were allowed to grow on the Petri dishes exposed to 60, 70, 80, 90 and 100 per cent relative humidity levels maintained using different concentrations of sulphuric acid (H_2SO_4) under desiccators at 25 ± 1°C for three weeks. Observations on colony diameter and sporulation were recorded.

Pathogenic variability: Six young healthy leaves of the *var*. Shubhra were inoculated with three weeks old pure culture of 19 isolates through 'Detached Leaf Technique' in the moist chamber. For 'Pin Prick Method' a spore suspension of concentration 5×10^6 spores/ml was used for inoculation. Observations were recorded at periodic intervals *i.e.*, 24, 48 and 72 hours of post inoculation (hpi) along with Disease Incidence (DI) and Lesion diameter.

$$\text{Disease incidence (\%)} = \frac{\text{No.of leisons formed}}{\text{No.of inoculations performed}} \times 100$$

RESULTS AND DISCUSSION

Morphological variability among *A. linicola* isolates. The four isolates of *A. linicola* formed colonies with raised and thick mycelium with smooth margins when grown on PDA at 25±1°C for seven days. ALN-1, 2 and 4 were found to produce greyish-black colony with white margins, whereas ALN-3 had a grey colony with white margin and colour of the substratum was black for all the isolates (Table 2). Among them, maximum radial growth was recorded in ALC-1(32mm) followed by ALC-2 and ALC-4 with 30mm radial growth and least was recorded in ALC-3 (28mm). The conidial size was found maximum in ALC-2 (40.2-44.6 × 9.5-10µm) with 6-8 horizontal and 3-4 vertical septation followed by ALC-3 (37.2-43.6 × 11-12.5µm) with septation 7-9 × 1-3 and ALC-4 (35.2-40.6 × 8.3-10.2 µm) having 6-7 × 3-4 horizontal and vertical septa. Spore dimensions were found minimum in ALC-1 (35.5-38.0 × 10-12.5µm) with 5-6 X 2-3 septa. *A. linicola* isolates took 10-14 days for sporulation where theleast time was taken by ALC-4 (10 days) followed by ALC-2 and ALC-3 (12 days) and maximum time was taken by ALC-1 (14 days) (Table 3). Earlier reports suggests that, the average size of conidia *A. linicola* is about, about 50 x 14 µm, including the beak (Ellis, 1971). Whereas, *A. lini* produces an air-borne flask shaped conidia having a size of 24 × 7µm including the beak (Dey, 1933). *A. linicola* is seed-borne pathogen characterized by having simple conidiophores occurring singly or in bundles (David 1991; Corlett and Corlett 1999).

Morphological variability among *A. lini* isolates. A considerable amount of variability was found among the fifteen isolates of *A. lini*. The colony colour ranged from white (ALN-2 and 11), whitish grey (ALN 1, 3 and 5), greyish (ALN-6), greyish white (ALN-7, 8, 9, and 13) to greyish black (ALN-4, 10, 12 and 14). Colony margin appeared as white in all the isolates except ALN-6 where it was grey. Colour of the substratum was black with a greyish margin (ALN -1, 2 3, 5, 7, 8, 9, 11 and 13) in the majority of the isolates but it was black in ALN-4, 6, 10 and 12. Among the 15 isolates maximum radial growth on PDA after one week of incubation at 25±1°C was recorded in ALN- 5 (34mm) followed by ALN-1 and 15 (33 mm). ALN-7, 8 and 14 had a radial growth of 32 mm followed by ALC-2, 4 (30mm) and least ALN-9 (25mm). Spore size ranged from 16.9-19.6 × 8.6-9.1µm (ALN-7) to 21.4-23.6 × 12.3-12.9µm (ALN-14). Maximum septation was recorded in ALN-11 (6-7 × 3-4) followed by ALN-10 (5-7 × 3-4) and the least was recorded in ALN-6 (3-4 × 1-2). Similarly, among the 15 isolates, maximum number of days for sporulation was 16 (ALN-1, 6 and 15) followed by 15 days (ALN-5 and 14), 13days (ALN-2, 8, 11, and 13). The least was 11 days (ALN-3 and 12) followed by 12 days as observed in ALN-4, 7,

