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Survey and identification of some fungal diseases of vegetable crops of Kamrup (M) district of Assam, India

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The present study was conducted to survey and identify foliar fungal diseases of some vegetables crops of Kamrup (M) district of Assam, India. A total of 17 fungal pathogens were identified and were found associated with 15 different host vegetable crops. The common foliar disease symptoms were leaf spots, leaf blights, anthracnoses, wilts, powdery mildews and rusts. The major pathogens were identified to be of the fungal genera *Alternaria, Colletotrichum, Cercospora* and *Erysiphe*. Species of *Alternaria* were isolated from diseased plant belonging to *Brassica juncea, Raphanus raphanistrum, Solanum lycopersicum* and *Xanthosoma violaceum*. For the first time, *Alternaria* leaf blight of *Xanthosoma violaceum* had been reported in the present study. Similarly, *Colletotrichum* species causing anthracnose diseases were found associated with disease vegetable crops of *Lablab purpureus* and *Lagenaria siceraria* while *Cercospora* spp. were found associated with diseased vegetable crops of *Solanum melongena, Spinacia oleracea, Capsicum annuum*. Powdery mildew diseases caused by *Erysiphe* spp. were found in *Brassica juncea,* and *Lagenaria siceraria*. The present investigation is first-hand information of foliar fungal diseases of Kamrup district of Assam, India. This study may help in effective management of the fungal diseases of vegetable crops of the area.

Key words: Vegetables crops, Foliar diseases, Fungal pathogens, *Xanthosoma violaceum*

INTRODUCTION

Various types of vegetables are grown worldwide and are consumed by human for nutrition in terms of bioactive nutrient molecules such as dietary fiber, vitamins and minerals, and non-nutritive phytochemicals. In addition to nutritional and health benefits, vegetables bring an aesthetic value to the table (Koike *et al.* 2007). However, vegetables suffer huge losses in term of quality and productivity from several fungal and bacterial diseases. It is estimated that around 85% of the diseases of vegetables are caused by fungi or fungal-like pathogens.

Losses are more severe in developing than developed nations of the world (Enyiukwu *et al.* 2014). Therefore, fungi constitute the largest disease-causing plant pathogens damaging vegetables crops in term of growth and yield. In the recent years, effect of climate change has also increased the incidence of fungal diseases. Climate change has resulted into alteration of the host, the pathogen and the environment. This phenomenon has also driven into the emergence of novel, uncommon, or adapted fungal species, with consequences for health, biodiversity, and food security (Jain *et al.* 2019).

Rapid identification of fungal disease and its associated pathogens by timely recognition of their symptoms is an effective management practice and may help control and prevent their spread and progress (Mancini *et al.* 2016). Besides, many fungal diseases may be controlled if detected and correctly identified in a timely manner. Thus, early detection of fungal pathogens associated with vegetables crops become important in plant health monitoring. This may help to manage disease infections in different stages of development, minimizing the risk of disease spreading and avoiding the introduction of new ones (Brasier, 2008).

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Kamrup (M) district of Assam, India is situated at 90.36° and 92.12° East latitude and 25.53° and 26.52° North longitude. The district covers an area of 1,527.84 km^2 (589.90 sq m) and has a population of 12,60,419 according to the census of India, 2011(Saikia and Konwar 2020). The climate of Kamrup (M) district is sub-tropical with cold winter and semi-dry summer. Average annual rainfall received in the district ranges from 1500-2600 mm. Annual temperate range in the district varies from 7° to 38.5°C and average humidity is 75%. Agriculture is one of the main occupations in the district. Due to favourable climatic conditions like heavy precipitation, soil moisture and climate of the region is well suited for cultivation of vegetables. Different types of vegetables both *kharif* and *rabi* crops are grown in the district. Although several fungal diseases affecting vegetables crops are prevalent in the district, but there is no systematic study till date.

Therefore, the present investigation was undertaken to make a detailed survey on fungal diseases of vegetable crops of Kamrup (M) district of Assam and to identify the associated fungal pathogens.

