1. Early Blight (Alternaria solani)

Cause:

- Fungal pathogen *Alternaria solani*.
- Favored by warm temperatures (24–29°C) and high humidity.

Symptoms:

- **Leaves:**
  - Small, dark brown to black lesions with concentric rings (target spots).
  - Lesions often surrounded by yellow halos.
  - Lower leaves affected first, progressing upwards.
- **Stems:**
  - Dark, elongated lesions.
- **Tubers:**
  - Dark, sunken spots on the surface.
  - Internal tissue beneath lesions may appear dry, corky, and brown.

Life Cycle:

- Fungal spores (conidia) are spread by wind, rain, and insects.
- The fungus survives in plant debris, tubers, and soil.
- Infection occurs when leaves are wet for several hours.

Prevention:

- Use certified disease-free seed potatoes.
- Rotate crops (avoid planting potatoes/tomatoes in the same location for consecutive years).
- Remove and destroy infected plant debris.
- Space plants properly to improve air circulation and reduce leaf wetness.

Treatment:

- Apply fungicides such as chlorothalonil, mancozeb, or azoxystrobin.
- Begin fungicide treatments early, especially during favorable conditions.

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2. Late Blight (Phytophthora infestans)

Cause:

- Water mold pathogen *Phytophthora infestans*.
- Thrives in cool, wet conditions (10–20°C, with high humidity).

Symptoms:

- **Leaves:**
  - Water-soaked, pale green to dark brown lesions.
  - White fungal growth (sporangia) often visible on the underside of leaves under humid conditions.
- **Stems:**
  - Black or brown lesions that may girdle and kill stems.
- **Tubers:**
  - Irregular, brown, sunken lesions on the surface.
  - Reddish-brown, granular rot in the interior.

Life Cycle:

- The pathogen produces sporangia, which are dispersed by wind, water, and physical contact.
- Infects leaves, stems, and tubers.
- Survives in infected tubers, plant debris, and soil.

Prevention:

- Plant resistant potato varieties (e.g., `Kufri Jyoti`, `Kufri Himalini`).
- Avoid overhead irrigation to keep foliage dry.
- Harvest tubers in dry weather to prevent infection.
- Destroy infected plants and debris promptly.

Treatment:

- Use systemic and contact fungicides such as metalaxyl, dimethomorph, or cymoxanil.
- Apply fungicides preventively or at the first sign of disease.
- Alternate fungicides to avoid resistance development.

Comparison of Early and Late Blight

Feature	Early Blight	Late Blight
Pathogen	*Alternaria solani*	*Phytophthora infestans*
Conditions	Warm, humid	Cool, wet
Symptoms on Leaves	Target-like lesions, yellow halos	Water-soaked lesions, white growth
Tuber Symptoms	Dry, corky rot	Granular, reddish-brown rot
Prevention	Crop rotation, proper spacing	Resistant varieties, dry foliage

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Additional Steps for Management:

1. **Integrated Pest Management (IPM):**
    - Combine cultural practices with chemical control.
    - Monitor weather conditions and use predictive models for outbreaks.
2. **Biological Controls:**
    - Use biofungicides like *Trichoderma* species to suppress fungal growth.

Economic Importance:

- Both diseases significantly reduce potato yield and quality.
- Severe late blight outbreaks caused the Irish Potato Famine in the 1840s.

By adopting a proactive approach, you can minimize the impact of these diseases on your potato crops.

Potato is a critical crop in India, being a staple food and an important cash crop for millions of farmers. **Early Blight** and **Late Blight** are two of the most destructive diseases affecting potato production. Here's a deeper dive into their causes, spread, impacts, and region-specific management strategies:

Early Blight (Alternaria solani)

Spread and Risk Factors:

1. **Environmental Factors:**
    - Thrives in **warm and humid conditions** (24–29°C).
    - Frequent in areas with intermittent rain and prolonged leaf wetness, common during **Kharif (monsoon)** in eastern and central India.
2. **Transmission:**
    - Spread through windborne spores.
    - Survives in soil and infected crop debris.
    - Infection is more severe in stressed plants, particularly those suffering from **nutrient deficiency** (especially nitrogen and potassium).

Economic Losses:

- Reduces yields by **20–30%**, especially in regions with poor disease management practices.

Region-Specific Strategies in India:

1. **Northern States (Punjab, Haryana, Uttar Pradesh):**
    - Focus on **balanced fertilization** and irrigation management to avoid plant stress.
    - Use **Kufri Jyoti** and **Kufri Pukhraj**, which show moderate resistance.
2. **Eastern States (West Bengal, Bihar, Odisha):**
    - High humidity and poor drainage increase the risk; promote **drainage systems** and **timely planting** to avoid peak disease periods.

    - Rotate with non-host crops like maize or legumes.

Research and Government Initiatives:

- The **Central Potato Research Institute (CPRI)** in Shimla works on improving resistant potato varieties.
- Subsidies for fungicides such as **Chlorothalonil** and **Mancozeb** are provided under the **National Horticulture Mission (NHM)**.

Late Blight (Phytophthora infestans)

Spread and Risk Factors:

1. **Environmental Factors:**
    - Favored by **cool, wet, and humid weather** (10–20°C with >90% relative humidity).
    - Prevalent in **rabi (winter)** potato-growing regions like the Indo-Gangetic plains and Himalayan foothills.
    - Outbreaks occur during prolonged foggy or cloudy weather.
2. **Transmission:**
    - Sporangia are spread by wind, rain, irrigation water, and infected tubers.
    - The pathogen survives in infected plant debris, cull piles, and volunteer plants.

Economic Impact:

- Can cause **70–100% yield loss** if unchecked.
- Affects India's position as the **second-largest potato producer globally**, impacting domestic supply and exports.

Region-Specific Challenges and Strategies:

1. **Hilly Regions (Himachal Pradesh, Uttarakhand):**
    - Late blight thrives in cool, moist conditions. Use early-maturing varieties like **Kufri Megha** and ensure **timely harvesting**.
    - Encourage farmers to use **forecast-based fungicide sprays**.
2. **Plains (Punjab, Uttar Pradesh, Bihar, West Bengal):**
    - Ensure **deep planting** to reduce tuber exposure.
    - Train farmers on early disease detection through **agriculture extension services**.

Government and Scientific Interventions:

- **Blight Forecasting Systems:**
    - CPRI provides SMS alerts and advisories for blight outbreaks based on weather conditions.
    - Use of **Blitecast**, a forecasting model.

- **Resistant Varieties:**
    - Varieties like **Kufri Himalini**, **Kufri Pukhraj**, and **Kufri Jyoti** offer high resistance.
    - Efforts are underway to develop more resistant, high-yielding hybrids.

Integrated Disease Management (IDM) Approaches for Both Blights

Cultural Practices:

1. **Crop Rotation:**
    - Rotate potatoes with cereals (e.g., wheat, maize) or pulses (e.g., chickpeas) for 2–3 years to reduce soilborne inoculum.
2. **Planting Practices:**
    - Use **certified disease-free seeds**.
    - Opt for **timely planting** to avoid peak disease conditions.
3. **Field Hygiene:**
    - Destroy infected plants and weeds that harbor pathogens.
    - Avoid excessive nitrogen fertilization, which makes plants more susceptible to blight.

Biological Control:

- Use biofungicides like *Trichoderma harzianum* and *Bacillus subtilis*.
- Promote the use of **neem-based formulations** for eco-friendly disease management.

Chemical Control:

1. **Preventive Sprays:**
    - **Early Blight:** Mancozeb, Chlorothalonil.
    - **Late Blight:** Metalaxyl, Dimethomorph, Cymoxanil.
2. **Curative Sprays:**
    - In case of severe infection, use systemic fungicides like **Fosetyl-Al** or **Cymoxanil-Mancozeb combinations**.
3. **Spray Timing:**
    - Begin fungicide applications 30–40 days after planting.
    - Reapply after heavy rain or as per weather conditions.

Technological Interventions:

1. **AI and IoT in Blight Prediction:**
    - Smart sensors and AI-based tools are being introduced to detect humidity, temperature, and disease risk.
    - Apps like **Kisan Suvidha** provide real-time alerts on disease outbreaks.
2. **Government Programs:**
    - Farmers can avail of support under **Rashtriya Krishi Vikas Yojana (RKVY)** and **Pradhan Mantri Fasal Bima Yojana (PMFBY)** for crop loss due to blight.

Future Trends and Research in India:

1. **Development of Biotech Varieties:**
    - Work is ongoing to develop **GM potatoes resistant to late blight** through RNA interference and other biotechnological methods.
2. **Nano-Fungicides:**
    - Research on **nanoparticle-based fungicides** offers potential for more efficient and eco-friendly control.
3. **Awareness and Training Programs:**
    - **ICAR-KVKs** conduct regular workshops to educate farmers on disease management and fungicide usage.

In India, the government has implemented various policies, programs, and regulations to mitigate the impact of potato diseases such as **early blight** and **late blight**. These initiatives aim to support farmers, enhance crop productivity, and ensure food security. Here's an overview of the key government policies and regulations addressing potato blight diseases:

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1. Disease Management Programs

Integrated Pest Management (IPM):

- The **Directorate of Plant Protection, Quarantine, and Storage** under the Ministry of Agriculture promotes IPM strategies to control potato blights.
- Farmers are trained in:
    - Crop rotation practices.
    - Use of biocontrol agents like *Trichoderma*.
    - Adoption of resistant varieties.
- Emphasis is placed on reducing dependency on chemical fungicides to minimize environmental impact.

Plant Health Clinics:

- The government has established **Plant Health Clinics** in various districts to provide:
    - Diagnosis of plant diseases.
    - Recommendations for control measures, including suitable fungicides and bio-pesticides.
    - Advisory services for farmers.

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2. Research and Development

Indian Council of Agricultural Research (ICAR):

- ICAR, through its **Central Potato Research Institute (CPRI)** in Shimla, focuses on:

    - Developing high-yielding, disease-resistant potato varieties like **Kufri Himalini**, **Kufri Pukhraj**, and **Kufri Jyoti**.
    - Conducting research on disease-resistant biotech varieties (e.g., late blight-resistant GM potatoes).
    - Weather-based disease forecasting systems like **Blitecast**, which predict late blight outbreaks.

Support for Biocontrol:

- The **National Institute of Plant Health Management (NIPHM)** promotes the use of bio-fungicides as an eco-friendly alternative to chemicals.
- Efforts to enhance the adoption of biopesticides for disease control.

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3. Subsidies and Support

Rashtriya Krishi Vikas Yojana (RKVY):

- Provides financial support to farmers for adopting modern farming techniques, including pest and disease management.
- Subsidies on disease-resistant potato seeds and fungicides like Mancozeb and Metalaxyl.

National Horticulture Mission (NHM):

- Promotes potato production and disease management under its mission to support horticultural crops.
- Facilitates:
    - Access to high-quality seeds.
    - Subsidies for fungicides.
    - Farmer training programs.

Soil Health Cards:

- Introduced under the **Soil Health Management Scheme** to help farmers assess soil conditions and apply balanced fertilizers, reducing plant stress that makes crops susceptible to diseases like blights.

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4. Insurance and Compensation

Pradhan Mantri Fasal Bima Yojana (PMFBY):

- Provides insurance coverage for crop losses caused by diseases like early and late blight.
- Farmers can claim compensation for yield losses due to disease outbreaks.
- Encourages farmers to report disease outbreaks promptly.

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5. Disease Surveillance and Forecasting

Blight Forecasting Systems:

- ICAR and CPRI use **weather-based models** to predict late blight outbreaks and disseminate warnings through:
    - SMS alerts to registered farmers.
    - Mobile apps like **Kisan Suvidha** and **mKisan**.
- Real-time advisories include recommended fungicide sprays and agronomic practices.

State Agriculture Departments:

- Several state-level programs monitor disease outbreaks and provide localized support to farmers, particularly in high-risk states like Punjab, Himachal Pradesh, West Bengal, and Uttar Pradesh.

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6. Seed Certification and Quality Control

Seed Act of 1966:

- Enforces strict certification norms for seed quality to ensure that farmers receive disease-free potato seeds.
- Seed certification agencies monitor and certify seed potatoes to prevent the spread of blight through infected tubers.

Plant Quarantine (Regulation of Import into India) Order, 2003:

- Regulates the import of potato seeds and tubers to prevent the introduction of new strains of *Phytophthora infestans* or other pathogens.
- Ensures compliance with international phytosanitary standards.

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7. Farmer Training and Awareness

Krishi Vigyan Kendras (KVKs):

- KVKs organize regular workshops to educate farmers on:
    - Early detection of blight symptoms.
    - Safe and effective use of fungicides.
    - Adoption of integrated disease management (IDM) practices.

Agri-Clinics and Agri-Business Centers Scheme (ACABC):

- Supports agri-entrepreneurs in providing disease management advisory services to farmers.

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8. Export and Trade Regulations

Export-Quality Standards:

- Under the **Agricultural and Processed Food Products Export Development Authority (APEDA)**, stringent quality checks are imposed to ensure disease-free potatoes are exported.
- Special focus on blight-free certification to maintain India's reputation as a reliable exporter.

Restrictions on Imports:

- Restrictions are placed on importing potatoes from countries with a high incidence of late blight to prevent introducing new, aggressive strains of the pathogen.

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9. Climate-Resilient Agriculture Initiatives

National Innovations in Climate Resilient Agriculture (NICRA):

- Focuses on developing climate-resilient potato varieties to withstand disease pressure caused by erratic weather.
- Promotes micro-irrigation and efficient nutrient management to reduce stress-related susceptibility to diseases.

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10. Collaborative Efforts

International Cooperation:

- Partnerships with organizations like **CIP (International Potato Center)** for research on disease-resistant potato varieties.
- Collaboration with global blight research initiatives to exchange knowledge and best practices.

Challenges in Policy Implementation:

- Lack of awareness among small and marginal farmers about disease management practices.
- Limited access to certified seeds and timely fungicide applications in remote areas.

- High dependency on chemical fungicides, leading to environmental concerns and resistance development in pathogens.

By leveraging these policies and programs, India aims to enhance potato productivity, minimize economic losses, and support the livelihoods of millions of farmers. However, successful implementation requires a combination of farmer education, infrastructure support, and timely interventions.

Early Blight and Late Blight of Potato

Early Blight

Early blight and late blight, two serious diseases of potato, are widely distributed. Both are found everywhere potatoes are grown. The terms “early” and “late” refer to the relative time of their appearance in the field, although both diseases can occur at the same time.

Early blight of potato is caused by the fungus, *Alternaria solani*, which can cause disease in potato, tomato, other members of the potato family, and some mustards. This disease, also known as target spot, rarely affects young, vigorously growing plants. It is found on older leaves first. Early blight is favored by warm temperatures and high humidity.

Symptoms. Spots begin as small, dark, dry, papery flecks, which grow to become brown-black, circular-to-oval areas. The spots are often bordered by veins that make them angular. The spots usually have a target appearance, caused by concentric rings of raised and depressed dead tissue. A yellowish or greenish-yellow ring is often seen bordering the growing spots. As the spots become very large, they often cause the entire leaf to become yellow and die. This is especially true on the lower leaves, where spots usually occur first and can be very abundant. The dead leaves do not usually fall off. Dark brown to black spots can occur on stems.

Tubers are affected, as well, with dark, circular to irregular spots. The edges of the spots are often raised and purple to dark metallic gray in color. When the tuber is sliced open, the flesh under the spots is usually brown, dry, and leathery or corky in texture. As the disease advances, the potato flesh often becomes water soaked and

yellow to greenish yellow. Early blight spots are less likely to become rotted by secondary organisms than the other tuber rots.

Prevention. Varieties resistant to this disease are available. In general, late maturing varieties are more resistant than the earlier maturing varieties. Keep plants healthy; stressed plants are more predisposed to early blight. Avoid overhead irrigation. Do not dig tubers until they are fully mature in order to prevent damage. Do not use a field for potatoes that was used for potatoes or tomatoes the previous year. Keep this year's field at least 225 to 450 yards away from last year's field. Surround the field with wheat to keep wind-blown spores from entering. Use adequate nitrogen levels and low phosphorus levels to reduce disease severity. See current recommendations for chemical control measures.

Late Blight

Late blight of potato is a serious disease caused by *Phytophthora infestans*. It affects potato, tomato and, occasionally, eggplant and other members of the potato family. Late blight is the worst potato disease. It was first reported in the 1830s in Europe and in the US. It is famous for being the cause of the 1840s Irish Potato Famine, when a million people starved and a million and a half people emigrated. Late blight continued to be a devastating problem until the 1880s when the first fungicide was discovered. In recent years, it has reemerged as a problem. It is favored by cool, moist weather and can kill plants within two weeks if conditions are right.

Symptoms. Leaf spots begin as small, pale to dark green, irregularly shaped spots. The spots often have pale green to yellow rings surrounding them. The spots are not bordered by veins but can grow across them. In cool, moist weather, the spots grow rapidly into large brown to purplish black areas. The disease may kill entire leaflets or grow down the petioles and into the stem, killing the plant above it. When the weather is moist, a white fungal growth appears on the edges of the dead areas, usually on the undersides of the leaves. In the field, plants often give off a distinctive fetid or decaying odor.

On susceptible potato varieties, the tubers can become infected. Small to large, slightly depressed areas of brown to purplish skin can be seen on the outside of the tuber. When the tuber is cut open, there is a tan-brown, dry, granular rot, which extends ½" to ¾" into the tuber. The border of this area is indistinct. If potatoes are stored under warm or humid conditions, the rot will continue to progress. Often secondary rot organisms set in and completely destroy the tubers.