9 and 10. Presence significant morphological variability among the *A. lini* was previously documented by Verma and Singh (2017). However, the present investigation also revealed considerable variability among *A. lini* causing seedling blight. The members of Alternaria genus are known to exhibit wide range of cultural and morphological variability across geographical locations and host plants (Goyal *et al*., 2011; Sharma *et al*., 2013; Lingwal *et al*., 2022).

Phylogenic relationship among various isolates based on morphological features. The dendrogram (Fig. 1) revealed two major clusters differentiating *A. linicola* (4 isolates) and *A. lini* (15 isolates). Under Cluster-1, four *A. linicola* isolates were divided into sub-clusters where ALC-1 and 4 were grouped in the first cluster, whereas, ALC-2 and 4 fell into a separate cluster. Among *A. lini* isolates, a total of two clusters were revealed. Cluster-2A included a total of five isolates *viz*., ALN-9, 11, 3, 10, and 13. Among them ALN-10 and 13 were found to have more resemblance. Under cluster 2B *A. lini* isolates were again divided into two sub-clusters. Sub-cluster 2A (i) included a total of four isolates *viz*., ALN-7, 8, 2 and 6 with maximum similarity between ALN-7 and 8. In cluster 2A (ii) a total of six isolates (ALN-14, 1, 5, 15, 4 and 15) were divided into two groups of 3 each. Among them, maximum similarity was seen between ALN-1 and 5. The clustering of isolates based on the morphological features of the isolates clearly indicates the presence of a large amount of variability in the pathogen population.

Grouping of isolates based on the morphological characters was evident in the phylogenic tree which indicates a good amount of variability. The present study is in accordance with the earlier description of about the pathogens involved in the disease (David 1991; Corlett and Corlett 1999). Considerable variability exists among the population of pathogenic Alternaria has been reported in various host pathogen combinations (Singh *et al*., 2015).

Physiological variability of various isolates of Alternaria infecting linseed. Six isolates *viz*., ALC 1, ALN-2, 4, 10, 15, 16 were selected for physiological variability tests.

Variability at various temperature levels: All six isolates exhibited various degrees of growth at different temperature regimes. The results indicate that, among the five different temperatures (15, 20, 25, 30 and 35°C), the isolates grew better at 25°C. The average dry mycelial weight of representative isolates at temperatures 15, 20, 25, 30 and 35°C was 23.2, 36.9, 57.2, 45.1 and 30.2 mg respectively, but the growth of *A. linicola* (ALC-1) was better at 15°C (31.4mm). The highest dry mycelial weight was recorded for isolate ALN-15 (71.4 mg) at 25°C (Table 4).

Variability at various levels of relative humidity (RH): Though there was no significant difference in the radial growth of isolates, the interaction effect between RH and the isolates was found significant. The average radial growth of isolates was found maximum at 90 per cent (36.9 mm) followed by 80 per cent with a mean colony diameter of 34.6mm. The least radial growth of all isolates was observed at 60 per cent RH (24.6 mm). The highest radial growth of 30.8mm was noticed in isolate ALN-4 at 80 percent RH and the least radial growth of 29.4 mm was observed for isolate ALN-15 followed by ALN 2 (29.8 mm) at 60 per cent RH. Interaction between isolates and RH levels on colony diameter weas found significant. Higher mycelial growth was recorded at 90 per cent RH in isolates ALN-4 (39.7mm) and followed by ALN-10 (36.7 mm). In general, *Alternaria lini* and *A. linicola* isolates recorded higher mycelial growth over a range of RH tested. Results indicate that there is not much difference in the adaptation to various RH levels, all the isolates show similar requirements for humidity *i.e*., 90 per cent is optimum for better radial growth (Table 5).

