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Major diseases of cole crops and their management

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Cole crops, including cabbage, cauliflower, broccoli and knol-khol are crucial vegetables for nutrition and income security in wide range of climate like temperate, sub-tropical and tropical regions in India. The production of these crops is threatened by diseases such as black rot, sclerotinia rot, and damping-off, which significantly reduce its yield and quality. This article describes the occurrence, symptoms, and epidemiology of these diseases occurring on major cole crops growing regions of Himachal Pradesh. These diseases can be managed by using integrated disease management strategies which combines cultural practices, resistant cultivars, seed treatment, and use of biological control agents such as Trichoderma *spp. and* Pseudomonas fluorescens*, along with need based judicious use of chemicals. Adoption of eco-friendly bio-agent based measures is vital to ensure sustainable production, minimise economic losses, and maintain soil and environmental health.*

Keywords: Black rot, Damping-off, Integrated disease management, Sclerotinia rot

COLE crops, belonging to the family Brassicaceae (formerly Cruciferae), include economically important vegetables such as cabbage, cauliflower, broccoli, kale, knol-khol and Brussels sprouts. These crops are grown for their edible heads, curds, stems and leaves, and are vital source of vitamins (A, C, K), minerals (calcium, iron), dietary fibre, and antioxidants. Cole crops thrive best in cool-season conditions, making them especially suited to temperate and sub-tropical regions, including the hill states of India. Cole crops hold considerable economic significance in India. They are a major component of vegetable production systems, providing employment to millions of small and marginal farmers. Their high market demand throughout the year ensures steady farm income beside contributing to nutritional security. India also exports fresh cabbage and cauliflower to neighbouring countries, boosting foreign exchange earnings.

India's position in global cole crop production

India stands as the world's second-largest producer of cole crops, contributing nearly 32.5% of global production, and is recognised as the largest producer of cauliflower. Among cole crops, cabbage and cauliflower records productivity as high as 28.96 Mt/ha and 22.16 Mt/ha, respectively in Himachal Pradesh, underscoring its significance as a leading production hub.

However, these crops suffer badly from major biotic stresses. Sclerotinia rot (*Sclerotinia sclerotiorum*) and black rot (*Xanthomonas campestris* pv. *campestris*) have emerged as serious threats to cole crop production, particularly in the high-potential regions of Solan, Sirmaur, Kullu, Mandi, and Shimla districts of Himachal Pradesh. These diseases are responsible for yield losses ranging from 20–40% under field conditions, and in severe outbreaks, it may reach up to 100%. Thus, an Integrated Disease Management (IDM) strategy to sustain productivity and protection

Table 1. Status of cole crops at national and global level

State/ Country	Crop	Area ('000 ha)	Production ('000 Mt)	Productivity (Mt/ha)
World	Cabbage	2,400.00	73,800.00	30.80
	Cauliflower and broccoli	1,404.93	26,472.04	18.80
India	Cabbage	442.33	10,431.7	23.58
	Cauliflower	507.30	9,794.36	19.31
Himachal Pradesh	Cabbage	4.44	128.59	28.96
	Cauliflower	5.55	123.07	22.16

Source: https://www.indiastat.com/Ministry of Agriculture and Farmer's welfare, FAOSTAT 2023 and country production summaries

Symptoms of black rot disease

of farmers' livelihood in these vulnerable regions is needed. IDM strategies supports sustainable production of cole crops, maintains yields, and enhances the soil health and the environment.

Black rot

Black rot disease, caused by *Xanthomonas campestris* pv. *campestris* (Pam.) Dowson (*Xcc*), is one of the most devastating bacterial diseases in cole crops worldwide. It infects the crop from nursery to seed production stage causing reduction in yield up to 10–50% and in severe cases up to 100% yield loss.

***Symptoms*:** Black rot in cole crops starts as yellow, V-shaped lesions at the leaf margins pointing toward the midrib. The veins inside these lesions turn dark brown to black, originating the name of disease. As infection spreads through the vascular system of plants, leaf blight, stunting, and sometimes wilting is observed. In cabbage, heads remain small or deformed, while cauliflower curds and broccoli heads become discoloured and unmarketable. The disease often appears in patches and spreads rapidly under warm, humid and rainy conditions.