Disease Identification. White, fluffy fungal growth is present on the bottoms of leaves in moist weather. Leaf spots are not bordered by veins.

Prevention. Use disease-free seed potatoes. Keep cull/compost piles away from potato growing areas. Destroy any volunteer potato plants. Keep tubers covered with soil throughout the season to prevent tuber infection. Remove infected tubers before storing to prevent the spread of disease in storage. Kill vines completely before harvest to avoid inoculation of the tubers during harvest. Resistant varieties are available, although some fungicides must still be applied to resistant cultivars. See current recommendations for chemical control measures.

By: Pam Mercure, IPM Program Assistant, University of Connecticut, 1998

Reviewed by: T. Jude Boucher, IPM, University of Connecticut. 2012

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This information was developed for conditions in the Northeast. Use in other geographical areas may be inappropriate.

Potato is a major vegetable crop cultivated on more than 89993 ha area with annual production of 22.6 Lakhs tonnes in the Punjab state (Deptt. of Horticulture, Punjab 2014-15), most of which is meant for seed production. The major potato growing districts are of Jalandhar, Hoshiarpur, Kapurthala,

Ludhiana, Amritsar, Bathinda and Fatehgarh Sahib. Its cultivation is also picking up in south-western districts like Bathinda, Moga and Faridkot. Commonly grown varieties are Kufri Pukhraj, Kufri Badshah, Kufri Jyoti, Kufri Chipsona-1 and Kufri Jawahar. Among various diseases affecting potato crop in Punjab, late blight caused by the fungus *Phytophthora infestans* is the most destructive disease that can cause huge economic losses under congenial weather conditions. While Kufri Pukhraj, Kufri Ashoka and Kufri Bahar are susceptible, others are moderately resistant to late blight under Punjab conditions.

Area and Production of Potato Crop in major potato growing districts of Punjab during 2014-15*

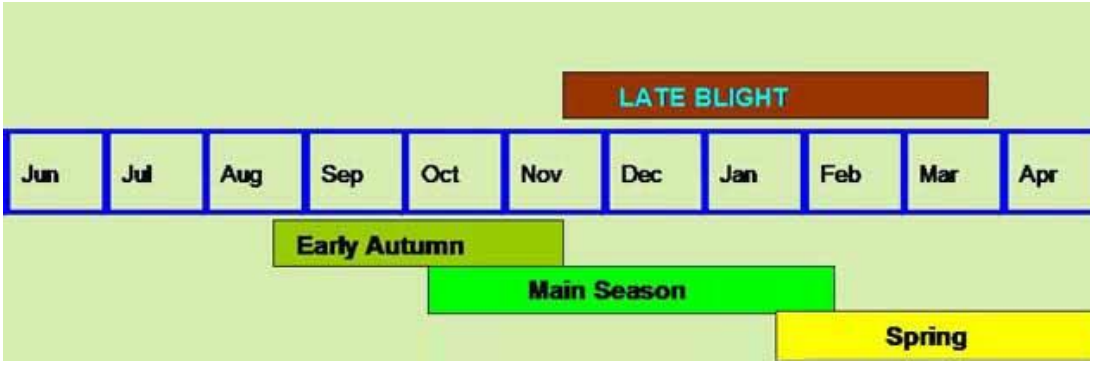
Districts	Area (ha)	Production (MT)
Hoshiarpur	12612	310306
Jalandhar	20438	528404
Ludhiana	10016	256440
Amritsar	6786	1673063
Kapurthala	9256	235713
Bathinda	5468	133753
Patiala	4313	106462
Fatehgarh Sahib	4483	111631
Moga	6175	157302
S.B.S Nagar	2415	59283

Department of Horticulture, Punjab, 2014-15*

Late blight caused by the fungus Phytophthora infestans is the most important disease of potato that can result into crop failures in a short period if appropriate control measures are not adopted. Losses in potato yield can go as high as 80% in epidemic years. During past years, epidemics of the disease have appeared in 1985-86, 1989-90, 1992-93, 1997-98, 2006-07 and recently during 2007-08 season.

Distribution in State

Late blight occurs frequently in the districts of Hoshiarpur, Jalandhar, Nawan Shehar, Kapurthala, Ropar and Amritsar. Hoshiarpur is generally considered to be the hot spot for this disease. The disease is generally observed first in certain pockets of district Hoshiarpur like Sham Chaurasi, Mehtiana, Phuglana and areas around Tanda and spreads further to adjoining regions under favourable weather conditions. In the districts like Ludhiana, Patiala, Fatehgarh Sahib, Moga and Sangrur, the disease is noticed in moderate incidence and does not appear every year or develops late in the season. South-western districts such as Bathinda, Faridkot and Ferozepur mainly remain free from the disease or its attack is observed very rarely during prolonged epidemic years only. Based on prevalence of the disease in different regions recorded over the past years, a late blight map for Punjab has been prepared. Normally, early sown crop, planted in early September and harvested in mid-November for table purpose, escapes attack of the disease because of high temperature prevailing during this period or may be affected slightly at the end without causing any significant damage.



Potato Cropping Period and Late Blight favourable Period

Symptoms of Late Blight

On leaves:

- **Small water-soaked spots develop at the tips, margins or any other part of the leaf which enlarge to form irregular dark brown lesions surrounded by a light green halo.**
- **During morning hours, a whitish cottony growth of the fungus is visible around the dark brown lesions on the under surface of the leaves especially when weather remains sufficiently humid or when there is dew fall in the morning hours.**
- **If the weather turns dry, the lesions become necrotic and dry up.**
- **Under favourable weather conditions (low temperature, high humidity due to intermittent winter rains) the disease spreads rapidly and whole of the crop may be killed within 10-14 days giving blighted appearance.**

Potato Leaf Showing late blight Symptoms

Potato foliage affected by late blight

Sporulation of *P.infestans* on lower leaf surface

Potato field affected by late blight

On Stem:

- **In case of infection originating from infected tubers, elongated brown stripes develop on the stem from below the ground level and encircle it.**

- **The lesions also appear on the stem near the growing point when the inoculum of the fungus comes from the infected plants.**
- **The infection can also start at nodes and extend both up and down the stem and the plant topples down under congenial weather conditions.**
- **The infected portions of the stem bear white fungal growth especially visible in early morning hours but are not as prominent as on leaves.**

Late blight symptoms on potato stem

On Tubers

- **Infected tubers show irregular, shallow or sunken reddish brown patches. Inside infected tissue is spongy and rusty brown to varying depths. In sub-mountainous areas, the lesions on tubers are locally called "Pathar Dag". Later on, these lesions are often invaded by secondary pathogens especially in wet soils or in storage resulting into soft rot.**
- **Smaller immature tubers are more prone to infection as compared to the larger ones and rotting is more in heavy wet soils.**
- **Late blight does not spread from tuber to tuber in cold stores.**
- **Varieties with short stolons bearing tubers near to stem are more liable to tuber infection as in case of variety Kufri Chandramukhi.**

Late blight symptoms on potato tubers

Late blight on spring crop

In spring crop, which is planted in January, sprouts are attacked at very young stage as the inoculum of the fungus is readily available from the already infected main season crop. Under such conditions, young leaves and stems near the growing points are infected by the fungal spores called sporangia. Brown necrosis is evident around growing points. Ultimately whole of the young sprouts are killed causing almost complete loss in the yield.

Young potato plant attacked by late blight

Disease source, development and spread

- **The primary source of the disease is infected seed tubers planted after cold storage.**
- **Not all, but a few of the infected tubers give rise to primary sporangial inoculum which further infects the nearby plants creating a primary focus of infection in the field.**
- **Some of the infected tubers do not sprout or are soon killed after sprouting giving patchy appearance in the field.**

Diseased tubers piled up near potato field

- **The heaps of culled infected potato seed piled near the cold stores also serve as source of primary inoculum for the adjoining fields.**
- **In the district of Hoshiarpur and adjoining areas of Nawan Shahar, the disease always appears early due to presence of primary inoculum in the form of infected tubers and favourable weather conditions such as high relative humidity and low to moderate temperature.**

For late sown or spring crop or where successive crops are grown, the previous infected crop often serve as the major source of huge primary inoculum.

Disease cycle

- **The fungus over-summers as mycelium in the infected seed potato kept in cold stores.**
- **These tubers when planted in the next crop season (main crop and subsequent ones) serve as the source of primary inoculum.**
- **When the plants emerge from such tubers, the fungus invades a few of the growing sprouts and sporulates (produce sporangia)**

under humid conditions. Further spread of the disease takes place by these sporangia through air or rain splashes.

- **Initiation of the disease generally takes about 3-7 days before clearly visible symptoms develop. The fungus produces white sporulation on the underside of the leaves which is clearly visible in the early morning hours.**
- **These sporangia further infect new leaves and stems of the nearby plants and this cycle continues after every 4-10 days depending upon the prevailing temperature and humidity levels.**
- **If the temperature is lower than 10o C, disease development slows down and takes more time up to 12 days while at temperature of 16-18o C, it takes only 4-5 days to complete one cycle.**
- **Sporangia washed by rain or carried by irrigation water cause infection on tubers in the soil.**
- **Partially exposed tubers can easily become infected.**
- **These infected tubers serve as the primary source of inoculum for the next year's crop.**

Disease Cycle of Late Blight of Potato in Punjab

Races of Phytophthora infestans

Presently, there are multigene complex races of *P.infestans* on Potato in Punjab.

Commonly occurring races in the State are:

- **1.2.3.4.5.7.10.11**
- **1.2.3.4.7.10.11**

- **1.2.3.4.5.7.11**

- In Punjab, late blight generally makes its first appearance in first or second week of November when the main season crop is about 40-50 days old.
- Early planted crop (September planted) generally escapes the attack of late blight because of relatively warmer climate.
- The sporangia of the fungus are killed at temperature above 30^0 C.
- The main season crop planted in October and the successive crops are invariably attacked due to favourable climatic conditions and the disease may continue up to March.
- The mean temperature and relative humidity during the main crop period usually range between 15-18^0 C and 60-80 % respectively coupled with dew deposition during night and accompanied by sunny days. Under such conditions, the disease may not develop severely and it may be restricted and localized or remain confined.
- When winter rains occur raising the humidity to > 90% and cloudy or foggy days persist for 6-7 days with atmospheric temperature in the range of 10-20^0 C (during November-December), late blight develops rapidly on upper leaves, stems and multiple infections take place on the adjoining plants and then on the entire field through spread by the air-borne sporangia of the fungus.
- Due to rapid disease spread, epidemic situation may develop, if humid weather conditions persist for longer duration. Normally five infection cycles are completed before uniform spread of the disease is observed in the crop.
- It may take about 3 weeks from the first disease appearance for development of an epidemic situation, if favourable weather conditions continue. With the return of dry conditions and sunny days, development and spread of the disease is slowed down.
- Even one infected tuber in 1 ha crop is enough to create severe disease situation under favourable climatic conditions.

Management of Late Blight

Sanitation

- Infected tubers and cull piles stocked near cold stores serve as primary source of inoculum and should therefore, be destroyed or buried deep in the soil.
- By doing this a large quantity of initial inoculum from such sources can be reduced.

Use of healthy seed

- Since the fungus responsible for causing late blight survives in the infected seed tubers kept in cold stores during summer, visible blighted tubers from all seed stocks should be carefully sorted out and destroyed after storage.
- It is advisable to pile up harvested tubers for few days (7-15) in the field before storing in cold stores.
- Only disease free certified seed should be used.
- At the time of harvesting, grading and picking seed tubers should be properly examined and infected seed tubers should be sorted out and burnt or buried deep in the soil.

Cultural practices

- In the potato fields, exposed tubers and those poorly covered with soil area easily get infected by sporangia which are washed down from foliage by rain.
- To reduce the tuber infection, proper hilling and earthing up should be practiced. About 2-3 weeks before harvest, foliage of late blight affected crop, from which seed is to be obtained, should be cut and destroyed. This will reduce the chances of tuber infection.
- The planting dates may be advanced to avoid the epidemic build up as the disease does not appear on early sown crop in Punjab.
- Wider intra-row and inter-row spacings are useful as these create unfavourable conditions for disease development. Wide spacings also help adequate earthing up of plants. Rows facing sun also discourage infection.
- Digging of potatoes should be done after 2-3 weeks of dehaulming by which time the tuber skin hardens while soil infection diminishes.

Resistant varieties

- Kufri Ashoka, kufri Chandramukhi, Kufri Bahar and Kufri Pukhraj varieties of potato are highly susceptible to late blight.

- Kufri Jyoti, Kufri Sutluj and Kufri Badshah are moderately resistant.
- Central Potato Research Institute, Shimla has released potato varieties like, Kufri Chipsona-1 and Kufri Chipsona-2 for cultivation in northern plains of the country. These varieties are also moderately resistant to late blight and are suitable for processing.
- Planting of unknown varieties should be avoided.

Chemical control

- It has been observed that late blight of potato generally makes its appearance on Kufri Chandramukhi and Kufri Pukhraj in first or second week of November in some areas of Hoshiarpur district from where it then spreads to the adjoining fields. Therefore, it is advisable to spray the crop at this time with protectant fungicides such as mancozeb (Indofil M-45/Mass M-45/Markzeb) or cholorothalonil (Kavach) or propineb (Antracol) each @ 500-700 gm/acre or Blitox-50/Markcopper @ 750-1000 gm/acre. However, these fungicides have to be applied as preventive measures and the spray is to be repeated after 7 days. Once the infection has established and symptoms developed, these fungicides prove ineffective.
- Successful control of the disease depends on both efficacy of the fungicide and good foliage coverage with the spray solution. The neighboring farmers should also be advised to spray crops with fungicides so that inoculum of the disease is minimized.
- Under more favourable weather conditions (highly humid due to rains, foggy, cloudy weather), late blight is likely to develop in an epidemic form.
- Under these conditions, sprays of systemic fungicides in pre-packed mixture with protectants such as Ridomil Gold (8 % mefanoxam + 64 % mancozeb) or Curzate M-8 (8% cymoxanil + 64% mancozeb), Sectin (10% fenamidon+50% mancozeb) @ 700 g/acre or Revus (mandipropamid 250SC) or Equation pro (16.6% famoxadone+22.1% cymoxanil) @ 200ml/acre should be given and repeated once at 10 days interval.

Need - based Fungicide Spray Schedule for Late Blight Control

- Under low to moderate disease risk situation, spray Indofil M-45/Mass M-45/Markzeb or Kavach or Antracol each @ 500-700 g/acre or Blitox-50/Markcopper @ 750-1000 gm/acre (starting from first week of November) before disease appearance. Give five more

sprays at weekly intervals depending on disease situation and weather conditions.

- In high disease risk situation, due to favorable weather conditions (high relative humidity due to rainy spells) 3rd and 4th spray may be given with Ridomil Gold or Curzate M-8 or Sectin @ 700 g/acre or Revus or Equation pro @ 200ml/acre at 10 days interval. Give one more spray of Indofil M-45 or Kavach or Antracol subsequently.
- On successive late sown crops and spring crop, if the preceding crop is already attacked by late blight and the inoculum is abundantly present, first spray may be given with Ridomil Gold, followed by Indofil M-45 sprays at weekly interval.
- Caution: Do not use under dose of Ridomil Gold or self prepared tank mixtures of metalaxyl and mancozeb as this may lead to development of resistant strains of the pathogen.

Cautions and Useful Tips

- Use only healthy seed free from late blight infection.
- Cull piles near cold stores should be destroyed.
- Give timely application of fungicides like Indofil M-45 or Mass M-45 or Markzeb and Mark Copper or Kavach or Antracol as prophylactic sprays i.e. before appearance of disease (1st week of November for main crop). Repeat the sprays if it has been washed down by the rain.
- Use Ridomil Gold or Curzate M-8 or other recommended systemic fungicides only when disease risk is likely to be severe and favourable weather conditions persist.
- Avoid the use of formulations containing metalaxyl alone and avoid using their self prepared mixtures of metalaxyl and mancozeb.
- High ridges and proper earthing up prevents tuber infection.
- Excessive irrigation should be avoided. Restrict irrigation during cloudy days.
- Digging of tubers should be done after 2-3 weeks of dehaulming.
- Sort out and destroy infected tubers after harvesting and before or after storage.
- Sowing of unrecommended varieties and spray of such fungicides should be avoided.
- Successive potato crop in the same field should be avoided during same crop season.