Earlier reports on the aspects of growth conditions of Alternaria blight of mustard support the results of the present investigation. Humpherson and Phelps (1989) reported a temperature range of 18-24ºC as an optimum temperature for sporulation of *Alternaria brassicae* and 20-30ºC for *Alternaria brassicicola* at which both the fungi produce spores at 12-14hours. Similarly, the field studies conducted by Sinha *et al*. (1992) revealed rapid Alternaria leaf blight development on Indian mustard at low temperature (8-12°C) minimum and maximum 21-26°C and high relative humidity (90%) with an annual average rainfall of 0.3mm. The study also inferred that disease intensity increased with the increasing plant age (21days to 71days) cultures ageing 15-35 days was more virulent than older inoculum.

Pathological variability of various isolates of *Alternaria* spp. infecting linseed. Disease incidence recorded at 24 hours indicate that maximum DI was recorded in the case of ALN-4 (22.2 %) which was statistically at par ALC-1 & 3, ALC-4 & 11. After 48 hours significant progress in the disease was observed and the maximum incidence was observed for ALN-1 (77.8 %) which was statistically at par with ALN-4 & 5 (66.7 %). The lowest DI was observed for ALC-1 (16.7 %), at par with ALC-2 (25.0%) followed by ALC-4, ALN-8 and ALN-15 (36.1 %). The highest DI at the end of 72 hours after inoculation was recorded in ALN-4 (97.2 %) which was statistically at par with ALN-1, 3 & 7 (91.7 %) followed by ALN-5, 11, & 15 (88.9%) while the least incidence was observed in ALC-1 (47.2 %). Among the *A. linicola* isolates, maximum incidence was recorded inALC-2 (75.0%) at par with the other two isolates *viz*., ALC-2 and 3 (63.9 %).

Lesion diameter was measured for each isolate to understand the aggressiveness of the isolate on linseed leaves. After 24 hours of inoculation, the maximum lesion diameter was found in ALN-14 (1.87mm). It was followed by ALN-11 (1.73 mm) and ALN-9 (1.67 mm), at par with ALN-15 (1.53mm). The least size of the lesion after 24 hours was recorded in ALC-3 (0.77mm) followed by ALC-1 and ALC-6 (0.83 mm) which were at par with ALC-2 and ALC-4 (0.90mm). After 48 highest lesion diameter was recorded in ALN-12 (5.53mm) followed by ALN-14 (5.13mm) and ALN-13 (4.90mm). The least size of the lesion was recorded under ALC-3 (2.23mm) at par with ALC-4 (2.30 mm) followed by ALC-1 (2.53mm) and ALC-2 (2.77mm).

After 72 hours, the highest lesion diameter was recorded in ALN-3 and ALN-4 (7.4mm), followed by ALN-13 (6.80mm), at par with ALN-11 (6.43mm). They were followed by ALN-9 (5.90mm) which is at par with ALN-14 (5.87mm). The lowest diameter of lesion at 72 hours was recorded in ALN-6 (4.57 mm) which was at par with ALC-1 (4.87mm) followed by ALC-3 (4.93mm).

Pathogenic variability among different isolates on leaves. The detached leaf and pod inoculation technique successfully produced the symptoms on the leaves in all the isolates indicating the suitability of the method for further studies. The difference in the ability of all isolates to cause disease was also evident from the results. The time taken for the appearance of lesions on leaves was about 12-24 hours of incubation at room temperature. Among the different isolates inoculated on leaves, *A.lini* isolates were comparatively more aggressive than *A. linicola* in producing disease as well as in lesion diameter. At the end of 72 hours of inoculation, maximum DI was recorded in ALN- 4 (97.2 %) which is statistically at par with ALN-1, 3 & 7 (91.7 %) followed by ALN-5, 11, & 15 (88.9%). The least incidence was observed in ALC-1 (47.2 %) which was significantly lower than the rest of the isolates. Lesion diameter, after 72 hours highest lesion diameter was noted under ALN-3 and ALN-4 (7.4mm) followed by ALN-13 (6.80mm). The smallest diameter of the lesion at 72 hours was recorded in ALN-6 (4.57mm) (Table 6).