MATERIALS AND METHODS

Field survey and sample collection

Frequent field visits were conducted to the vegetables growing areas of Kamrup (M) district of Assam, India. Diseased samples were collected and sampling was done during morning hours. Diseased plant materials from infected parts (leaf) of the vegetable crops were collected from various fields and placed them separately in sterile polybags. The vernacular name of each vegetable crop was recorded and host plants were identified and assigned scientific nomenclature. Prior to the laboratory work, the specimens were photographed separately. Infected vegetables with their collection sites are shown in the Table 1. Symptoms of different diseases of vegetable crops were observed and studied in the field and laboratory conditions. The most distinctive and common identified characteristics of fungal infections were the physical presence of signs of the diseases. Different diseased like leaf spots, blights, wilts, anthracnose, rusts, mildews and formation of mycelia, fruiting bodies and spores of fungal pathogen were recorded and identified based on their symptoms.

Microscopic observation and identification of the associated pathogen

A portion of the diseased plant material was placed on a clean glass slide with the help of a needle and forcep, cut in thin sections with the help of a blade or sometimes teased with a needle for the release of fungal spores and semi-permanent slides were prepared using lactophenol cotton blue stain. The prepared slides were observed under a compound microscope at 10X, 40X and 100X magnifications. The fungal pathogen associated with the diseased materials was identified based on the morphological characters of spores and spores bearing structure by using direct microscopy. Identification of fungi was also based on the structure and colour of mycelia and microscopic examinations of vegetative and reproductive structures. Plant disease symptoms were identified using standard identification manuals (Jim, 2012). Pathogens were identified up to genus and species level taxa using manuals of Barnett and Hunter (1998) and referring manual of soil fungi by Gilman (1957).

RESULTS AND DISCUSSION

Fungal pathogens associated with diseased vegetable crops

In the present study, a total of 17 fungal pathogens were identified and found associated with 15 different host vegetable crops (Table 1**).** The isolated pathogens belonged to the fungal classes Oomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. The common diseases were leaf spots, leaf blights, anthracnoses, wilts, powdery mildews and rusts. In many instances these diseases have been reported to be caused by plant pathogenic fungi declining both quality and productivity in various commercial crops including vegetables (Iqbal *et al*. 2018). The dominant fungal pathogens were identified as of the genera *Alternaria, Colletotrichum, Cercospora* and *Erysiphe*. Species of *Alternaria* were isolated from

Table. 1: - Collected disease samples of vegetable crops along with their collection sites

Name of Vegetables	Local Name	Pathogen Sample	Collection Site
Brassica juncea	Lai Xaak	*Erysiphe cruciferarum*	GU Road, near GU quarter, Jalukbari, 26° 9' 13.5" N, 91° 39' 37.4" E
Raphanus sativus	Mula	*Alternaria raphani*	GU Road, near GU quarter, Jalukbari, 26° 9' 13.5" N, 91° 39' 37.4" E
Lagenaria siceraria	Jati Lao	*Colletotrichum lagenarium*	Bhakunda suice gate roa d, Jalukbari, 26° 9' 16.3" N, 91° 38' 41.1" E
Lagenaria siceraria	Jati Lao	*Erysiphe cichoracearum*	Bhakunda suice gate road, Jalukbari, 26° 9' 15.8" N, 91° 38' 41.3" E
Brassica juncea	Lai Xaak	*Alternaria brassicicola*	Lankeshwar, Jalukbari, 26° 9' 4.4" N, 91° 38' 42.8" E
Raphanus raphanistrum	Bonoriya-mula	*Alternaria brassicae*	Aquaculture & Biodiversity Center, GU 26° 9' 15.8" N, 91° 40' 8.2" E
Solanum lycopersicum	Bilahi	*Alternaria tomatophila*	Aquaculture & Biodiversity Center, GU 26° 9' 15.8" N, 91° 40' 8.3" E
Lagenaria siceraria	Jati Lao	*Podosphaera xanthii*	Lankeshwar, Jalukbari, 26° 9' 4.6" N, 91° 38' 43.0" E
Lablab purpureus	Urohi	*Colletotrichum lindemuthianum*	Forest gate road, Jalukbari, 26° 9' 18.5" N, 91° 38' 59.4" E
Solanum melongena	Bengena	*Cercospora melongenae & Alternaria alternata*	Garigaon, near GU campus, 26° 9' 4.2" N, 91° 39' 17.5" E
Spinacia oleracea	Paleng	*Cercospora beticola*	Lankeshwar, Jalukbari, 26° 8' 55.5" N, 91° 38' 21.8" E
Momordica charantia	Teeta-Kerela	*Podosphaera xanthii*	Garigaon, near GU campus, 26° 9' 4.9" N, 91° 39' 17.5" E
Capsicum annuum	Krisno Jolokia	*Cercospora capsici*	GU Road, near GU quarter, Jalukbari, 26° 9' 13.5" N, 91° 39' 37.4" E
Xanthosoma violaceum	Dudh-kochu	*Alternaria sp.*	Garigaon, near GU campus, 26° 9' 1.9" N, 91° 39' 16.1" E
Brassica oleracea	Bondha-Kobi	*Fusarium oxysporum & Alternaria brassicicola*	Lankeshwar, Jalukbari, 26° 8' 55.5" N, 91° 38' 21.8" E
Basella alba	Puroi khak	*Cercospora beticola*	Lankeshwar temple, Jalukbari, 26° 8' 46.1" N, 91° 38' 44.0" E
Phaseolus vulgaris	Raz-Maah	*Uromyces appendiculatus*	Garigaon, near GU campus, 26° 9' 4.5" N, 91° 39' 17.0" E
Vigna unguiculata	Lesera	*Uromyces vignae*	Garigaon, near GU campus, 26° 9' 1.7" N, 91° 39' 16.3" E