Early and Late Blight of Potato

[For B.Sc. III year (paper III unit IV) and B.Sc. Ist Sem.(unit VII)]

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Varanasi

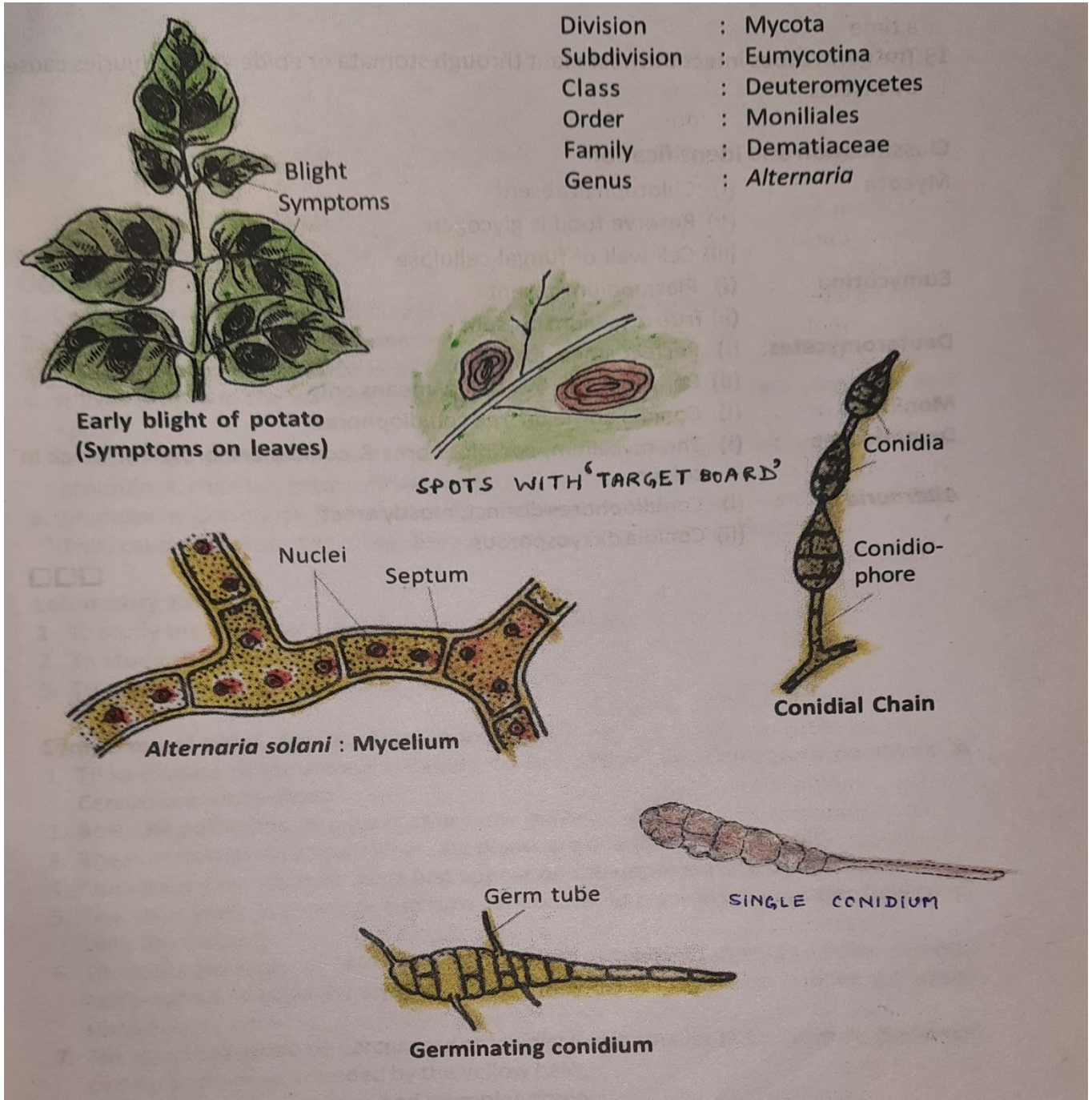
EARLY BLIGHT OF POTATO

- The name of the disease is because of the infection on potato crop taking place in earlier part of growing season.
- The disease is worldwide in distribution.
- In India, when the disease is severe it may lead to almost 40% loss of yield in potato crops.
- Besides potato other members of family Solanaceae such as tomato, cabbage, Chili, brinjal, cauliflower etc. and a number of wild species of plants act as Collateral hosts for the fungal pathogen.

SYMPTOMS

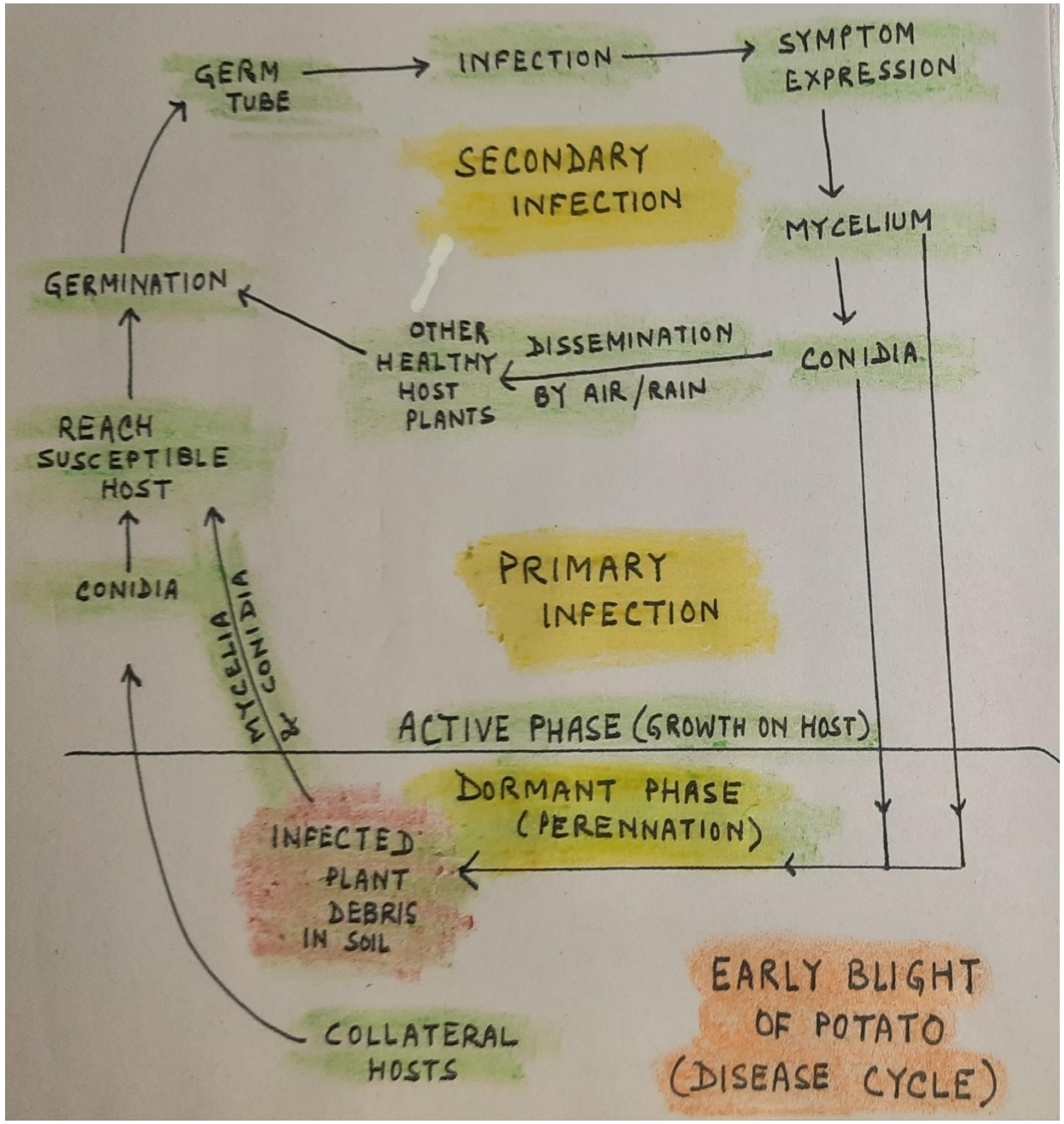
- Being an early infecting pathogen, the symptoms of the disease start appearing when the plant is 3 weeks old.
- The leaves which are near the ground first show small circular or irregular dark brown to black spots.
- The peculiar characteristic of these pots is the presence of concentric rings which give it a target board like appearance.
- These spots later enlarge in size and adjacent is spots coalesce to form large angular sports.
- The symptoms later also develop on the petiole and stem in the form of elongated brown to black lesions.
- In the advanced stage of growing season numerous lesions appear on the upper leaves.
- The leaves drop - a case of premature leaf senescence.
- Tubers also show symptoms in form of dark and sunken lesions on the surface which are circular or irregular in shape. If cut open, the tubers show dry corky texture with dark brown colour inside.

- **CAUSAL ORGANISM**:
  Alternaria Solani
- Mycelium of the fungus is branched, septate and grows both inter and intracellularly through the host tissue.
- Haustoria are absent.
- Each cell of the hypha is usually multinucleate.
- At maturity the mycelium produces conidiophores.
- Conidiophores emerge through stomata or dead epidermal cells.
- Conidiophores are short, dark coloured, aerial, septate and little curved at the tip.
- Conidia are produced at the tip of conidiophores either singly or in chain.
- Each conidium is beaked, bottle shaped, obclavate (club shaped), muriform (having horizontal and vertical septa - dictyospore).



DISEASE CYCLE

- The fungus survives on the plant debris left in the field on decaying potato tubers or on some collateral host such as tomato or some wild species of family Solanaceae.
- The **primary inoculum** which is usually in the form of a mycelium or a spore, disseminates through the agency of wind or rain splash or irrigation water and reaches the host leaf surface where it germinates and brings about **primary infection.**
- After the fungus establishes itself inside the host tissue the stage of **secondary infection** starts.
- In this stage, the pathogen producers conidia on the surface of the leaves.
- Conidia are produced in large numbers.
- They are disseminated by wind, splashes of rainwater or irrigation water and reach other healthy potato plants where they cause secondary infection.



CONTROL MEASURES:

Proper fertilization, irrigation and management of pests through various means.

Cultural Practices:

- Crop rotation
- Field sanitation
- Growing late sowing varieties
- Diseased plant parts should be destroyed completely by burning.

Chemical Pesticides:

- Fungicides should be use in justified manner and only when symptoms appear.
- Example of fungicides : Copper fungicides such as **maneb, mancozeb**, **Zineb** (**Dithane Z-78**), **Blitox-50** (.25%), **Captan**, **Bordeaux mixture** etc.

Biocontrol:

Fungal species ***Trichoderma harzianum*** and ***T. viride*** are used as bio fungicide.

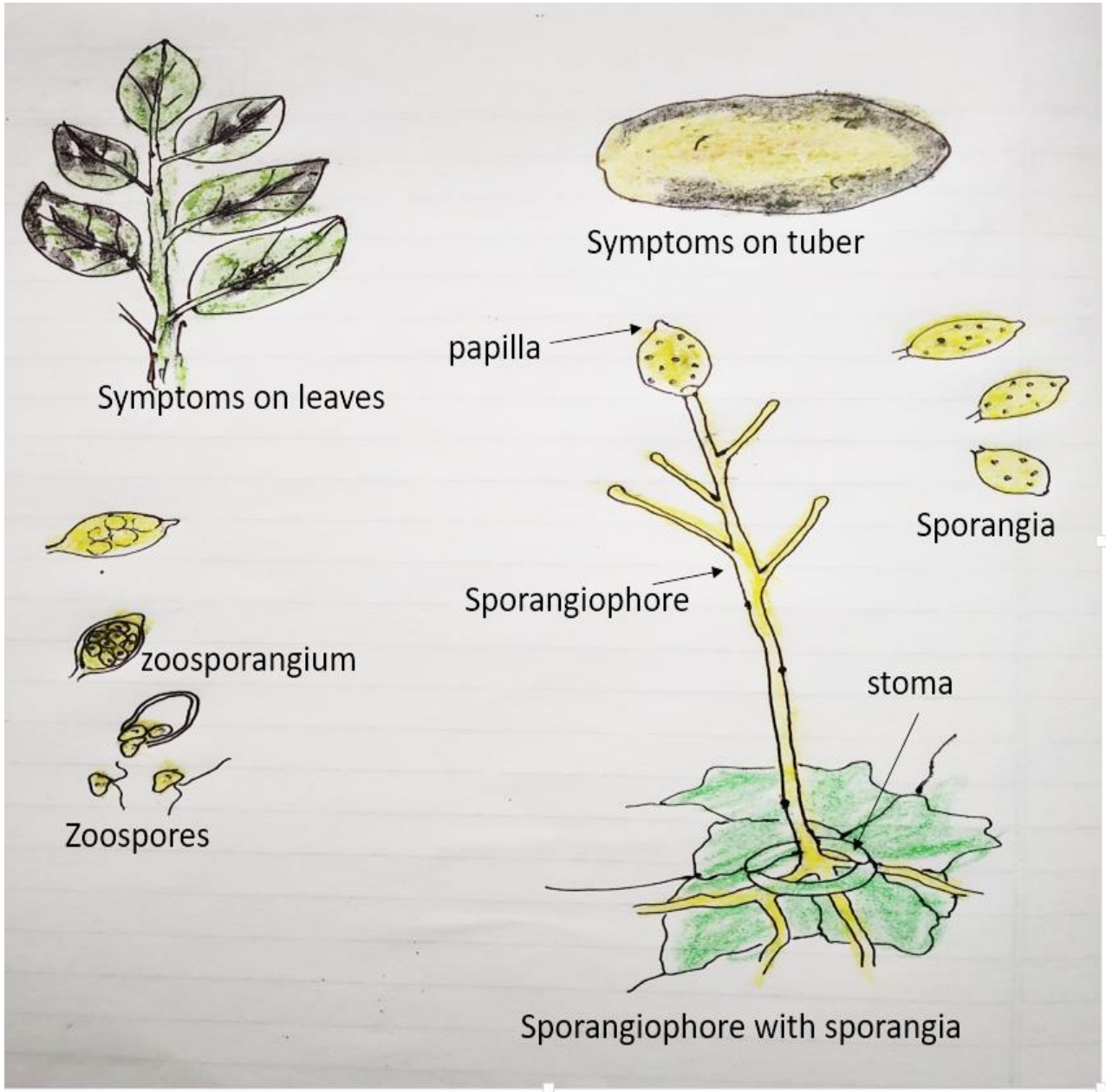
LATE BLIGHT OF POTATO

- A very serious and important disease of potato which can result in total destruction of potato crop in a short period of time.
- Losses due to this disease can reach up to 80% in years of epidemic.
- It was the cause of the infamous **Irish Famine** which occurred during 1843-45. About a million people lost their lives and an equal number migrated to USA and other countries due to the epiphytotic disease.
- In India it was first recorded in 1870-80 in Nilgiri hills. Now occurs in many states such as U.P. Punjab, W.B., Karnataka, Uttarakhand etc.

SYMPTOMS:

- Late blight of potato appears in the fields only after blossoming period.
- Above ground parts of the plant body are infected initially but later on the infection spreads in the tubers also.
- Symptoms appear first on the surface of leaves in the form of dark brown or black coloured small patches.
- Under favourable Seasons the spots gradually increase and occupy almost entire surface of the leaf.
- The sporangia are formed on the lower side of the leaf as powdery mass surrounded by a distinct border thus producing blight.

- The blight represents the rapid death of the cells which later on get transformed into dark brown to black lesions giving burnt appearance.
- Under severe conditions these spots also appear on stems.
- Under warm and humid conditions the spots change their colour and stems also get infected.
- The infected Tuber gives the smell of decaying vegetable matters.
- It is remarkable feature of this disease.
- The skin of tubers become soft sunken and dark in colour.



CAUSAL ORGANISM : *Phytophthora infestans*

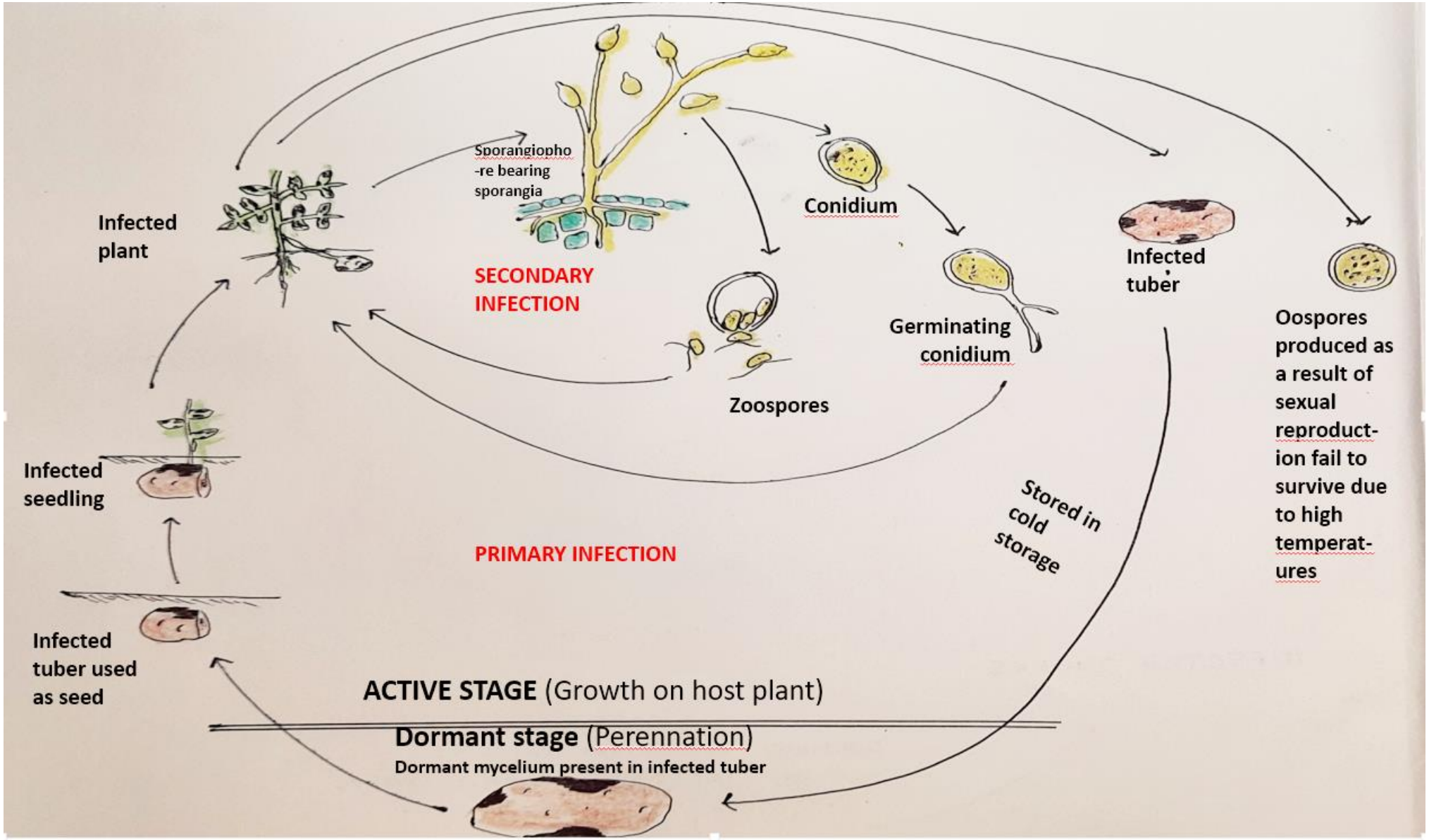
Division ……Mycota
Sub-division ……Eumycota
Class……Oomycetes
Order……Peronosporales
Family……Pythiaceae
Genus…….. *Phytophthora*
Species……. *Infestans*