Pathogenic variability among different isolates on pods. The highest disease incidence at the end of 72 hpi was found in ALC-3 (66.7 %), being at par with other *A. linicola* isolates. Among *A. lini* isolates maximum incidence after 72hpi was recorded in ALN-1, 4 & 15 (41.7%) at par with ALN-5, 7, 10 & 11. The incidence recorded for the remaining isolates was 29.2 % (Table 7).

The variability in the pathogenicity indicates that there is considerable adoption of *A. linicola* towards infection pods which supports the fact that the fungi is seed borne in nature. Similarly, the fungi is also known to cause seedling blight which is supported by the fact that, ALC isolates were found more adapted to lower temperatures in the present investigation. Similarly, *A. lini* isolates were found more aggressive on leaves and produced lesions more rapidly while ALN isolates were generally performing better under higher temperatures. Doullah *et al*. (2006), while conducting the pathogenicity of *Alternaria brassicicola* on *Brassica rapa* by three inoculation methods observed the detached leaf inoculation method most appropriate exhibiting symptom development within 24 hours of inoculation of the fourth true leaves. Gupta *et al*. (2013) also reported that the suitable temperature for the growth and sporulation of *Alternaria lini* was found to be 25°C.

Table 1: Sources of different isolates of *Alternaria* spp. Involved in leaf blight of linseed and their identity.

Isolates designation	Zone	District	Locality	Origin	Isolates identified
ALC-1	IIIA	Bhagalpur	Sabour	Seed	*Alternaria linicola*
ALC-2	IIIB	Mokama	Mokama	Seed	*Alternaria linicola*
ALC-3	IIIA	Bhagalpur	Sabour	Cotyledenary leaf	*Alternaria linicola*
ALC-4	IIIA	Bhagalpur	Sabour	Cotyledenary leaf	*Alternaria linicola*
ALN-1	IIIA	Bhagalpur	Sabour	Leaf	*Alternaria lini*
ALN-2	IIIA	Bhagalpur	Sabour	Lower leaf	*Alternaria lini*
ALN-3	II	Kishanganj	Kishanganj	Leaf	*Alternaria lini*
ALN-4	IIIA	Bhagalpur	Sabour	Lower leaf	*Alternaria lini*
ALN-5	IIIA	Bhagalpur	Sabour	Lower leaf	*Alternaria lini*
ALN-6	IIIA	Bhagalpur	Sabour	Bud	*Alternaria lini*
ALN-7	IIIA	Bhagalpur	Sabour	Pod	*Alternaria lini*
ALN-8	IIIB	Patna	Khusrupur	Leaf	*Alternaria lini*
ALN-9	IIIB	Patna	Khusrupur	Leaf	*Alternaria lini*
ALN-10	IIIA	Bhagalpur	Bhitti	Leaf	*Alternaria lini*
ALN-11	IIIA	Bhagalpur	Sabour	Middle leaf	*Alternaria lini*
ALN-12	IIIA	Bhagalpur	Sabour	Stem	*Alternaria lini*
ALN-13	IIIA	Bhagalpur	Sabour	Middle leaf	*Alternaria lini*
ALN-14	IIIB	Arwal	Arwal	Stem	*Alternaria lini*
ALN-15	IIIB	Jahanabad	Jahanabad	Leaf	*Alternaria lini*

Table 2: Cultural variability among different isolates of *Alternaria linicola* and *Alternaria lini* infecting linseed.