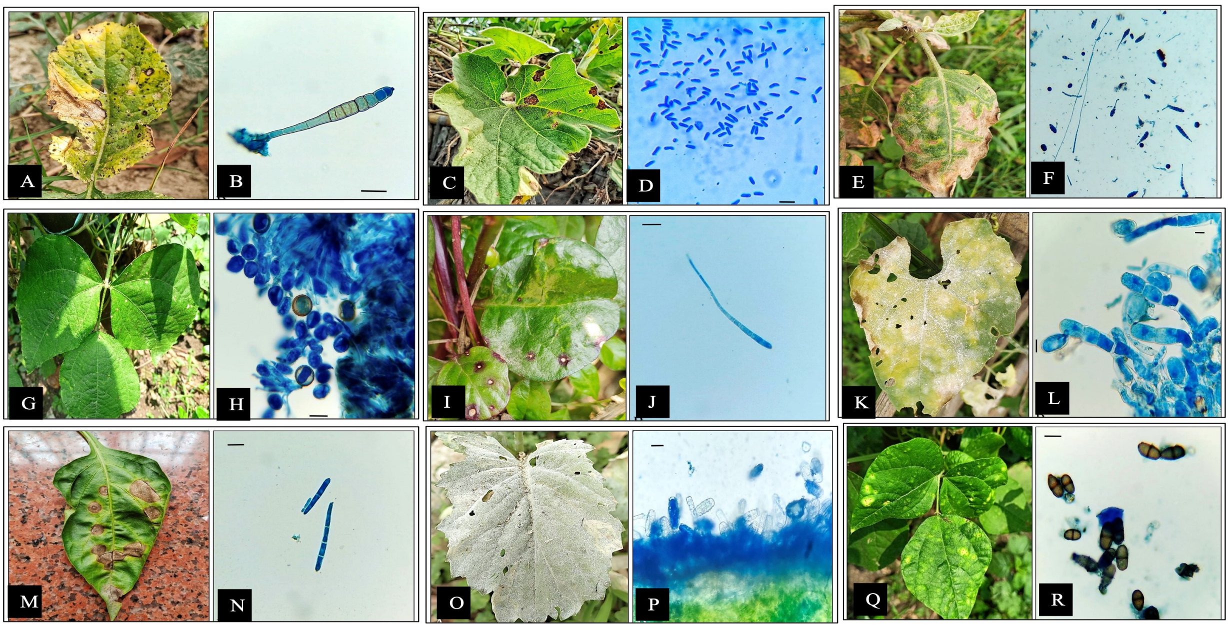

Fig.1. Infected leaves of (A) *Raphanus raphanistrum*, (C) *Lagenaria siceraria* , (E) *Solanum melongena*, (G) *Phaseolus vulgaris*, (I) *Basella alba*, (K) *Momordica charantia*, (M) *Capsicum annum*, (O) *Brassica juncea*, (Q) *Vigna unguiculata*; Conidia of (B) *Alternaria brassicae* , (D) *Colletotrichum lagenarium* , (F) *Cercospora melongenae* and *Alternaria alternata*, (H) *Uromyces appendiculatus* , (J) *Cercospora beticola* , (L) *Podosphaera xanthi* , (N) *Cercospora capsici,* (P) *Erysiphe cruciferarum*, (R) *Uromyces vignae* (Scale bars =20μm).