***Management*:** Managing this disease is challenging because it easily spreads through water splashes, moving from one plant to another and even between fields. Since cole crops do not have strong natural resistance against it; this makes it essential to adopt integrated disease management strategies.

Sclerotinia rot (White mold)

Sclerotinia rot, caused by the soil-borne fungus *Sclerotinia sclerotiorum*, is a major disease of cauliflower and other cole crops in Himachal Pradesh. First reported in 1973 from the Saproon Valley of Solan district, it has since become a serious constraint in major production belts like Solan, Kullu, and Shimla. These survival structures allow the pathogen to persist in the soil for years, leading to recurring infections.

***Symptoms*:** Sclerotinia rot in cole crops begins with small, water-soaked lesions on stems, leaves, or curds near the soil surface. Under cool (15–20°C) and humid (>85%) conditions, these lesions become soft and watery, and a white, cottony fungal growth appears on the affected tissue. As the disease progresses, hard, black sclerotia (resting bodies) develop within the mycelium, enabling the pathogen to survive in the soil for years. Severely infected plants wilt, collapse, and

Table 2. IDM practices to control black rot

Practices	Management
Cultural practices	➢ Grow nursery in a soilless mix or use a new, pasteurised or fumigated seedbed. ➢ Avoid sowing in low, wet sites with poor soil drainage. Planting on raised beds, which provide better soil drainage, may help reduce disease spread, especially in seed beds. ➢ Plough cole crop fields after harvest to hasten the decomposition of crop residues. ➢ Practice a 3-year rotation between crop.
Physical practices	Hot water treatment of seeds at 45–55°C can help reduce or eliminate the seed borne pathogen. As a bacterium, Xcc can spread over long distances via seeds. The usual lethal temperature of Xcc is 40°C; therefore, Xcc in seeds can be killed by hot water treatment at higher temperatures.
Chemical control	Seedling dip in 100 ppm streptocycline significantly reduces the incidence of black rot. Spray copper oxychloride (2.5 g/L) and streptocycline (100 ppm) at 7–10 day intervals. Farmers are advice to avoid use of antibiotics like streptocycline unless it is very essential.
Biological control	➢ **Seed treatment:** Treat seeds with formulation of *Pseudomonas fluorescens* @2 g/kg of seed (CFU ~10^8/g) before sowing. Alternatively, treat with *Bacillus subtilis* and *B. amyloliquefaciens* @4 g/kg of seed (WP formulation). ➢ **Nursery treatment:** Drench nursery beds with *P. fluorescens* suspension @0.2% (2 g/L water) or *B. subtilis* @5 g/L of water, 7–10 days before transplanting. ➢ **Seedling treatment**: Dip seedlings (3–4 leaf stage) before transplantation in the freshly prepared biocontrol formulation suspension of *Trichoderma harzianum* or *T. viride* (10 g/L of water) or bacterial antagonists *P. fluorescens* and *B. subtilis/B. amyloliquefaciens* (10 g/L) for 30 min. After dipping, shade-dry the seedlings for 10–15 min and transplant immediately into the field. ➢ **Main field application:** Mix *P. fluorescens* or *T. harzianum* @2.5 kg/ha with 100 kg well-decomposed FYM and broadcast in the field one week before transplanting. Spray *P. fluorescens* @0.2% (2 g/L) or *B. subtilis* @2–4 g/L water starting 20–25 days after transplanting, repeat at 10–15 day intervals during humid/rainy periods.

Table 3. IDM practices to control sclerotinia rot

Practices	Management
Cultural practices	➢ Maintain field sanitation by removing infected plant debris soon after harvest to reduce sclerotia load in soil. ➢ Deep ploughing during summer exposes sclerotia to heat and sunlight, which kills them. ➢ Avoid continuous cropping of cole crops and follow 3–4 years crop rotation with cereals, maize, or other non-host crops. ➢ Avoid rotation with susceptible crops like beans, peas, sunflower, or mustard (they are also hosts of *Sclerotinia*). ➢ Maintain wider plant spacing to allow good air circulation and reduce canopy humidity. ➢ Avoid overhead irrigation during cool and humid weather; prefer drip or furrow irrigation to keep foliage dry. ➢ Ensure good field drainage to prevent waterlogging.
Seed and nursery treatment	Cover nursery soil with transparent polyethylene sheet for 4–6 weeks during summer to kill sclerotia. To raise healthy seedlings in nursery, treat seeds with *Trichoderma* formulation @ 2 g/kg seed or carbendazim (2 g/kg seed) or *Trichoderma* with vitavax power (Corboxin + Thiram) (2 g/kg seed) to reduce initial inoculum before sowing.
Biological control	Apply *Trichoderma harzianum* or *T. viride* enriched compost/FYM in the field (2.5 kg/ha mixed with fully decomposed 100 kg FYM).