- Mycelium is tubular, hyaline, irregularly branched, aseptate and coenocytic.
- Hyphae may be intracellular or intercellular.
- The intercellular hyphae develop globular, finger or club-shaped haustoria inside the neighbouring host cells.
- The cell wall lacks chitin and is mainly composed of glucan.
- The Protoplasm contains numerous nuclei, vacuoles and oil globules used as reserve food.
- Asexual reproduction takes place by conidia or sporangia developed on branched conidiophore or sporangiophore.
- Sporangia are formed at an optimum temperature ranging between 18 and 22ºC.
- The sporangiophore show swelling at the place of attachment of sporangia.
- Two coarse of germination of sporangia occurs based on the prevailing temperature.
- **When the temperature is above 15^{o} C , the sporangia behave like conidia and directly germinate forming a germ tube (DIRECT GERMINATION).**
- **If the temperature is lower than 15^{o} C (around 9^{o} C) with 100% relative humidity , then the sporangium produces 3 to 8 biflagellate zoospores. These zoospores settle, encyst and then germinate producing germ tube (INDIRECT GERMINATION)**

DISEASE CYCLE:

- Infected tubers are the primary source of inoculum in India.
- The use of cold storage for storing potatoes and the fast means of transportation of seed materials from hilly regions to plains has lead to rapid spread of disease.
- Crop residue is the source of **primary infection** in hilly areas. This is not possible in plains due to the high temperatures.
- When infected tubers (in which fungal mycelium is present) is used as seed material and is sown, the plant which arises gets infected.
- The fungal mycelium grows systemically with the growing seedling.
- Lower leaves first show symptoms.
- **Secondary infection** takes place from spores produced on primary infected parts.
- Spores in form of **zoospores (INDIRECT GERMINATION)** or **sporangia behaving as conidia (DIRECT GERMINATION)** serve as secondary inoculum.
- Secondary inoculum reaches healthy plants through the agency of wind, rain, irrigation water or insects.

Disease cycle:



CONTROL MEASURES:

- Only healthy tubers should be selected and used as seed material.
- Before sowing the tubers should be immersed in 1: 1000 mercuric chloride solution for 90 minutes.
- Bordeaux mixture (copper sulphate: lime : water = 4:4:50) is most effective fungicide to control the disease.
- Dithiocarbamates such as zineb, maneb etc. are now widely used to control the disease.
- Other chemical fungicides used are : copper-lime dust, zinc sulphate etc.
- Growing resistant varieties of potato such as kufri alankar, kufri moti, kufri badshah, kufri swarna, JH 232, F 5242 etc. is another means of avoiding the disease.

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Early blight of Potato

- Contents –
- Introduction
- Symptoms
- Causal organism
- Etiology
- Disease cycle
- Control

Early blight of Potato 1

Host- Solanum tuberosum Pathogen or C\O- Alternaria solani

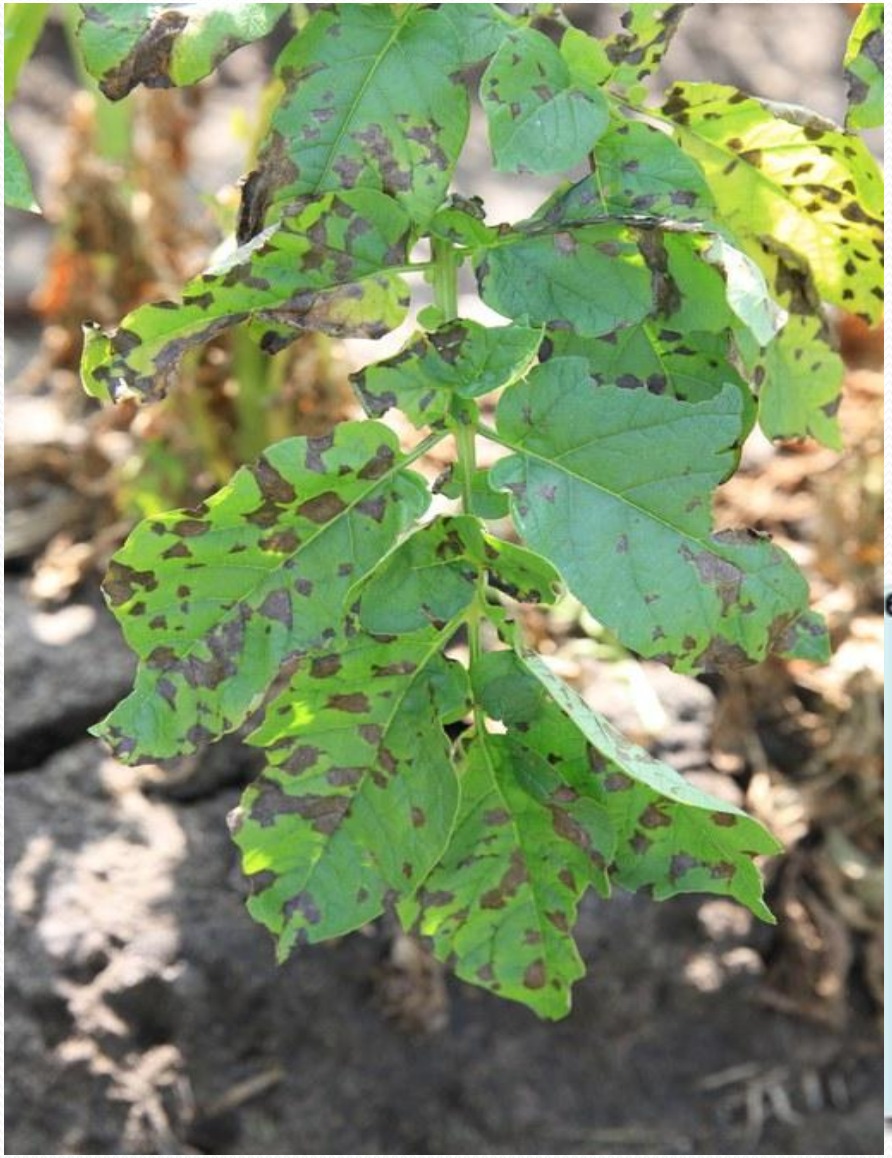
Introduction- Early blight is a disease of potato caused by the fungus Alternaria solani It is of common occurrence both in cold as well as in warm regions in India and abroad ie wherever potatoes are grown (worldwide).Among the fungal disease, early blight is most destructive. This disease may cause serious damage to the crop.

Symptoms- 1. The disease first becomes visible as small, isolated, scattered, pale brown spots on the leaflets. The lowest leaves are attacked first and the disease progresses upwards.

- 2. In the necrotic spots, **concentric rings appear on older leaves** and darkened areas on the stem. This gives a **target board- like effect.** There is usually a narrow **chlorotic zone around the spots**.
- 3.There may be a few spots or a large numbers of spots on the leaves.
- 4. In dry weather, the **spots become hard and the leaves curl**.
- 5. In humid weather, the affected areas increase and large **rotting patches** may appear.
- 6. In severe attacks, leaves shrivel, become **yellow** and **fall down** ie defoliation also occurs. All the aerial portions of the **plant** have a **blighted appearance**.
- 7. **Tuber** lesions are dry, dark and pressed into the tuber surface, with the underlying **flesh turning dry, leathery and brown. Reduces the potato yield also.**

Symptoms- infected plants 2

Symptoms



Symptoms 4

Early blight of Potato 5

- **Causal organism** - Alternaria solani

Deuteromycetes

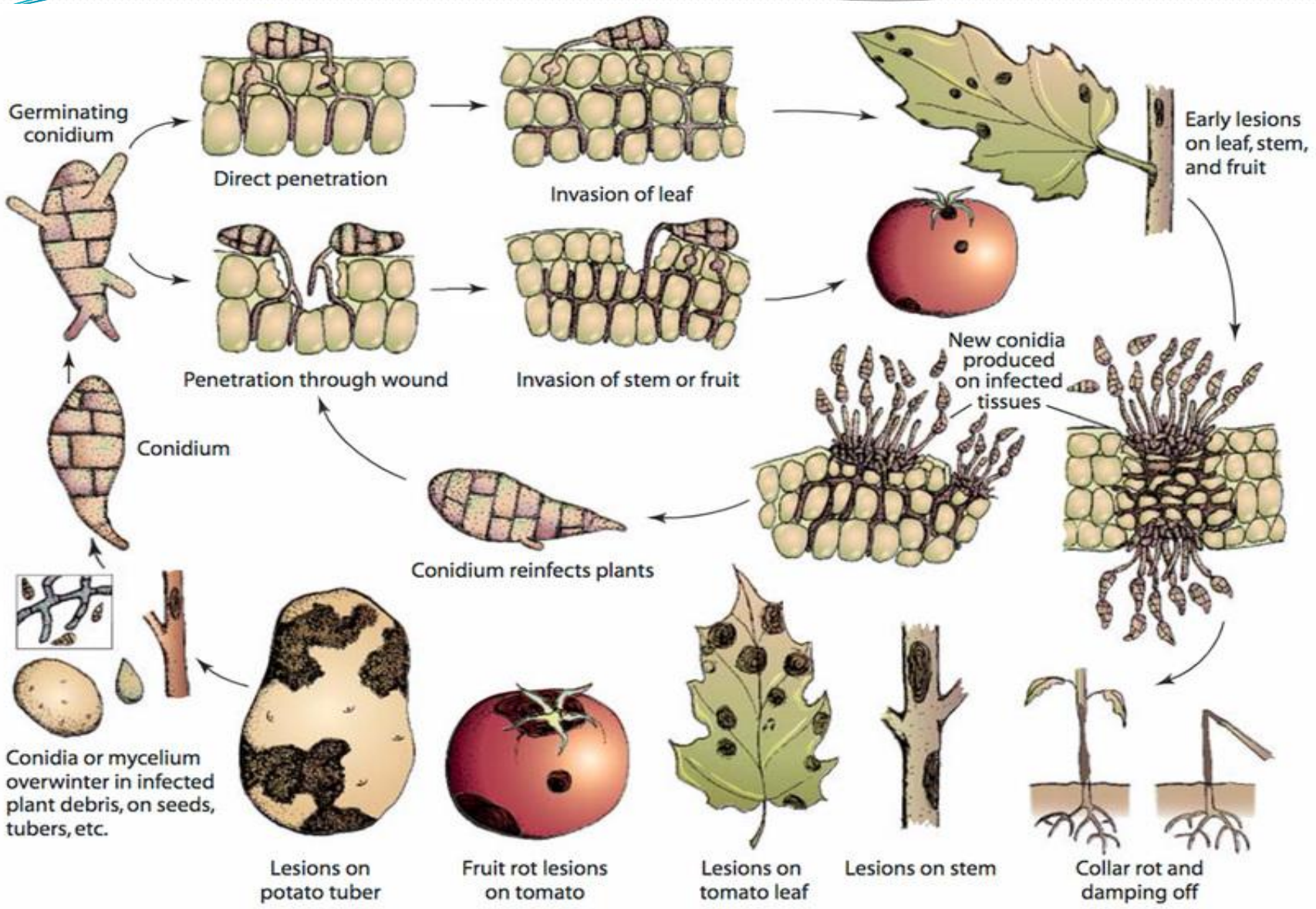
Moniliales

Dematiaceae

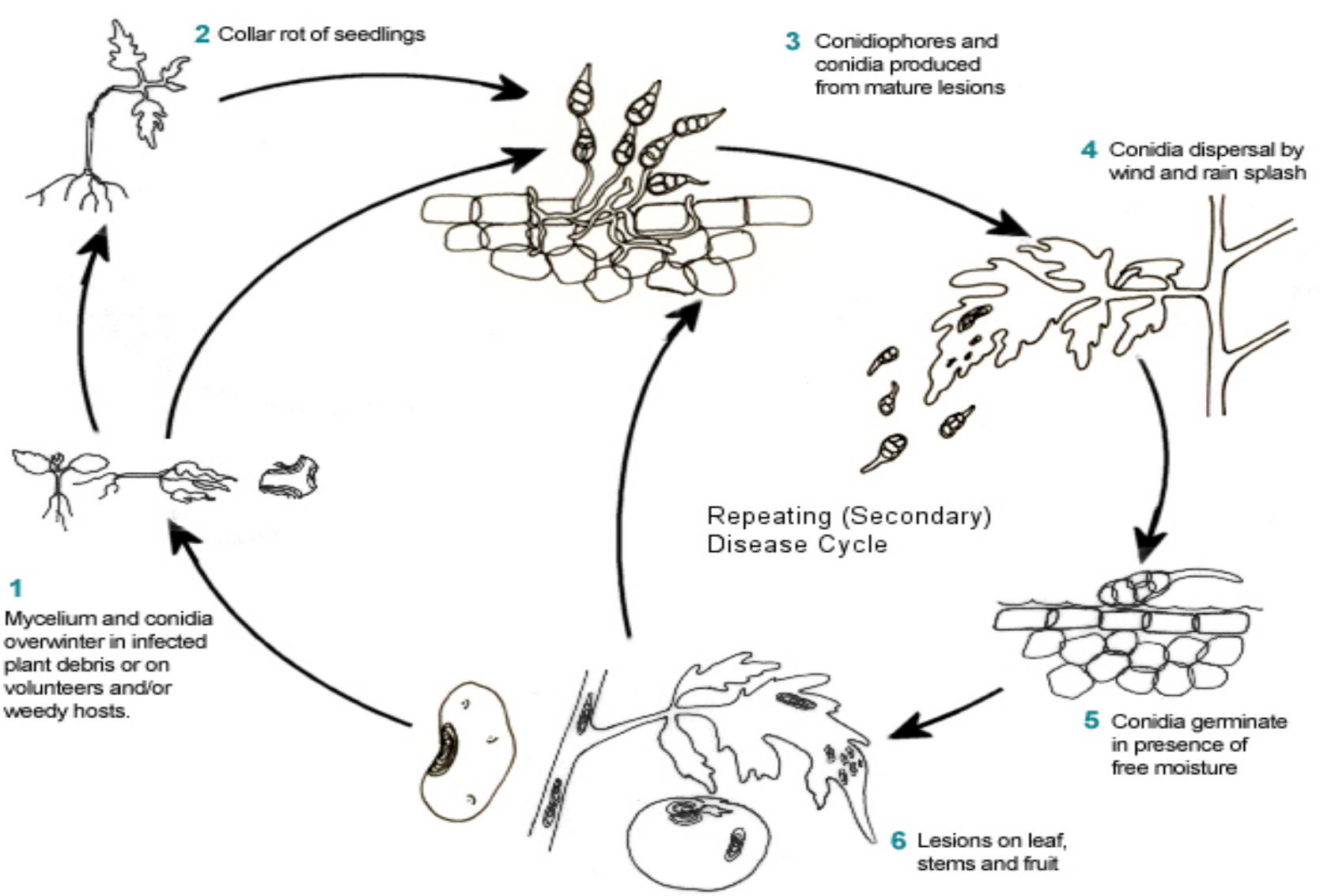
- **Etiology**- **1.** The mycelium consists of septate , branched, light brown hyphae which become darker with age. The hyphae are at first intercellular, later penetrating into the cells of the invaded tissue.
- **2.** Conidiophores emerge through the stomata from the dead centre of the spots. These are 50-90 x 9 u, dark coloured and borne singly. They form chains of 2-3 conidia.
- **3.** Conidia are beaked, muriform, dark coloured and 120-296 x 12-20u. There are both transverse and longitudinal septa in mature conidia.
- **4.** A. solani produces a non- specific toxin known as alternari acid.
- Pathogen is both Air borne and Soil born.