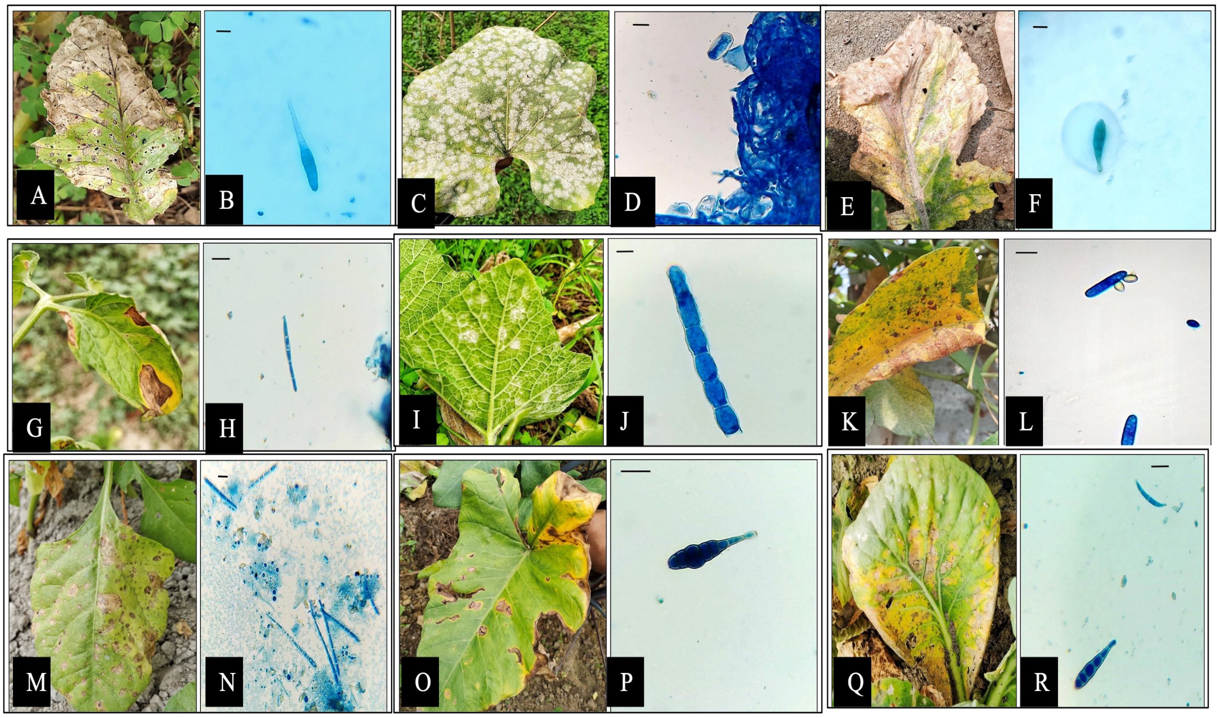

Fig.2. Infected leaves of (A) *Raphanus sattivus*, (C) *Lagenaria siceraria* , (E) *Brassica juncea* ,
(G) *Solanum lycopersicum* , (I) *Lagenaria siceraria*, (K) *Lablab purpureus*, (M) *Spinacia oleracea*, (O) *Xanthosoma violaceum*, (Q) *Brassica oleracea*; Conidia of (B) *Alternaria raphani* , (D) *Erysiphe cichoracearum* , (F) *Alternaria brassicola* (H) *Alternaria tomatophila* , (J) *Podosphaera xanthii* , (L) *Colletotrichum lindemuthianum* , (N) *Cercospora beticola* ,(P) *Alternaria* sp., (R) *Alternaria brassicicola* (Scale bars =20μm)