Sr. No.	Isolate No.	Colony colour	Colour of margin	Type of margin	Type of mycelial growth	Substratum
1.	ALC-1	Greyish black	White	Smooth	Raised&thick	Black
2.	ALC-2	Greyish black	White	Smooth	Raised& thick	Black
3.	ALC-3	Grey	White	Smooth	Raised&thick	Black
4.	ALC-4	Greyish black	White	Smooth	Raised&thick	Black
5.	ALN-1	Whitish grey	White	Smooth	Raised&thick	Black with Greyish margin
6.	ALN-2	White	White	Smooth	Raised& thick	Black with Greyish margin
7.	ALN-3	Whitish grey	White	Smooth	Raised&thick	Black with Greyish margin
8.	ALN-4	Greyish black	White	Smooth	Raised&thick	Black
9.	ALN-5	Whitish grey	White	Smooth	Raised&thick	Black with Greyish margin
10.	ALN-6	Greyish	Grey	Smooth	Raised& thick	Black
11.	ALN-7	Greyish white	White	Smooth	Raised&thick	Black with Greyish margin
12.	ALN-8	Greyish white	White	Smooth	Raised&thick	Black with Greyish margin
13.	ALN-9	Greyish white	White	Smooth	Raised&thick	Black with Greyish margin
14.	ALN-10	Greyish black	White	Smooth	Raised& thick	Black
15.	ALN-11	White	White	Smooth	Raised&thick	Black with Greyish margin
16.	ALN-12	Greyish black	White	Smooth	Raised&thick	Black
17.	ALN-13	Greyish white	White	Smooth	Raised&thick	Black with Greyish margin
18.	ALN-14	Greyish black	White	Smooth	Raised& thick	Black
19.	ALN-15	Greyish black	White	Smooth	Raised&thick	Black

Table 3: Variability in Morphological and growth characteristics among different isolates of *Alternaria linicola* and *Alternaria lini* infecting linseed

Sr. No.	Isolate No.	Radial growth of fungi (mm)#	* Size of conidia (µm)		Septation*		Days to sporulation
			Length	Breadth	Horizontal	Vertical	
1.	ALC-1	32	35.5-38.0	10.0-12.5	8-11	2-3	14
2.	ALC-2	30	40.2-44.6	9.5-10.0	9-12	3-4	12
3.	ALC-3	28	37.2-43.6	11.0-12.5	7-9	1-3	12
4.	ALC-4	30	35.2-40.6	8.3-10.2	8-10	3-4	10
5.	ALN-1	33	20.2-26.6	10.5-11.2	5-6	2-3	16
6.	ALN-2	31	7.5-22.5	7.5-10.0	3-5	1-2	13
7.	ALN-3	28	18.5-19.8	10.5-11.3	3-4	1-3	11
8.	ALN-4	33	19.2-22.6	9.5-10.0	5-7	2-3	12
9.	ALN-5	34	21.2-23.6	11.0-12.5	6-7	3-4	15
10.	ALN-6	30	18.2-19.6	8.3-10.2	3-4	1-2	16
11.	ALN-7	32	16.9-19.6	8.6-9.1	5-6	2-3	12
12.	ALN-8	32	17.2-20.1	9.3-10.2	4-5	1-3	13
13.	ALN-9	25	18.7-19.8	8.3-9.8	5-6	2-3	12
14.	ALN-10	29	19.5-21.9	10.1-11.3	5-7	3-4	12
15.	ALN-11	27	20.3-22.4	10.6-12.3	6-7	3-4	13
16.	ALN-12	31	20.4-21.9	10.3-11.8	4-7	2-3	11
17.	ALN-13	28	19.3-21.7	9.4-11.4	4-6	1-2	13
18.	ALN-14	32	21.4-23.6	12.3-12.9	5-7	2-3	15
19.	ALN-15	33	19.8-21.8	10.4-12.1	5-6	2-3	16

**Pooled data of measurement of 50 spores of each isolate; #Radial growth one week after inoculation

Table 4: Mycelial dry weight of different isolates of *Alternaria lini* and *Alternaria linicola* under different temperature conditions.