Mycelium & conidia 6

Life- cycle


Germinating conidium
Direct penetration
Invasion of leaf
Early lesions on leaf, stem, and fruit
Penetration through wound
Invasion of stem or fruit
New conidia produced on infected tissues
Conidium
Conidium reinfects plants
Conidia or mycelium overwinter in infected plant debris, on seeds, tubers, etc.
Lesions on potato tuber
Fruit rot lesions on tomato
Lesions on tomato leaf
Lesions on stem
Collar rot and damping off

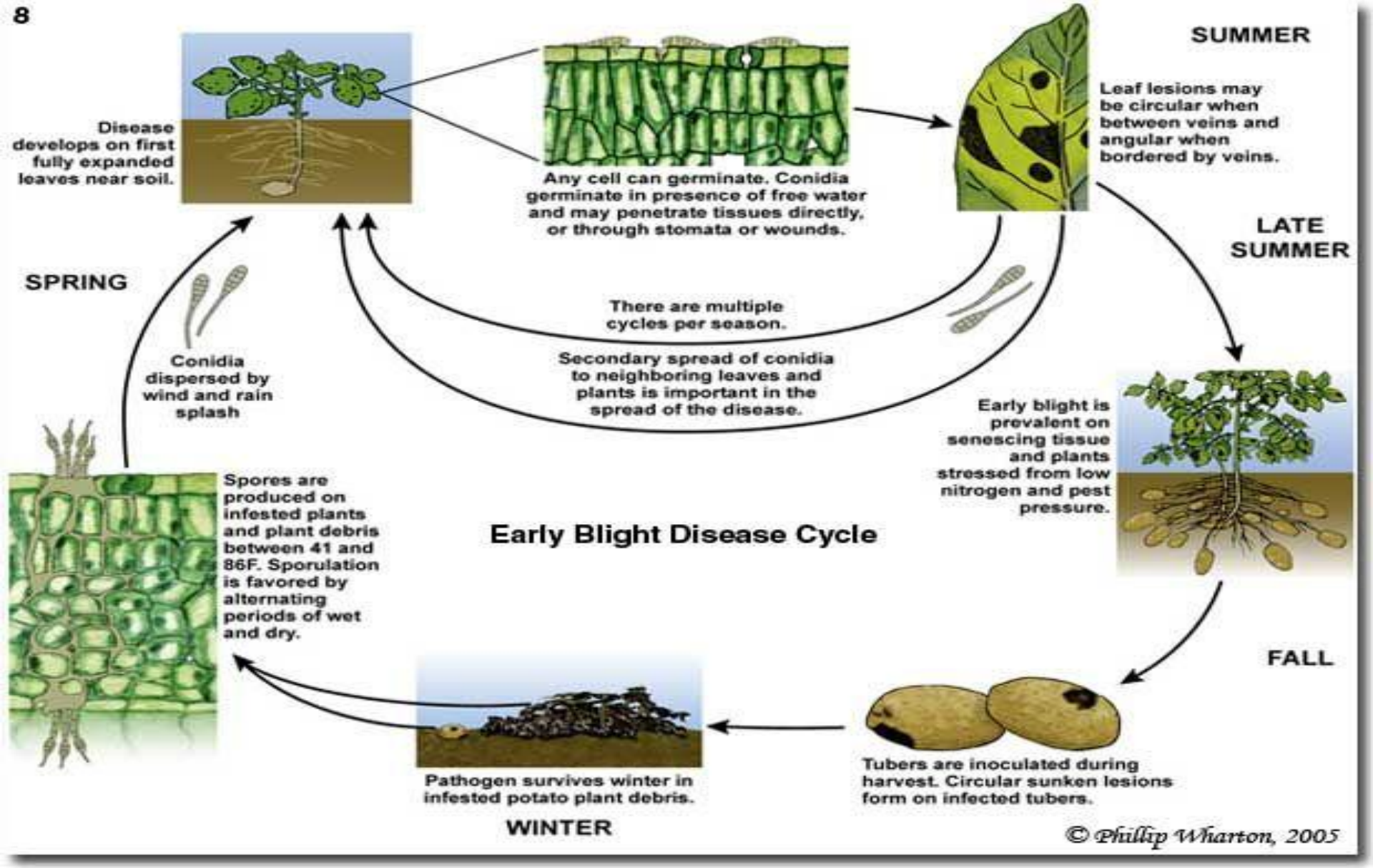
Life- cycle


2 Collar rot of seedlings
3 Coniidiophores and conidia produced from mature lesions
4 Conidia dispersal by wind and rain splash
Repeating (Secondary) Disease Cycle
1 Mycelium and conidia overwinter in infected plant debris or on volunteers and/or weedy hosts.
5 Conidia germinate in presence of free moisture
6 Lesions on leaf, stems and fruit

Early blight of Potato 9

- **Disease-cycle** – 1. The pathogen is mainly air borne.
- 2. The primary infection may be through tubers.
- 3. The mycelium and conidia of the fungus remains dormant in dry infected leaves for a year or more. Mycelium and conidia thus survive in in the soil in the diseased plant debris to cause primary infection in the next year,s crop.
- 4. Collateral hosts such as tomato play an important role in the perpetuation and dissemination of the pathogen.
- 5. The climate as temperature and abundant moisture and soil exert a considerable influence on the development of the disease.

Disease cycle



Early blight of Potato 11

- **Control** - 1. Since the disease is soil borne, **crop rotation** is helpful.
- 2. Infected dead stems and leaves should be **burned** immediately.
- 3. Copper oxychloride sprays have been recommended for the control of the disease.
- 4. Azariah et al (1962)found **Bordeaux mixture** to be effective .
- 5. Apparao et al (1966) from Andhra pradesh advocated the application of 0.312% Zineb for the field control of this disease.
- 6.Mathur et al.(1971) recommended control of this disease with **Brestan 60, Dithane M-45 and Zineb ie spray of copper fungicides .**
- 7. Use of **resistant varieties** as Sarpo Mira, Cara etc .

THANKS

Early Blight and Late Blight of Potato

Early Blight

Early blight and late blight, two serious diseases of potato, are widely distributed. Both are found everywhere potatoes are grown. The terms “early” and “late” refer to the relative time of their appearance in the field, although both diseases can occur at the same time.

Early blight of potato is caused by the fungus, *Alternaria solani*, which can cause disease in potato, tomato, other members of the potato family, and some mustards. This disease, also known as target spot, rarely affects young, vigorously growing plants. It is found on older leaves first. Early blight is favored by warm temperatures and high humidity.

Symptoms. Spots begin as small, dark, dry, papery flecks, which grow to become brown-black, circular-to-oval areas. The spots are often bordered by veins that make them angular. The spots usually have a target appearance, caused by concentric rings of raised and depressed dead tissue. A yellowish or greenish-yellow ring is often seen bordering the growing spots. As the spots become very large, they often cause the entire leaf to become yellow and die. This is especially true on the lower leaves, where spots usually occur first and can be very abundant. The dead leaves do not usually fall off. Dark brown to black spots can occur on stems.

Tubers are affected, as well, with dark, circular to irregular spots. The edges of the spots are often raised and purple to dark metallic gray in color. When the tuber is sliced open, the flesh under the spots is usually brown, dry, and leathery or corky in texture. As the disease advances, the potato flesh often becomes water soaked and yellow to greenish yellow. Early blight spots are less likely to become rotted by secondary organisms than the other tuber rots.

Prevention. Varieties resistant to this disease are available. In general, late maturing varieties are more resistant than the earlier maturing varieties. Keep plants healthy; stressed plants are more predisposed to early blight. Avoid overhead irrigation. Do not dig tubers until they are fully mature in order to prevent damage. Do not use a field for potatoes that was used for potatoes or tomatoes the previous year. Keep this year’s field at least 225 to 450 yards away from last year’s field. Surround the field with wheat to keep wind-blown spores from entering. Use adequate nitrogen levels and low phosphorus levels to reduce disease severity. See current recommendations for chemical control measures.

Late Blight

Late blight of potato is a serious disease caused by *Phytophthora infestans*. It affects potato, tomato and, occasionally, eggplant and other members of the potato family. Late blight is the worst potato disease. It was first reported in the 1830s in Europe and in the US. It is famous for being the cause of the 1840s Irish Potato Famine, when a million people starved and a million and a half people emigrated. Late blight continued to be a devastating problem until the 1880s when the first fungicide was discovered. In recent years, it has reemerged as a problem. It is favored by cool, moist weather and can kill plants within two weeks if conditions are right.

Symptoms. Leaf spots begin as small, pale to dark green, irregularly shaped spots. The spots often have pale green to yellow rings surrounding them. The spots are not bordered by veins but can grow across them. In cool, moist weather, the spots grow rapidly into large brown to purplish black areas. The disease may kill entire leaflets or grow down the petioles and into the stem, killing the plant above it. When the weather is moist, a white fungal growth appears on the edges of the dead areas,

usually on the undersides of the leaves. In the field, plants often give off a distinctive fetid or decaying odor.

On susceptible potato varieties, the tubers can become infected. Small to large, slightly depressed areas of brown to purplish skin can be seen on the outside of the tuber. When the tuber is cut open, there is a tan-brown, dry, granular rot, which extends ½" to ¾" into the tuber. The border of this area is indistinct. If potatoes are stored under warm or humid conditions, the rot will continue to progress. Often secondary rot organisms set in and completely destroy the tubers.

Disease Identification. White, fluffy fungal growth is present on the bottoms of leaves in moist weather. Leaf spots are not bordered by veins.

Prevention. Use disease-free seed potatoes. Keep cull/compost piles away from potato growing areas. Destroy any volunteer potato plants. Keep tubers covered with soil throughout the season to prevent tuber infection. Remove infected tubers before storing to prevent the spread of disease in storage. Kill vines completely before harvest to avoid inoculation of the tubers during harvest. Resistant varieties are available, although some fungicides must still be applied to resistant cultivars. See current recommendations for chemical control measures.

By: Pam Mercure, IPM Program Assistant, University of Connecticut, 1998

Reviewed by: T. Jude Boucher, IPM, University of Connecticut. 2012

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Early Blight of Potato

Alternaria solani

Rainer Zachmann

Early blight leaf symptom

Technical Information Bulletin 17
May 1982

INTERNATIONAL POTATO CENTER (CIP) Lima — Peru

Technical Information Bulletin 17

Early Blight of Potato

Alternaria solani

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Early Blight of Potato

Alternaria solani

Objectives. Study of this bulletin should enable you to:

- explain the importance of early blight,
- describe the symptoms,
- describe disease development (epidemiology),
- explain the biology of the fungus,
- discuss methods of monitoring spore propagation,
- discuss methods of control,
- demonstrate methods of disease evaluation.

Study materials.

- Infected plants and tubers to demonstrate symptoms.
- Spore trap, trapped spores and microscope to demonstrate trapping method.
- Fields with different varieties to practice disease evaluation.

Practicum.

- Observe and discuss early blight attack and possible control measures in the field.
- Set up a spore trap and observe the results one or a few days later (depending on intensity of secondary spore propagation).
- Practice different disease evaluation methods in the field.

Questionnaire.

1. How serious is early blight in your country?
2. On which plant parts does the disease occur?
3. How can you distinguish early blight from late blight symptoms?
4. How does *A. solani* inoculum survive?
5. What is the damage of primary infection?
6. Which climatic conditions favor early blight incidence?
7. What is the epidemiological importance of primary infection?
8. How can you observe start of secondary spore propagation visually?
9. How can you reduce disease incidence by proper agronomic management?
10. What is the relation between crop maturity or maturity type of varieties and disease incidence?
11. Why should infected residues be removed from the field after harvest?
12. Which effect has crop rotation as control measure?
13. How would you best schedule fungicide applications?
14. Which are the most resistant varieties in your country?

Technical Information Bulletin 17

Early Blight of Potato

Alternaria solani

1 INTRODUCTION

Early blight of potato is caused by the fungus *Alternaria solani*. It attacks principally potato foliage, but also tubers. The disease is an important problem in many areas that are too warm and dry for *late* blight, another fungal disease caused by *Phytophthora infestans*. Various possibilities for control of early blight exist.

2 IMPORTANCE OF EARLY BLIGHT

Early blight was first described in 1882. It is a serious problem in many areas of the world where it not only affects potato, but also tomato and other solanaceous plants. Early blight has received less study than late blight, but in recent years it has been observed as an important disease in many of the warmer potato growing areas.

The disease occurs on foliage and sometimes also on tubers. Yield reductions caused by foliage attack reach more than 50 %. The effect of early blight may sometimes be obscured by severe incidence of other diseases, such as verticillium wilt.

In stored potatoes, losses caused by *A. solani* may be substantial and reach 80 % of tubers affected by early blight lesions. In some instances, tuber infection has caused large losses in potatoes stored for processing at temperatures of 10 °C or higher.

3 SYMPTOMS

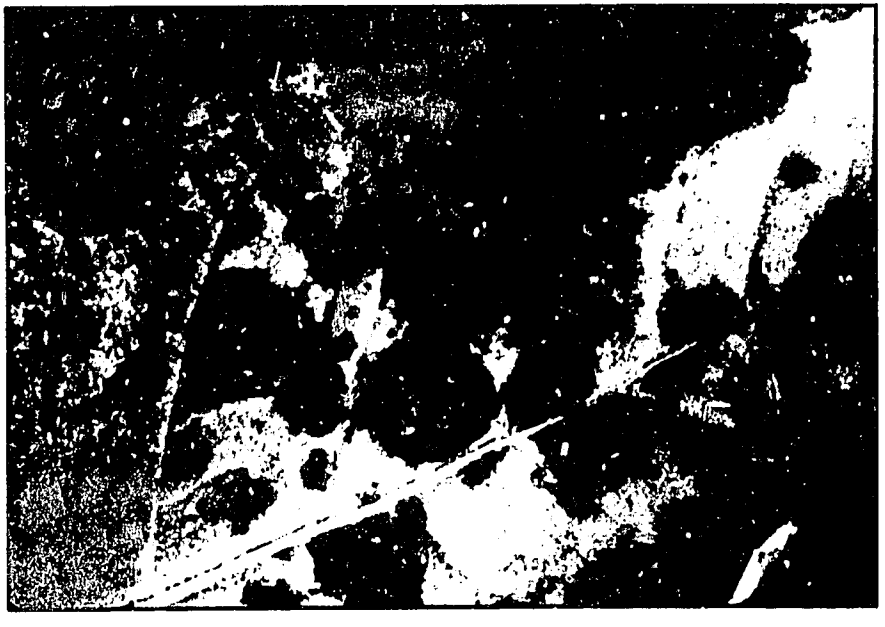
Symptoms occur on foliage and tubers.

On leaves, dark brown, more or less circular lesions, with concentrically arranged rings resembling a target board, first develop on the lower, older leaves. Depending on environmental conditions and potato variety, lesions enlarge to 0.5 to 2.0 cm in diameter, and become associated with chlorotic leaf area around and between the lesions. Under dry conditions lesions may drop out leaving a hole (shot-hole appearance). Leaves eventually become totally chlorotic, dry and die. The disease generally leads to defoliation but drying leaves remain sometimes hanging on the plant. Similar lesions also occur on petioles and stems. Stem infection may cause breaking of stems and death of the uninfected plant portions above the lesion. Foliage symptoms can be confounded with early maturity and verticillium wilt symptoms.

Tuber infections are characterized by irregular, sunken lesions with elevated borders. They are randomly distributed on the tuber surface. Their color varies from gray, to brown or purple to black. The tissue below the lesions is dark brown, solid and dry, and extends into the tuber from a few millimeters up to 2-3 cm. It is often surrounded by a narrow water soaked zone.

Early blight symptoms should not be confused with those caused by *Phytophthora infestans* (late blight). Late blight lesions on leaves are usually not zonate. Under high relative humidity they show sporulation in the form of a white mildew on the underside of leaves, which early blight does not. In contrast to early blight, late blight typically occurs under prolonged humid and cool conditions. Tuber lesions caused by early blight do not extend irregularly into the flesh as in late blight. (See: "Late blight of potato", section 9 of this bulletin).

In the humid tropics leaf lesions may additionally be caused by other fungi, such as *Alternaria alternata,* and *Phoma, Septoria* and *Macrophomina* spp. Symptoms are sometimes similar and can be confused with those caused by *A. solani*.



On leaves, early blight lesions present a characteristic zonate or target board appearance. Under dry conditions they may drop out leaving a hole.