diseased plant belonging to *Brassica juncea, Raphanus raphanistrum, Solanum lycopersicum and Xanthosoma violaceum*. Although diseases caused by *Alternaria* are common in Brassicaceae plants such as *Brassica juncea, Raphanus raphanistrum* and in *Solanum lycopersicum*, but there is meagre information of occurrence of *Alternaria* in *Xanthosoma violaceum*. Similarly, *Colletotrichum* species causing anthracnose diseases were found associated with disease vegetable crops of *Lablab purpureus,* and *Lagenaria siceraria*. Species of *Cercospora* caused leaf spot diseases were found associated with diseased vegetable crops of *Solanum melongena, Spinacia oleracea, Capsicum annuum* and *Erysiphe* spp. were found to cause powdery mildew diseases in *Brassica juncea,* and *Lagenaria siceraria*. These pathogens were mostly responsible for foliar diseases of vegetables causing huge economical losses in term of yield and quality (Meghvansi *et al.* 2013; He *et al*. 2016).

Symptoms and identification of the pathogens

Alternaria leaf blight of *Raphanus raphanistrum* (Fig. 1A) was characterized by presence of small, dark or yellow leaf spots which becomes dark brown to grey in colour with or without concentric rings and with black or purple borders. *Causal organism* - Mycelium forming a loose, hyphae septate and branched. Conidia obclavate, with a conspicuous beak, smooth, with 11-18 cross septa, and 0-6 longitudinal ones, slightly constricted at the septa, 75-25 µm x 10-16 µm in size and usually single when produced on their plant hosts, sometimes in chains was identified as *Alternaria brassicae* (Fig. 1B).

Anthracnose of *Lagenaria siceraria* (Fig. 1C) was characterized by presence of circular, sunken, water-soaked dark brown lesions on leaves, later coalesced and covered larger areas and old lesions turned black. *Causal organism* - Mycelium septate, hyaline when young, dark when old. Conidia hyaline, oblong to ovate measuring 11.5–15 × 3–5 µm in size and piled up in a slimy orange mass, germinate to produce dark, thick walled spherical appressoria was identified as *Colletotrichum lagenarium* (Fig. 1D).

Leaf spot/blight of *Solanum melongena* (Fig.1E) was characterized by presence of chlorotic lesions, angular to irregular in shape, later turn greyish-brown with profuse sporulation at the centre. *Causal organism* - Mycelium internal, caespituli amphigenous, Conidia solitary, subcylindrical, filiform to acicular, straight to mildly curved, hyaline, 5 to 9 septate, ranging from 95-115 x 2.5-6 µm in size was identified as *Cercospora melongenae*. Whereas branched, septate mycelium, Conidia obclavate, smooth, slighty elongated apical cell, with 7-11 cross septa, and 0-3 longitudinal ones, ranging from 45-65 x 9-15 µm in size was identified as *Alternaria alternata* (Fig. 1F).

Rust of *Phaseolus vulgaris* was characterized by presence of small yellow or white spots on upper and/or lower surfaces of leaves. These spots enlarge and form reddish-brown or rust-coloured pustules (Fig. 1G). *Causal organism* - Mycelium branched. Condia (Uredospores) shows oval, globose to sub-globose in shape, thin-walled, measuring 21.5-28.5 × 17.5-25 ìm in size, with spiny layer covering at the external surface of the spore was identified as *Uromyces appendiculatus* (Fig.1H).

Cercospora leaf spot of *Basella alba* was characterized by presence of circular to oval shaped, purple colour pinhead spots with a necrotic grey centre surrounded by a purple to brown border. (Fig. 1I). *Causal organism* - Mycelium branched, septate and caespituli amphigenous Conidiophores unbranched sparingly septate, straight to mildly curved, hyaline acicular conidia, 8 to 14 septate, slighty sharp at the apex, ranging from 80–145 x 2.5-5 µm in size was identified as *Cercospora beticola* (Fig. 1J).