Sr. No.	Isolate / Temperature	Mycelial dry weight(mg) *					Mean
		15ºC	20ºC	25ºC	30ºC	35ºC	
1.	ALC1	31.4	35.4	52.8	40.2	26.3	37.2
2.	ALN2	21.4	35.4	45.4	46.7	36.3	37.0
3.	ALN4	23.7	39.6	61.4	44.2	27.4	39.3
4.	ALN10	22.6	36.6	58.1	43.6	28.8	37.9
5.	ALN15	21.3	38.4	71.4	54.4	35.4	44.2
6.	ALN16	18.7	35.9	54.0	41.2	27.1	35.4
Mean		23.2	36.9	57.2	45.1	30.2	38.5
		Isolates (I)		**Temperature (T)**		**I × T**	
SEm		0.29		0.26		0.64	
C.D. at 1%		1.07		0.97		2.39	

*After 14 days of inoculation

Table 5: Radial growth of different isolates of *Alternaria linicola* and *Alternaria lini* under different relative humidity (RH) conditions.

Sr. No.	Isolate / RH	Radial growth (mm)*					Mean
		60%	70%	80%	90%	100%	
1.	ALC1	29.0	31.7	31.0	35.7	22.3	29.9
2.	ALN2	21.3	28.7	34.7	36.3	28.0	29.8
3.	ALN4	24.0	28.3	37.3	39.7	24.7	30.8
4.	ALN10	25.0	29.7	34.0	36.7	24.0	29.9
5.	ALN15	23.0	28.0	37.0	36.0	25.0	29.4
6.	ALN16	25.0	30.3	33.7	37.3	24.0	30.5
Mean		24.6	29.4	34.6	36.9	24.7	30.0
		Isolates (I)		**RH**		**I c RH**	
SEm		0.519		0.474		1.161	
C.D. at 1%		NS		1.34		4.36	

*After 7 days of inoculation

Table 6: Variability in pathogenicity among different isolates of *Alternaria linicola* and *Alternaria lini* on inoculated leaves of linseed.

Sr. No.	Isolate*	Disease Incidence (%)		
		24hpi	48hpi	72hpi
1.	ALC-1	5.6 (11.15)	16.7 (23.61)	47.2 (43.39)
2.	ALC-2	11.1 (19.19)	25.0 (29.77)	75.0 (60.18)
3.	ALC-3	5.6 (11.15)	44.4 (41.73)	63.9 (53.21)
4.	ALC-4	8.3 (16.73)	36.1 (36.78)	63.9 (53.06)
5.	ALN-1	13.9 (21.65)	77.8 (62.63)	91.7 (76.36)
6.	ALN-2	19.4 (25.57)	58.3 (49.82)	83.3 (70.19)
7.	ALN-3	11.1 (19.19)	25.0 (29.77)	91.7 (76.30)
8.	ALN-4	22.2 (28.02)	66.7 (54.82)	97.2 (84.40)
9.	ALN-5	11.1 (19.19)	66.7 (54.82)	88.9 (73.90)
10.	ALN-6	19.4(26.07)	41.7 (40.14)	86.1 (71.94)
11.	ALN-7	13.9(21.65)	47.2 (43.38)	91.7 (76.36)
12.	ALN-8	11.1 (19.19)	36.1 (36.74)	86.1 (71.94)
13.	ALN-9	16.7(23.61)	44.4 (41.58)	83.3 (66.35)
14.	ALN-10	16.7(24.11)	38.9 (38.54)	80.6 (64.60)
15.	ALN-11	8.3 (16.73)	47.2 (43.38)	88.9 (70.70)
16.	ALN-12	19.4 (26.07)	47.2 (43.33)	86.1 (71.94)
17.	ALN-13	11.1 (19.19)	58.3 (49.82)	86.1 (76.57)
18.	ALN-14	11.1 (19.19)	55.6 (48.22)	80.6 (64.60)
19.	ALN-15	11.1 (19.19)	36.1 (36.89)	88.9 (73.90)
20.	Control	0.0	0.0	0.0
C.D (0.01)		11.1	14.23	16.41
SEm		2.92	3.71	5.71

** Average of three independent observations; * 15 day old cultures

Table 7: Variability in aggressiveness among different isolates of *Alternaria linicola* and *Alternaria lini*on inoculated leaves of linseed.