4 EPIDEMIOLOGY

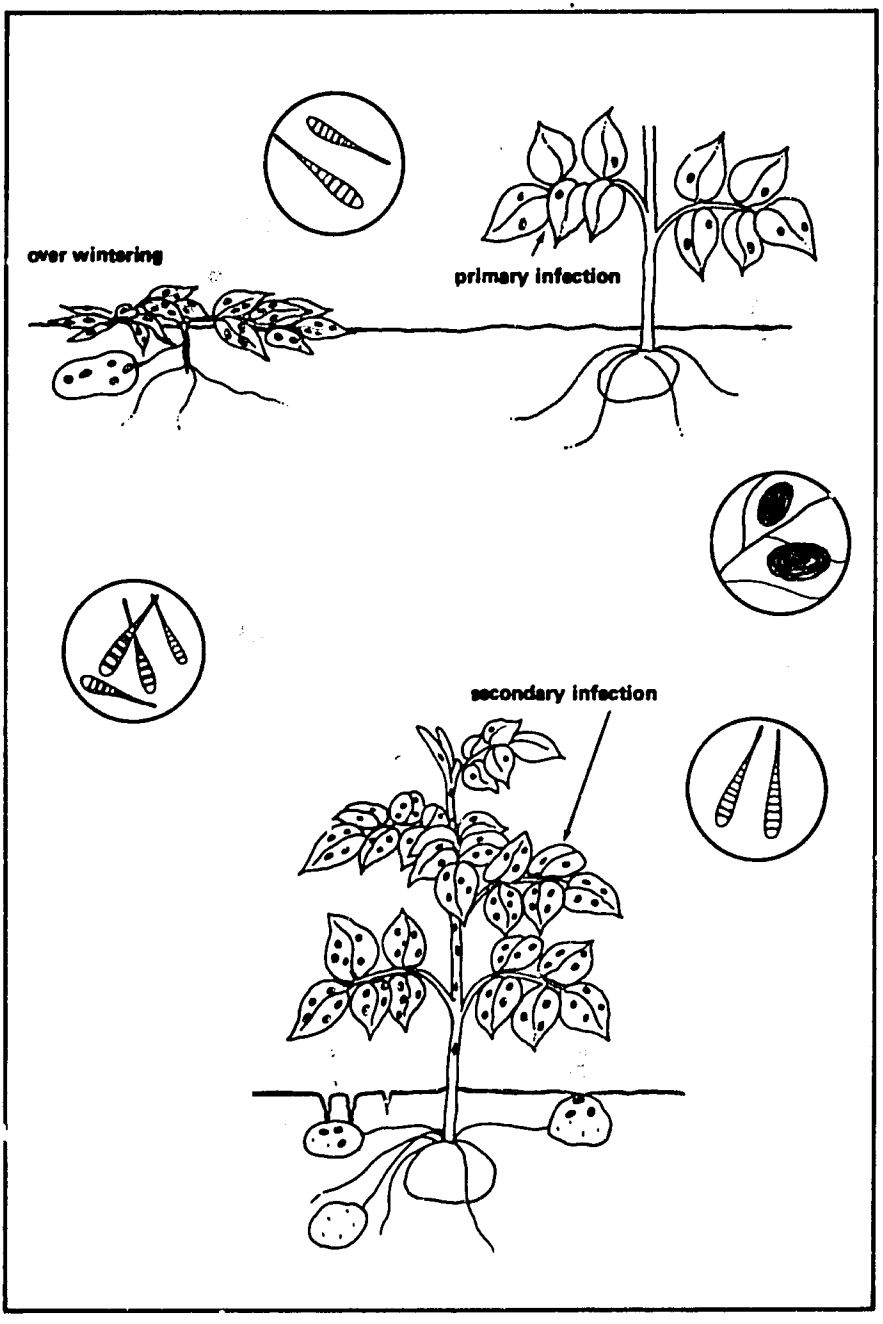
A. solani inoculum survives from season to season, but not over several years, as mycelium or spores on plant debris or at the soil surface from where spores spread by wind. Inoculum may also survive on tubers. Initial, *primary*, spread from this soil borne inoculum may remain restricted, but it is the basis for often heavy *secondary* disease propagation. Young leaves appear to be resistant to the primary development of the fungus. They may be infected but do not show symptoms for several weeks. When leaves begin to senesce, typical lesions develop, predominantly on the lower leaves. Middle and top leaves continue to appear healthy even though they may be as heavily infected as bottom leaves.

The relatively few lesions developing on the lower leaves are the source of *secondary* sporulation which leads to heavy infection later in the season. Since primary lesions are often inconspicuous, the beginning of secondary sporulation is hard to notice. It can be monitored by spore traps which reveal secondary sporulation long before spread of the disease (see section 6 below).

Relationship between disease development and plant maturity may be confirmed by several observations. Varieties maturing early often show heavier secondary infection. They may serve as a source of inoculum for later maturing varieties. Heaviest infection generally develops towards the end of the growing season. The effect of early blight is difficult to assess when other adverse conditions, such as drought and verticillium wilt, contribute to early senescence of a crop.

Foliar infection is favored by warm (around 25 °C) and wet conditions. Rainfall promotes the disease but is not required if heavy dew is frequent. Other factors that increase loss include overhead sprinkler irrigation, mechanical harvesting and storage at elevated temperatures (above 10 °C).

Inoculum present on infected foliage or on the soil surface infects injured tubers at harvest time. Tubers become less susceptible to mechanical damage and consequently to early blight infection when proper measures are taken to reduce tuber injuries.



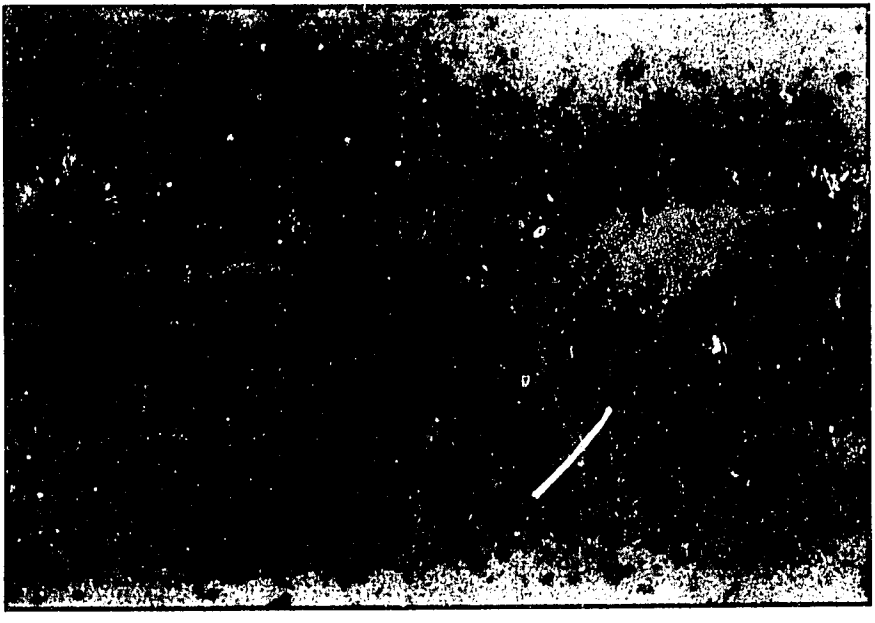
Epidemiological cycle of early blight. Inoculum survives on plant debris or soil. Upon *primary* infection, lesions develop on lower leaves. These are the source for *secondary* sporulation which leads to heavy infection later in the season.

5 BIOLOGY

The fungus *Alternaria solani* Sorauer (family *Dematiaceae,* form-class Deuteromycetes) is spread by spores, called *conidia.* Conidia are elliptic, oblong or club shaped, dark in color, transversally septated but often without longitudinal cell walls, and ending in a long terminal cell. They are microscopically small, 15 to 20 µm wide and 150 to 300 µm long. The terminal cell narrows towards its end to 2.5 to 5.0 µm.

Under optimum conditions of high moisture and temperatures between 24 and 34 °C, conidia germination is initiated within 30 minutes. The developing germ tube penetrates leaves through the epidermis or stomata. The septated and branched mycelium expands within the leaves. Due to toxic substances produced by the fungus, damage extends in advance to growth of the mycelium. In pure culture optimum growth is around 28 °C.

The spore bearing *conidiophores* are produced singly or in small groups. Light and temperatures between 19 and 23 °C stimulate development of conidiophores.



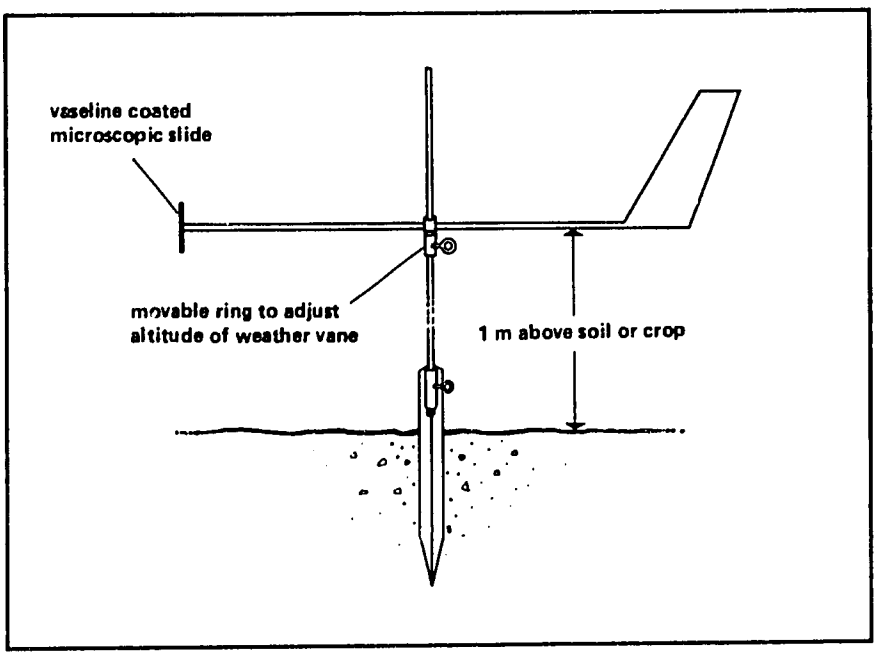
***A. solani* spores, so-called *conidia*, are club-like in shape, septated, ending in a long terminal cell, and dark in color. Under optimum conditions they may start to germinate within 30 minutes.**

6 MONITORING SPORE PROPAGATION

Primary infection has little economic effect, but it is important for epidemic development of the disease because it may lead to significant secondary spore propagation. Knowledge about the start of this secondary spore propagation is important for scheduling control measures.

Secondary spore propagation starts with the development of primary lesions on lower leaves. Development of these lesions may be monitored visually. However, primary lesions are difficult to see and may be easily overlooked. Considerable spore propagation might have started before the first lesions are detected visually.

A relatively easy trapping method may be carried out by experimental stations that own a simple microscope to provide an alerting service to potato growers of a region. The spore trap consists of a microscopic slide coated with vaseline attached to a weather vane which holds the slide against the wind. Air-borne *Alternaria* spores stick to the vaseline coating and can be easily distinguished under 100x magnification. (For details see under "Additional reading"). Spore trapping may not be practical for the individual potato grower.



The spore trap consists of a vaseline coated microscopic slide attached to a weather vane.

7 CONTROL

Control of early blight includes

- precautions during crop management,
- chemical control and
- use of resistant varieties.

Precautions during crop management. Because the development of early blight is related to crop vigor and maturity, agronomic management which promotes vigor and avoids rapid foliage senescence and plant weakness helps to reduce disease incidence. This includes correct irrigation and fertilizer application (observe local recommendations). Consider that sprinkler irrigation may promote disease development.

Because early maturing varieties contribute to heavy secondary spore propagation, plantings should be located so that wind-borne spores do not easily reach later varieties (down wind).

To prevent tuber infection, infected foliage should be eliminated some days before harvest and tubers left in the soil until the skin is mature and more resistant against mechanical damage.

As *A. solani* persists on plant debris, all infected residues should be removed from the field after harvest.

Although the organism is capable of overwintering from one season to another it cannot survive longer periods. Thus, crop rotation may help to reduce inoculum quantity in a field.

Chemical control. Early blight can be effectively controlled by a few fungicide applications, provided spraying is timed according to secondary sporulation. Earlier applications are of little effect, and indiscriminate continuous spray schedules do not improve the result. (They just cost more). Spore trap data give a good indication of fungus activity and secondary spore propagation.

The same protective fungicides used for the control of late blight are generally effective against early blight. At present, most frequently used are dithiocarbamates, zineb, maneb, captafol, chlorothalonil and triphenyl-tin-hydroxide. Note that fungicides specifically designed for late blight control (e.g. Ridomil) may be ineffective for early blight.

Use of resistant varieties. Potato varieties show different levels of field resistance but none are immune. Susceptibility is associated with early maturity. Later maturing varieties are generally less affected. Because resistance is the best means of control, varietal improvement programs should study the resistance of prevailing varieties or new breeding materials.

8 DISEASE EVALUATION

For comparing resistance of potato varieties or efficiency of control measures several evaluation methods have been proposed. Because the disease incidence is related to the physiological condition of a crop, plant maturity should also be recorded.

Plant maturity. Plant maturity can be evaluated at a certain date or at regular intervals (weekly) on a scale of one to five:

1 = very early, plants mature;
5 = very late, plants green and in bloom.

Percentage of leaves infected. Number of infected leaflets can be counted and related to the total number of leaflets, or the percentage of infected leaflets may be roughly estimated visually.

Lesion size and severity. Lesion size and severity can be evaluated on a one to five scale:

1 = very small leaf lesions (approx. 1 mm),
2 = moderate leaf lesions,
3 = large leaf lesions (approx. 1 cm),
4 = leaf lesions plus small stem lesions,
5 = leaf lesions plus severe stem lesions.

Percentage of defoliation. Visual estimations may be expressed as percentage of leaf area destroyed, or on a scale basis. Frequently used is a scale ranging from 0 (no visible damage) to 5 (total destruction). CIP uses such a system for estimation of late blight (*P. infestans*) which may be applicable for early blight evaluation also (see Henfling, 1979, in "Additional reading").

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Early and Late Blight of Potato

[For B.Sc. III year (paper III unit IV) and B.Sc. Ist Sem.(unit VII)]

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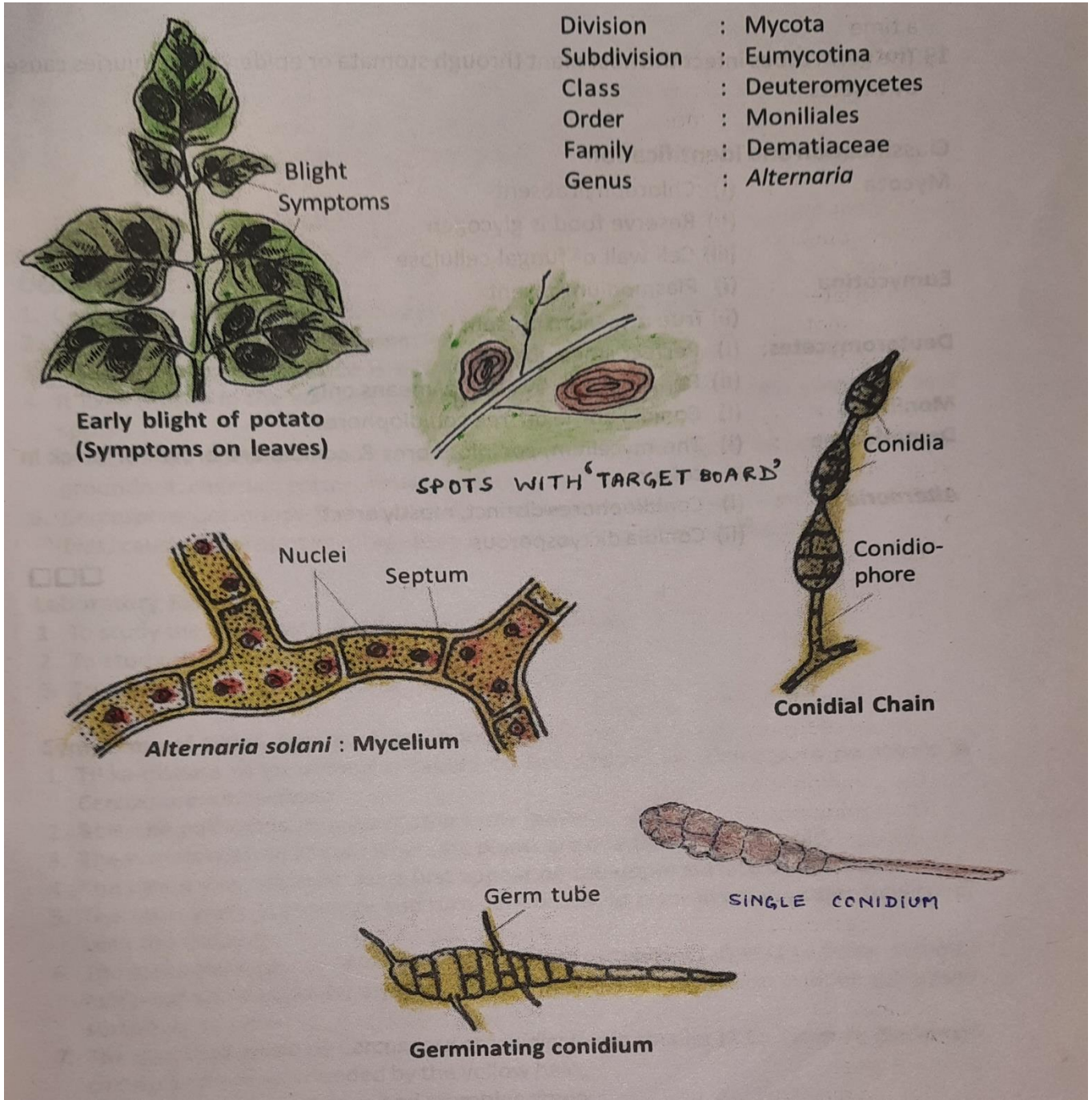
EARLY BLIGHT OF POTATO

- The name of the disease is because of the infection on potato crop taking place in earlier part of growing season.
- The disease is worldwide in distribution.
- In India, when the disease is severe it may lead to almost 40% loss of yield in potato crops.
- Besides potato other members of family Solanaceae such as tomato, cabbage, Chili, brinjal, cauliflower etc. and a number of wild species of plants act as Collateral hosts for the fungal pathogen.