Powdery mildew of *Momordica charantia* was characterized by presence of powdery mass of white mycelium and spores cover the entire leaf (Fig. 1K). *Causal organism* - Mycelium flexuous to straight, branched, septate. Conidiophores straight, 115-210 × 26-32 µm in size, producing 2 to 5 immature conidia in chains with a crenate outline. Conidia when mature, ellipsoid-ovoid to barrel-shaped, 28-42 × 11-18 µm in size was identified as *Podosphaera xanthii* (Fig.1L).

Cercospora leaf spot of *Capsicum annuum* was characterized by presence of browinsh circular spots with light grey center and reddish-brown margins which later coalesce to form circular water-soaked tan spots on the leaf surface (Fig. 1M). *Causal organism* - Mycelium branched, septate and caespituli amphigenous. Conidiophores usually continue to elongate, producing successive conidia, and hence 2 or more widely spaced scars. Conidia 68–106.5 × 5–11 µm in size, hyaline, 4 to 9 septate, smooth, acicular, straight or slightly curved, tip rounded, basal cell truncate with distinct scar was identified as *Cercospora capsici* (Fig. 1N).

Powdery mildew of *Brassica juncea* was characterized by presence of powdery mass of white mycelium and spores cover the entire leaf (Fig. 10). *Causal organism* - Mycelium amphigenous, white, septate spreading and persistent. Conidia hyaline, borne singly or in short chain measuring 37.5–55 × 15.5–22.5 µm in size and were ovoid to cylindrical in shape. Conidia germinate only from one end the germ tube. Based on these characters organism was identified as *Erysiphe cruciferarum* (Fig. 1P).

Rust of *Vigna unguiculata* was characterized by presence of small brown dots containing a brown powder, which are spores of the disease. Later, spots become larger and spores turn rust-coloured spots within yellowed areas (Fig. 1Q). *Causal organism* - Mycelium branched. Conidia (teliospores) shows two-celled, oval to cylindrical, tip forms a rounded beak structure, often dark-coloured and thick-walled, measuring 22.5-30 × 12.5-6.5 µm in size, with smooth external surface was identified as *Uromyces vignae* (Fig.1R).

Alternaria leaf blight of *Raphanus sativus* was characterized by presence of small, dark or yellow leaf spots which coalesce and becomes brown to grey in colour with or without concentric rings and with black or purple borders (Fig. 2A). *Causal organism* - Mycelium forming a loose, cobweb-like network, hyphae septate and branched. Conidia were attached to conidiophores in chain. Conidia broadly ellipsoid to ovoid or obclavate, with a bluntly rounded apical cell that may develop through an abrupt transition into a broad, 7-10 transverse septa and 1-2 longitudinal septa in the segments, spore body 90-125 x 14-20 µm in size. Therefore, from the above characters, the causal organism was identified as *Alternaria raphani* (Fig. 2B).

Powdery mildew of *Lagenaria siceraria* was characterized by presence of powdery patches of white mycelium and spores on the entire leaf surface (Fig. 2C). *Causal organism* - Mycelium tubular and septate in nature and at frequent interval, the multiseptated conidiophores were produced. Conidia hyaline, single celled, ellipsoid to barrel-shaped borne in long chains on short conidiophores, ranging from 30.5–42.5 × 18–22.5 µm in size. Based on these characters, the causal organism was identified as *Erysiphe cichoracearum* (Fig. 2D).

Alternaria leaf blight disease of *Brassica juncea* was characterized by presence of zonate necrotic lesions are surrounded by chlorotic areas typically causes sooty-brown lesions (Fig. 2E). *Causal organism* - Mycelium branched, septate and brownish in colour. Conidia cylindrical to obclavate in shape and produced in chains of 8-10 spores, ranging from 60–65 × 12.5–15.5 µm in size with 5-7 cross septa, and 1-2 longitudinal ones, are short conical beakless. Conidia are dark brown and smooth-walled borne in continuous, chain-like structure and was identified as *Alternaria brassicicola* (Fig. 2F).

Early blight disease symptom of *Solanum lycopersicum* was characterized by presence of initial small dark spots on older foliage near the ground later leaf spots become round, brown and have target-like concentric rings (Fig. 2G). *Causal organism* - Mycelium branched & septate. Conidia obclavate, smooth, slightly constricted at the septa, produced singly or produced in chains of two. Conidia are dark brown ranging from 55.5-78.5 x 6-9.25 µm in size with 5-8 transverse septa. Therefore, from the above characters, the causal organism was identified as *Alternaria tomatophila* (Fig. 2H).