Sr. No.	Isolate*	Lesion diameter (mm)**		
		24hpi	48hpi	72hpi
1.	ALC-1	0.83 (1.354)	2.77 (1.932)	4.87 (2.42)
2.	ALC-2	0.90 (1.377)	2.53 (1.878)	5.33 (2.51)
3.	ALC-3	0.77 (1.329)	2.27 (1.807)	4.93(2.43)
4.	ALC-4	0.90 (1.378)	2.30 (1.815)	5.17 (2.48)
5.	ALN-1	1.37 (1.538)	2.63 (1.903)	5.27 (2.50)
6.	ALN-2	1.33 (1.526)	3.80 (2.190)	5.27 (2.50)
7.	ALN-3	1.37 (1.538)	4.20 (2.280)	5.87 (2.62)
8.	ALN-4	1.33 (1.527)	4.57 (2.358)	7.40 (2.90)
9.	ALN-5	1.27 (1.504)	2.83 (1.957)	7.40 (2.90)
10.	ALN-6	0.83 (1.352)	3.07 (2.015)	4.57 (2.36)
11.	ALN-7	1.03(1.424)	3.40 (2.095)	4.87 (2.42)
12.	ALN-8	1.63 (1.622)	4.07 (2.251)	5.60 (2.57)
13.	ALN-9	1.67(1.633)	4.40 (2.322)	5.90 (2.63)
14.	ALN-10	1.43 (1.559)	4.07 (2.249)	5.43 (2.54)
15.	ALN-11	1.73 (1.652)	5.60 (2.568)	6.43(2.72)
16.	ALN-12	1.43 (1.559)	5.53 (2.556)	6.13 (2.67)
17.	ALN-13	1.43 (1.555)	4.90 (2.429)	6.80 (2.91)
18.	ALN-14	1.87 (1.692)	5.13 (2.476)	6.13 (2.66)
19.	ALN-15	1.53(1.591)	4.47 (2.336)	5.17 (2.48)
20.	Control	0.00	0.0	0.00
C.D (0.01)		0.11	0.16	0.27
SEm		0.037	0.057	0.072

** Average of three independent observations; * 15 day old cultures

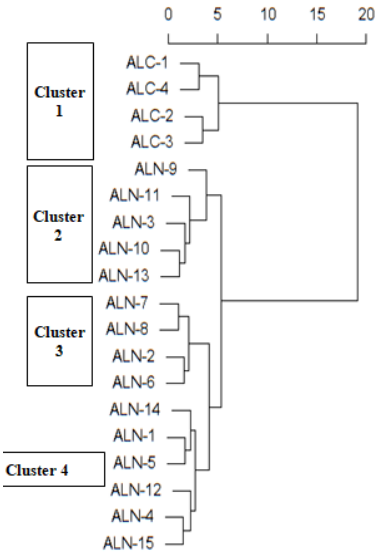

Fig. 1. Dendrogram depicting the morpho-physiological variability among various isolates of *Alternaria linicola* and *Alternaria lini*.

CONCLUSIONS

The present investigation has revealed considerable variability among both *Alternaria lini* and *Alternaria linicola* causing seedling blight and leaf blight respectively. Considering the level of variability the breeding programme must focus on identification of durable resistance to both the distinct pathogens which often co-exists and incite mutually confusing symptoms.

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Conflict of Interest. None.

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