SYMPTOMS

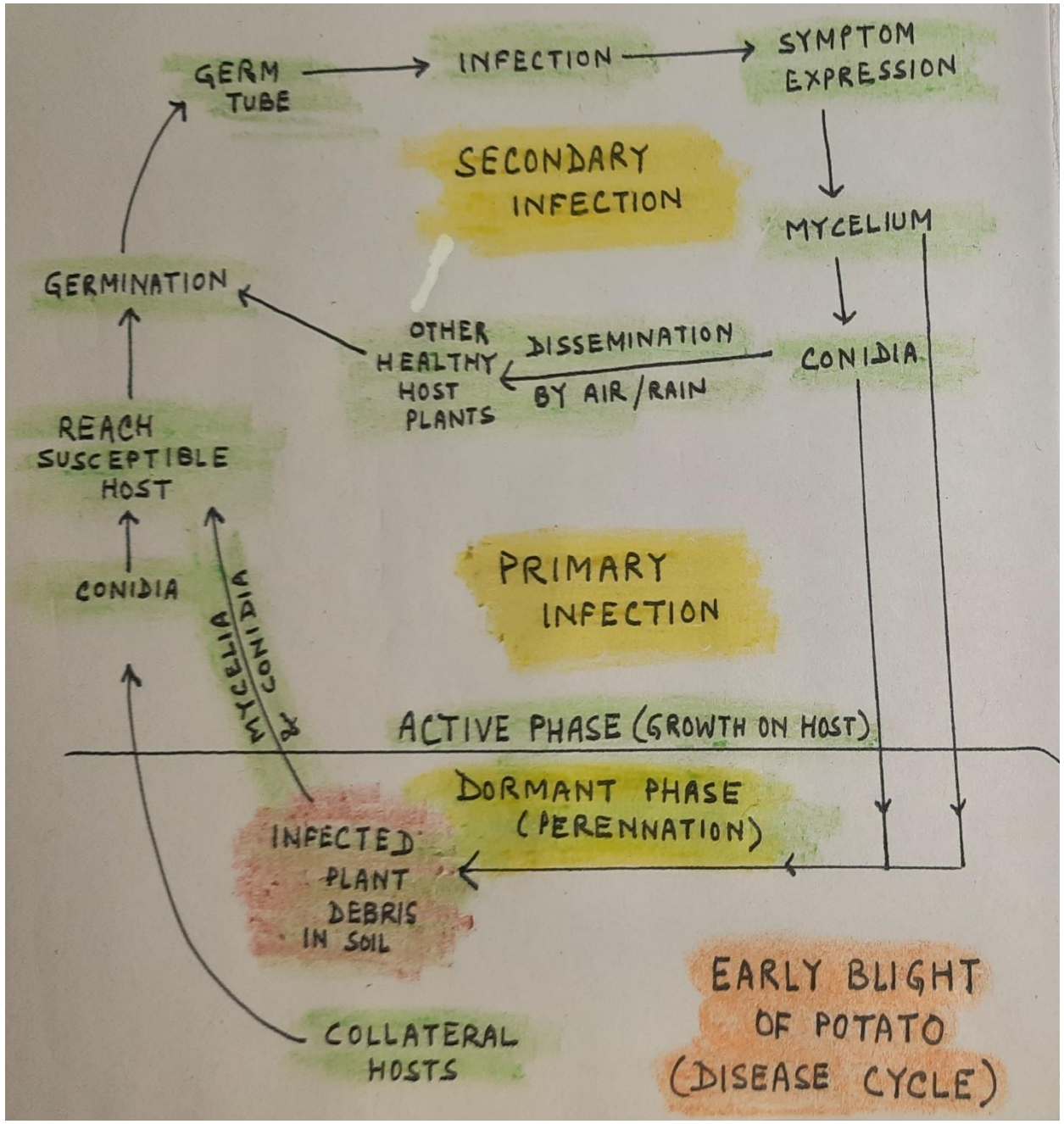
- Being an early infecting pathogen, the symptoms of the disease start appearing when the plant is 3 weeks old.
- The leaves which are near the ground first show small circular or irregular dark brown to black spots.
- The peculiar characteristic of these pots is the presence of concentric rings which give it a target board like appearance.
- These spots later enlarge in size and adjacent is spots coalesce to form large angular sports.
- The symptoms later also develop on the petiole and stem in the form of elongated brown to black lesions.
- In the advanced stage of growing season numerous lesions appear on the upper leaves.
- The leaves drop - a case of premature leaf senescence.
- Tubers also show symptoms in form of dark and sunken lesions on the surface which are circular or irregular in shape. If cut open, the tubers show dry corky texture with dark brown colour inside.

- **CAUSAL ORGANISM**:
  Alternaria Solani
- Mycelium of the fungus is branched, septate and grows both inter and intracellularly through the host tissue.
- Haustoria are absent.
- Each cell of the hypha is usually multinucleate.
- At maturity the mycelium produces conidiophores.
- Conidiophores emerge through stomata or dead epidermal cells.
- Conidiophores are short, dark coloured, aerial, septate and little curved at the tip.
- Conidia are produced at the tip of conidiophores either singly or in chain.
- Each conidium is beaked, bottle shaped, obclavate (club shaped), muriform (having horizontal and vertical septa - dictyospore).



DISEASE CYCLE

- The fungus survives on the plant debris left in the field on decaying potato tubers or on some collateral host such as tomato or some wild species of family Solanaceae.
- The **primary inoculum** which is usually in the form of a mycelium or a spore, disseminates through the agency of wind or rain splash or irrigation water and reaches the host leaf surface where it germinates and brings about **primary infection.**
- After the fungus establishes itself inside the host tissue the stage of **secondary infection** starts.
- In this stage, the pathogen producers conidia on the surface of the leaves.
- Conidia are produced in large numbers.
- They are disseminated by wind, splashes of rainwater or irrigation water and reach other healthy potato plants where they cause secondary infection.



CONTROL MEASURES:

Proper fertilization, irrigation and management of pests through various means.

Cultural Practices:

- Crop rotation
- Field sanitation
- Growing late sowing varieties
- Diseased plant parts should be destroyed completely by burning.

Chemical Pesticides:

- Fungicides should be use in justified manner and only when symptoms appear.
- Example of fungicides : Copper fungicides such as **maneb, mancozeb**, **Zineb** (**Dithane Z-78**), **Blitox-50** (.25%), **Captan**, **Bordeaux mixture** etc.

Biocontrol:

Fungal species ***Trichoderma harzianum*** and ***T. viride*** are used as bio fungicide.

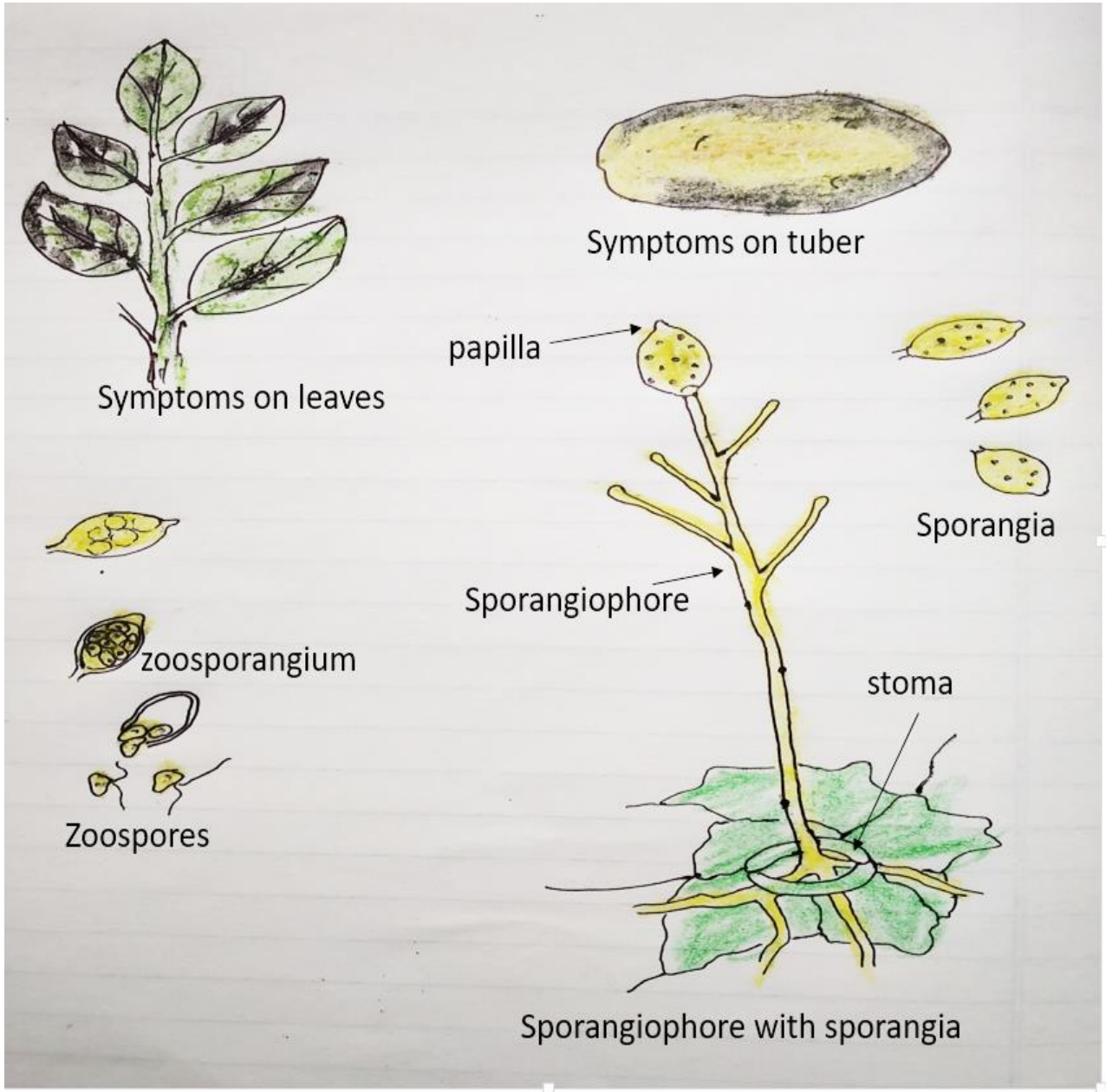
LATE BLIGHT OF POTATO

- A very serious and important disease of potato which can result in total destruction of potato crop in a short period of time.
- Losses due to this disease can reach up to 80% in years of epidemic.
- It was the cause of the infamous **Irish Famine** which occurred during 1843-45. About a million people lost their lives and an equal number migrated to USA and other countries due to the epiphytotic disease.
- In India it was first recorded in 1870-80 in Nilgiri hills. Now occurs in many states such as U.P. Punjab, W.B., Karnataka, Uttarakhand etc.

SYMPTOMS:

- Late blight of potato appears in the fields only after blossoming period.
- Above ground parts of the plant body are infected initially but later on the infection spreads in the tubers also.
- Symptoms appear first on the surface of leaves in the form of dark brown or black coloured small patches.
- Under favourable Seasons the spots gradually increase and occupy almost entire surface of the leaf.
- The sporangia are formed on the lower side of the leaf as powdery mass surrounded by a distinct border thus producing blight.

- The blight represents the rapid death of the cells which later on get transformed into dark brown to black lesions giving burnt appearance.
- Under severe conditions these spots also appear on stems.
- Under warm and humid conditions the spots change their colour and stems also get infected.
- The infected Tuber gives the smell of decaying vegetable matters.
- It is remarkable feature of this disease.
- The skin of tubers become soft sunken and dark in colour.



CAUSAL ORGANISM : *Phytophthora infestans*

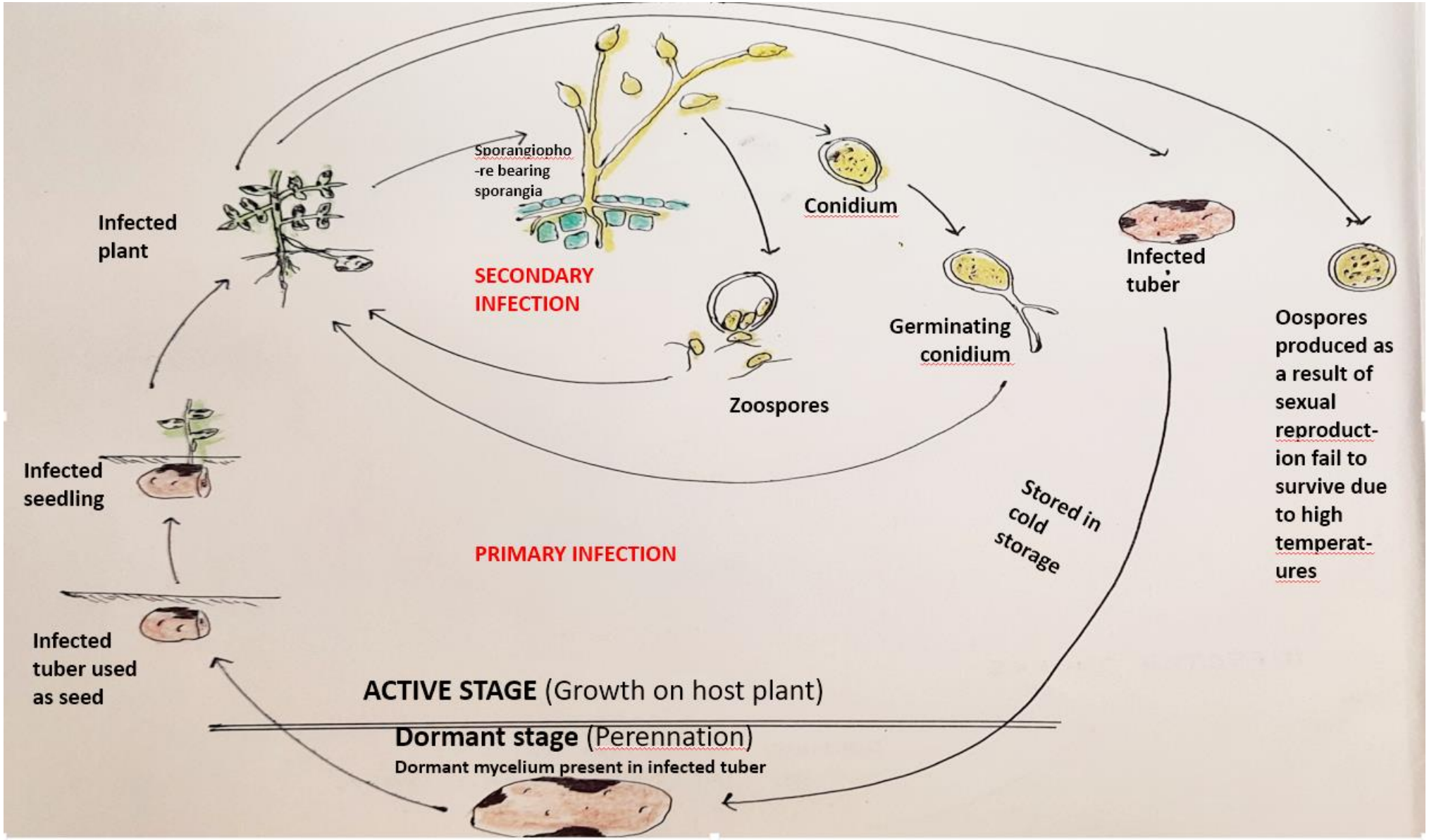
Division ……Mycota
Sub-division ……Eumycota
Class……Oomycetes
Order……Peronosporales
Family……Pythiaceae
Genus…….. *Phytophthora*
Species……. *Infestans*

- Mycelium is tubular, hyaline, irregularly branched, aseptate and coenocytic.
- Hyphae may be intracellular or intercellular.
- The intercellular hyphae develop globular, finger or club-shaped haustoria inside the neighbouring host cells.
- The cell wall lacks chitin and is mainly composed of glucan.
- The Protoplasm contains numerous nuclei, vacuoles and oil globules used as reserve food.
- Asexual reproduction takes place by conidia or sporangia developed on branched conidiophore or sporangiophore.
- Sporangia are formed at an optimum temperature ranging between 18 and 22ºC.
- The sporangiophore show swelling at the place of attachment of sporangia.
- Two coarse of germination of sporangia occurs based on the prevailing temperature.
- **When the temperature is above 15^{o} C , the sporangia behave like conidia and directly germinate forming a germ tube (DIRECT GERMINATION).**
- **If the temperature is lower than 15^{o} C (around 9^{o} C) with 100% relative humidity , then the sporangium produces 3 to 8 biflagellate zoospores. These zoospores settle, encyst and then germinate producing germ tube (INDIRECT GERMINATION)**

DISEASE CYCLE:

- Infected tubers are the primary source of inoculum in India.
- The use of cold storage for storing potatoes and the fast means of transportation of seed materials from hilly regions to plains has lead to rapid spread of disease.
- Crop residue is the source of **primary infection** in hilly areas. This is not possible in plains due to the high temperatures.
- When infected tubers (in which fungal mycelium is present) is used as seed material and is sown, the plant which arises gets infected.
- The fungal mycelium grows systemically with the growing seedling.
- Lower leaves first show symptoms.
- **Secondary infection** takes place from spores produced on primary infected parts.
- Spores in form of **zoospores (INDIRECT GERMINATION)** or **sporangia behaving as conidia (DIRECT GERMINATION)** serve as secondary inoculum.
- Secondary inoculum reaches healthy plants through the agency of wind, rain, irrigation water or insects.

Disease cycle:



CONTROL MEASURES:

- Only healthy tubers should be selected and used as seed material.
- Before sowing the tubers should be immersed in 1: 1000 mercuric chloride solution for 90 minutes.
- Bordeaux mixture (copper sulphate: lime : water = 4:4:50) is most effective fungicide to control the disease.
- Dithiocarbamates such as zineb, maneb etc. are now widely used to control the disease.
- Other chemical fungicides used are : copper-lime dust, zinc sulphate etc.
- Growing resistant varieties of potato such as kufri alankar, kufri moti, kufri badshah, kufri swarna, JH 232, F 5242 etc. is another means of avoiding the disease.