die, while cauliflower curds and cabbage heads turn soft, watery, and rendering them unmarketable.

***Management*:** Sclerotinia rot is one of the most destructive diseases of cole crops and a major constraint to their production in many regions, especially to seed crops. Managing this disease is crucial to sustain productivity and ensure the profitability of cole crop cultivation.

Symptoms of Sclerotinia rot

Damping-off

Damping-off is a major nursery disease of cole crops caused mainly by soil-borne fungi such as *Pythium* spp., *Rhizoctonia solani*, and *Fusarium* spp. It occurs both before and after seedling emergence. In pre-emergence damping-off, seeds rot in the soil and fail to germinate. In post-emergence damping-off, seedlings develop water-soaked lesions at the collar region, leading to stem constriction and collapse, causing the seedlings to topple over. High soil moisture, overcrowding, poor drainage, and moderate temperatures (20–30°C) favour disease development.

***Symptoms*:** In cole crops, damping-off appears in two phases. In the pre-emergence phase, seeds rot in the soil and fail to germinate, resulting in poor or patchy nursery stands. In the post-emergence phase, water-soaked, dark lesions develop at the collar region of seedlings, causing stem constriction and weakening. The affected seedlings become soft, shrivel, and collapse at the soil surface, often lying flat. Roots may turn brown and rotted, and the disease can spread rapidly, leading to large patches of dead seedlings in nursery beds. The disease is favoured by high soil moisture, poor drainage, overcrowding, and moderate temperatures (20–30°C), which create ideal conditions for the pathogens to thrive.

***Management*:** Damping-off is a widespread and serious nursery disease of cole crops that poses a major threat to seedling survival and overall crop establishment. Its presence can lead to significant

Symptoms of damping off

Table 4. IDM practices to control damping off

Practices	Management
Cultural practices	➢ Raise seedlings on well-drained, raised beds to prevent waterlogging. ➢ Avoid overcrowding and maintain proper spacing. ➢ Use sterilised soil or solarised nursery beds to reduce inoculum. ➢ Avoid overwatering and follow crop rotation to reduce inoculum load.
Chemical control	Seed treatment with thiram or captan (2–3 g/kg seed) before sowing. Soil drenching with carbendazim (2 g/L)/ copper oxychloride (2 g/L) or Fosetyl-Al (1 g/L) at early stage if disease appears. Fungicide drenches should be applied at the collar region soon after seedling emergence to protect the vulnerable stem base.
Biological control	Seeds treated with *Trichoderma* (2 g/kg seed), and nursery soil is mixed with *Trichoderma* formulation (2.5 kg/ha) enriched in 100 kg well-decomposed compost or FYM. Periodic soil drenching with suspensions of *Pseudomonas fluorescens* (10 g/L water) further suppresses soil-borne pathogens and improves seedling survival.

losses in nursery beds and negatively impact subsequent field productivity, making it an important concern for cole crop cultivation.

SUMMARY

Cole crops are a vital component of India's vegetable production system, contributing significantly to food and nutritional security as well as livelihoods. However, their productivity is severely challenged by destructive diseases such as black rot, sclerotinia rot, and damping-off, which can cause substantial economic losses if unmanaged. IDM is the most sustainable and effective approach to minimise these threats. Combining cultural practices (field sanitation, crop rotation, nursery management), biological agents (*Trichoderma* spp., *Pseudomonas fluorescens*, *Bacillus* spp.), and need-based chemical applications ensure long-term disease suppression while maintaining environmental safety. Adoption of IDM strategies, supported by resistant cultivars and farmer awareness programmes, will help safeguard yields, reduce chemical dependency, and ensure stable farm income, ultimately sustaining the productivity and profitability of cole crop.

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