Powdery mildew symptom of *Lagenaria siceraria* was characterized by presence of powdery mass of white mycelium and spores cover the entire leaf surface (Fig. 2I). Causal organism - Mycelium flexuous to straight, branched, septate. Conidiophores straight, 120-220 × 23-33 µm, producing 2 to 5 immature conidia in chains with a crenate outline. Conidia when mature, were ellipsoid-ovoid to barrel-shaped, 32.5-41.5 ×16-22 µm in size was identified as *Podosphaera xanthii* (Fig. 2J).

Anthracnose disease of *Lablab purpureus* was characterized by presence of water-soaked sunken lesions or reddish-brown blotches appears which becomes black in latter stages with sootyappearing spots (Fig. 2K). *Causal organism* - Mycelium septate, hyaline when young, dark when old. Conidia hyaline, unicellular, guttulate, smooth-walled, cylindrical, straight or slight curved, both ends obtuse or with an acute base, sometimes with one ends lightly pointed spore, ranging from 17-22.5 × 4-6 µm in size. Based on these characters, the causal organism was identified as *Colletotrichum lindemuthianum* (Fig.2L).

Infected leaf symptom of *Spinacia oleracea* was characterized by presence of circular lesions that are coloured tan to grey in the centre and are often delimited by tan-brown to reddish-purple rings (Fig. 2M) was identified as Cercospora leaf spot of *S. oleracea*. *Causal organism* - Mycelium branched, septate and caespituli amphigenous. Conidiophores unbranched sparingly septate, straight to mildly curved, hyaline acicular conidia, 8 to 14 septate, slighty sharp at the apex, ranging from 82.5–150 x 4-7 µm in size was identified as *Cercospora beticola* (Fig. 2N).

Alternaria leaf blight of *Xanthosoma violaceum* was characterized by presence of zonate necrotic lesions are surrounded by chlorotic areas with greyish centre typically causes sooty-black lesion (Fig. 2Q). *Causal organism* - Mycelium branched & septate. Conidia obclavate, smooth, slighty elongated apical cell, with 7-11 cross septa, and 0"3 longitudinal ones, ranging from 39″66 x 8″14 µm in size was identified as *Alternaria* sp. (Fig.2P).

Leaf blight of *Brassica oleracea* was characterized by presence of yellowing of the lower leaves, often on one side of the plant. These leaves later turn brown and spots coalesce into large necrotic areas (Fig. 2Q). *Causal organism* - Mycelium with branched, septate and brownish in colour. Conidia cylindrical to obclavate in shape and produced in chains of 8- 10 spores, ranging from 58–66 × 13.5–16 µm in size with 5-7 cross septa, and 1-2 longitudinal ones, are short conical beakless. Conidia are dark brown and smooth-walled borne in continuous, chain-like structure identified as *Alternaria brassicicola* (Fig. 2R).

CONCLUSION

Fungal foliar diseases have become a global threat to food security and ecosystem health. They are responsible for major yield and economic losses of commercially important vegetable crops. Many of the foliar pathogenic fungi are biotrophic obligate plant parasites while others are opportunistic species or secondary invaders. The impact of global climate changed has increased the incidence of foliar diseases in many parts of the world. Therefore, it has become necessary for rapid identification of such disease-causing fungal pathogens particularly in vegetable crops for effective management of the disease. In the present investigation various foliar diseases cause by fungal pathogens infecting vegetable crops of Kamrup (M) district of Assam, India has been elucidated. The major pathogens were identified to be of the fungal genera *Alternaria, Colletotrichum, Cercospora* and *Erysiphe*. These pathogens were known to cause severe foliar diseases in vegetables crops like *Solanum melongena, Spinacia oleracea, Capsicum annuum*, *Brassica juncea,* and *Lagenaria siceraria* resulting into mortality and reduction in yield. Our present study is one of the first-hand information of fungal diseases of Kamrup (M) district of Assam, India. The study may help in effective management of the foliar fungal diseases of the area.

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