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MICHIGAN
Potato Diseases

Early Blight

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Early Blight

Alternaria solani (E. & M.) Jones and Grout
(Hyphomycetes, Hyphales)

Introduction

Early blight is a very common disease of potato that is found in most potato-growing areas. Although it occurs annually to some degree in most production areas, the timing of its appearance and the rate of disease progress help determine the impact on the potato crop. The disease occurs over a wide range of climatic conditions and depends in large part on the frequency of foliage wetting from rainfall, fog, dew or irrigation, on the nutritional status of foliage and on cultivar susceptibility. Though losses rarely exceed 20 percent, if left uncontrolled, the disease can be very destructive. In Michigan and other potato-growing areas, intensive fungicide treatment has restricted losses to less than 5 percent. In the eastern United States, foliar infection is the most critical phase of the disease; in the West, particularly the Rocky Mountain production areas, tuber infection can be more important than foliage infection. In contrast to its name, the disease rarely develops early, and it usually appears on mature foliage.

Figure 1. Early blight lesions first appear as small, irregular to circular dark brown spots on lower leaves. Spots range in size from a pinpoint to 1/8 inch.

Symptoms

Foliar symptoms of early blight first appear as small, irregular to circular dark brown spots on the lower (older) leaves. These spots may range in size from a pinpoint to 1/8 inch in diameter (Fig. 1). As the spots enlarge, they become restricted by leaf veins and take on an angular shape. Early in the growing season, lesions on young, fully expanded, succulent leaves may be larger – up to 1/2 inch in diameter – and may, because of their size, be confused with late blight lesions (Fig. 2). Leaf lesions are relatively easy to identify in the field because lesion development is characterized by a series of dark concentric rings alternating with bands of light tan tissue (Fig. 3). A narrow band of chlorotic tissue often surrounds each lesion, and extensive chlorosis of infected foliage develops over time. Elongated, superficial brown or black lesions may also form on stems and petioles. By the end of the growing season, the upper leaves of infected potato plants may be peppered with numerous small early blight lesions (Fig. 4), and subsequently, lesions may coalesce to cover a large

Figure 2. Early blight lesions on young leaves may be up to 1/2 inch in size. Unlike late blight lesions, they are angular and become restricted by leaf veins.

Figure 3. Early blight lesions are characterized by an alternating series of light tan and dark concentric rings surrounded by a narrow band of chlorotic tissue.

Figure 4. Late in the growing season, the upper leaves of infected potato plants may be peppered with small early blight lesions.

area of the leaf (Fig. 5a). Severely infected leaves eventually wither and die but usually remain attached to the plant (Fig. 5b). Severe infection of foliage by the early to midbulking period can result in smaller tubers, yield loss and lower tuber dry matter content.

Tuber symptoms of early blight include circular to irregular lesions that are slightly sunken and often surrounded by a raised purple to dark brown border. The underlying tissues are leathery to corky in texture, dry and usually dark brown (Fig. 6). These lesions reduce the quality and marketability of fresh market tubers. Tuber infection also presents a challenge to processors because tuber lesions often require additional peeling to remove the darkened lesions and underlying tissues.

Disease cycle

Early blight is caused by the fungus *Alternaria solani*. The dark-colored spores (Fig. 7) and mycelia of the pathogen survive between growing seasons in infested plant debris and soil, in infected potato tubers, and in overwintering debris of susceptible solanaceous crops and weeds, including hairy nightshade (*Solanum sarrachoides*). Overwintering spores and mycelia of *A. solani* are melanized (darkly pigmented) and can withstand a wide range of environmental conditions, including exposure to sunlight and repeated cycles of drying, freezing and thawing. In spring, spores (conidia) serve as primary inoculum to initiate disease (Fig. 8). Plants grown in fields or adjacent to fields where potatoes were infected with early blight during the previous season are most prone to infection because large quantities of overwintering inoculum are likely to be present from the previous crop. Initial inoculum is readily moved within and between fields because the spores are easily carried by air currents, windblown soil particles, splashing rain and irrigation water.

Spores of *A. solani* (Fig. 7) are produced on potato plants and plant debris at temperatures between 41° and 86°F (the optimum is 68°F). Alternating wet and dry periods with temperatures in this range favor spore production. Few spores are produced on plant tissue that is continuously wet or dry. The dissemination of inoculum follows a diurnal pattern in which the number of airborne spores increases as leaves that are wet with dew or other sources of nighttime moisture dry off, relative humidity decreases and wind speeds increase. The number of airborne spores generally peaks in midmorning and declines in late afternoon and at night.

Spores landing on leaves of susceptible plants germinate and may penetrate tissues directly through the epidermis, through stomata, and/or through wounds such as those caused by sand abrasion, mechanical injury or insect feeding. Free moisture (from rain, irrigation, fog or dew) and favorable temperatures (68° to 86°F) are required for spore germination and infection of plant tissues. Lesions begin to form 2 to 3 days after initial infection.

Many cycles of early blight spore production and lesion formation occur within a single growing season once primary infections are initiated. Secondary spread of the pathogen begins when spores are produced on foliar lesions and carried to neighboring leaves and plants. Early blight is largely a disease of

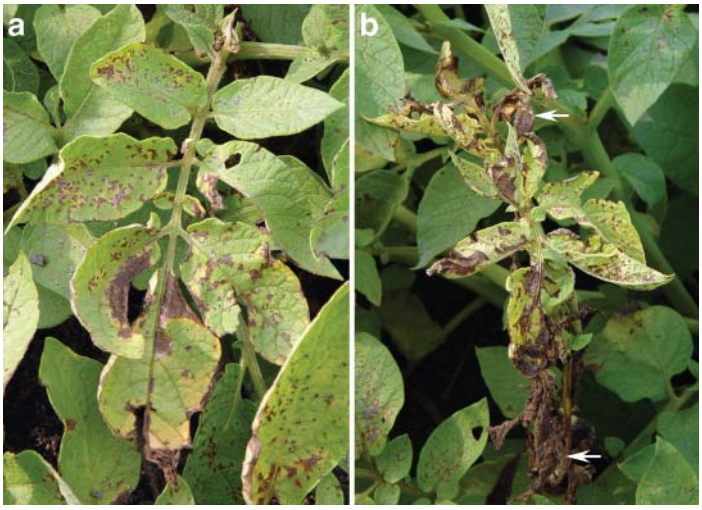

Figure 5. (a) On severely infected leaves, the small early blight lesions may coalesce to cover large areas of the leaf. (b) These leaves eventually wither and die but remain attached to the plant (arrows).

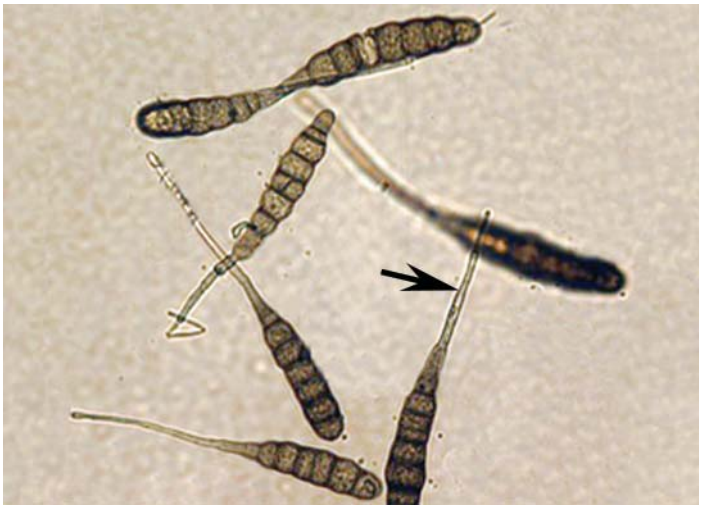

Figure 7. Spores of *Alternaria solani*, causal agent of early blight, are melanized and can withstand a wide range of environmental conditions. Note the transverse and vertical septa and the long "beak" (arrow).

older plant tissues and is more prevalent on senescing tissues on plants that have been subjected to stresses induced by injury, poor nutrition, insect damage or other types of stress. Early in the growing season, the disease develops first on fully expanded leaves near the soil surface and progresses slowly on juvenile tissues near the growing point. The rate of disease spread increases after flowering and can be quite rapid later in the season during the bulking period and during periods of plant stress. Early blight lesions are often found on most leaves of unprotected plants late in the growing season.

In potato tubers, germinated spores penetrate the tuber epidermis through lenticels and mechanical injuries to the skin. Tubers often become contaminated with *A. solani* spores during harvest. These spores may have accumulated on the soil surface or may have been dislodged from desiccated vines during harvest. Infection is most common on immature tubers and those of white- and red-skinned cultivars, since they are highly susceptible to abrasion and skinning during harvest. Coarse-textured soil and wet harvest conditions also favor infection. In storage, individual lesions may continue to develop, but secondary spread does not occur. Infected tubers may shrivel through excessive water loss, depending on storage conditions and disease severity. Early blight lesions on tubers, unlike late blight lesions, are usually not sites of secondary infection by other decay organisms.

Monitoring and control

Effective management of this disease requires implementation of an integrated disease management approach. The disease is controlled primarily through

Figure 6. (a) Early blight lesions on tubers are usually circular to irregular and slightly sunken, often surrounded by a raised purple to dark brown border. (b) Underlying tissues are leathery to corky in texture (arrows).

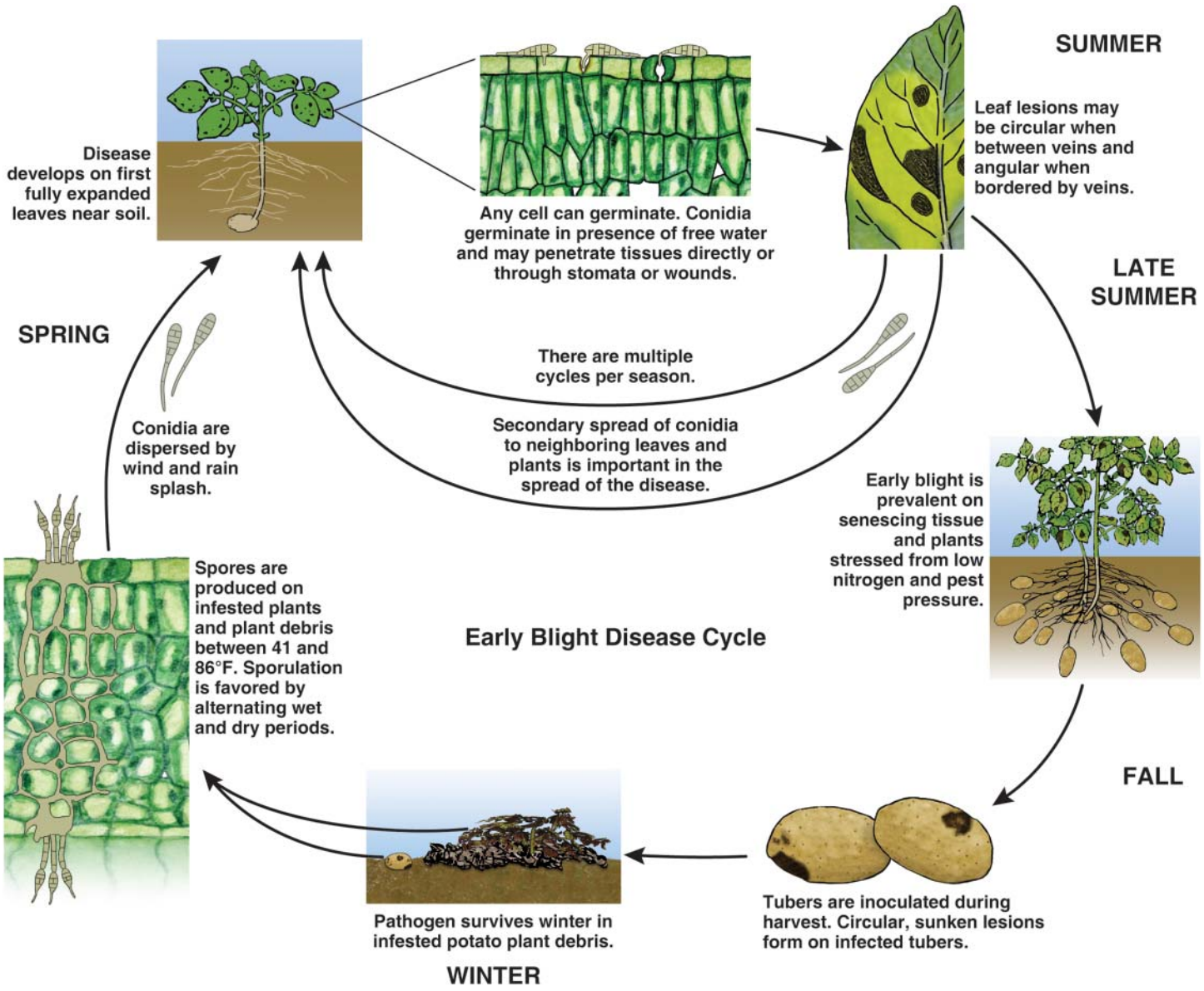

Figure 8. The disease cycle of the early blight pathogen, *Alternaria solani*.

the use of cultural practices, resistant cultivars and foliar fungicides.

Cultural control

Cultural practices such as crop rotation, removing and burning infected plant debris, and eradicating weed hosts help reduce the inoculum level for subsequent plantings. Because *A. solani* persists in plant debris in the field from one growing season to the next, rotation with non-host crops (e.g., small grains, corn or soybean) reduces the amount of initial inoculum available for disease initiation. Other cultural control measures include:

1. Avoid irrigation in cool, cloudy weather, and time irrigation to allow plants time to dry before nightfall.
2. Use certified disease-free seed.
3. Use tillage practices such as fall plowing that bury plant refuse.

To minimize tuber infection after harvest, tubers should be stored under conditions that promote rapid suberization because *A. solani* is unable to infect through intact periderm.

Resistant cultivars

Cultivars with good levels of field resistance are available, but no immunity to early blight has been found in commercial potato cultivars or in their wild parents. Highly susceptible cultivars such as Red Norland, Norchip and Superior should be avoided in locations where early blight is prevalent and disease pressure is high. Field resistance to foliage infection is associated with plant maturity.

Chemical control

The most common and effective control method for early blight is application of foliar fungicides (Table 1). Protectant fungicides recommended for late blight control (e.g., maneb, mancozeb, chlorothalonil and triphenyl tin hydroxide) are also effective against early blight when applied at approximately 7- to 10-day intervals. Resistance to the strobilurin group of fungcides (Group 11; Table 1) has been reported in Michigan. The geographical spread of this resistance is not known, but applications of strobilurins should be made in combination with tank mixtures of the fungicides listed above. Other fungicides that have shown efficacy against early blight contain azoxystrobin, trifloxystrobin, famoxodone, pyrethamil, fenamidone and boscalid.

The application of foliar fungicides is not necessary in plants at the vegetative stage, when they are relatively resistant. Accordingly, spraying should commence at the first sign of disease or immediately after bloom. The frequency of subsequent sprays should be determined according to the genotype and age-related resistance of the cultivar. Protectant fungicides should be applied initially at relatively long intervals and subsequently at shorter intervals as the crop ages.

Early-season applications of fungicides before secondary inoculum is produced often have minimal or no effect on the spread of the disease. Early blight can be adequately controlled by relatively few fungicide applications if the initial application is properly timed. Predictive models to time the first application are commonly used. Models for Michigan can be found at the Website http://www.potatodiseases.org. The first application for early blight control should be timed at 200 P days after emergence. Regular inspection of fields after plants reach 12 inches in height is recommended to detect early infections.

Table 1. Product name, FRAC[a] resistance management grouping, common name, rate of application and season limit of some currently registered products for control of early blight of potato in Michigan.

Product[b]	FRAC[a] group	Common name	Rate of application[c]	Season limit (lb or pt of product)
Quadris	11	azoxystrobin[d]	6.2 - 15.4 fl. oz/A	3.8 pt/A
Headline	11	pyraclostrobin[d]	6.0 - 9.0 fl. oz/A	4.5 pt/A
Gem	11	trifloxystrobin[d]	6.0 - 8.0 oz/A	3.0 lb/A
Tanos	11	famoxodone[d]	6.0 oz/A	3.3 lb/A
Scala	9	pyrethamil	7 fl. oz/A	2.2 pt/A
Reason	11	fenamidone[d]	5.5 - 8.2 fl. oz/A	1.5 pt/A
Endura	7	boscalid	2.5 - 4.5 oz/A	1.3 pt/A
Maneb	M3	maneb	1.5 - 2 lb/A	11.2 lb/A
Dithane, Manzate, Penncozeb	M3	mancozeb	0.5 - 2 lb/A	15.0 lb/A
SuperTin	30	triphenyl tin hydroxide	2.5 - 3.75 oz/A	11.25 oz/A
Bravo, Echo, Equus	M5	chlorothalonil	1.0 - 2.2 pt/A	15.0 - 22.5 pt/A, depending on product

[a] Fungicide Resistance Action Committee. See (http://www.frac.info) for more information.

[b] Product names are provided as a convenience only, and mention of them shall not be construed as an endorsement of the product, or sponsorship by or affiliation with the company manufacturing that product. Specific instructions are included on the labels of all of the products, and these must be adhered to.

[c] Rates of application are provided as a guide only. Consult specific instructions included on the label for complete details.

[d] Should always be used in combination with a protectant fungicide (i.e., maneb, mancozeb or chlorothalonil).

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For more information, please visit: **http://www.potatodiseases.org**.

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