# Threat Perception of Bacterial Plant Pathogen *Xanthomonas campestris pv. campestris (Pammel) Dowson*, Causing Black Rot Disease in Cabbage fields

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ABSTRACT

Black rot disease bacterium Xanthomonas campestris pv.campestris(Pammel)Dowson (Xcc) produced typical blackening of leaf veins of cabbage seedling and cabbage head on 6th day of inoculation and the entire cabbage head got rotten within 10-15 days. Different cole crop leaves infiltrated with Xcc produced either Hypersensitive/ incompatible /susceptible reaction. The infiltration of Xcc in to leaves of various weeds in /around cabbage field produced browning or yellowing reaction areas like the browning reaction produced by Xcc on other cole crops, These reaction areas had the presence of Xcc up to 15 days indicating that these serve as a source of inoculum. The Xcc re-isolated from browning areas of these weeds after 2 weeks and inoculated on cabbage head produced typical black rot disease. The black rot bacteria present on cabbage seeds reduced its germination and seedling vigour. The bacterium survived up to 15 days in dry soil , 30 days in moist soil and up to 3 months in the infected cabbage stumps in soil and thus act as a source of inoculum for infection to the succeeding cabbage crop. Thus, the presence of Xcc on the seeds purchased, in soil/ diseased plant stumps, on the weeds around the cabbage crop fields and other black rot diseased cole crops available in the cultivation area are the important components in determining the threat perception for this disease. Once the threat perception is known, it becomes easier to plan the black rot disease management according to the threat component.

***Keywords:*** *Threat perception, Black rot, X.c.pv.campestris, Bacterial survival, Disease management, Threat component.*

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## Highlights of this paper

- The paper highlights the importance of seed-borne Xanthomonas campestris pv. campestris (Xcc) on cabbage seed germination and seedling vigour, time taken by the bacterial inoculum for infection of leaves and cabbage head to develop black rot disease symptoms, reaction of different cole crop leaves to Xcc, survival period of Xcc in affected soil of two moisture regime, in infected cabbage stumps, role of soil borne Xcc on seed germination, and weed plants as source of inoculum for the black rot disease.
- These different components are important to determine the threat perception of black rot disease and the management module should be decided on the basis of threat components.

## 1. INTRODUCTION

Cabbage is an important vegetable of cole crop family. It is cultivated in 150 countries around the world on an area of 3 million hectors with production of 71 million metric tons [1]. China is the leading producer while India rank second in the production of cabbage in the world with an area of 0.23 million hector and share 7.6 % of cabbage production. Black rot/black leg disease of cabbage caused by Xanthomonas campestris pv. campestris(Pommel)Dowson (Xcc) is an important disease occurring in most of its growing area [2] causing up to 90% losses in Netherland [3] in Europe and similarly huge losses in India [4]. Different factors responsible for the onset of this disease, it's perpetuation, and recurrence are studied as a major component related to threat perception for this disease and are discussed in this paper.

## 2. MATERIALS AND METHODS

### *2.1. Collection of Black Rot Disease Sample and Isolation of Disease Inciting Bacterium*

Black rot disease infected samples of cabbage Figure 1 were collected from the Nashik district which grows the cabbage crop extensively in Maharashtra state, India.

**Figure-1.** Natural infection of black rot disease in cabbage.

The diseased samples were subjected to ooze test in the laboratory for the confirmation of association of bacterial pathogen with the diseased portion before isolation. The bacterial isolation was done on a nutrient agar media (composition: Peptone,5g; Beef extract,3g; Sucrose, 20 g; Agar, 20g; Distilled water, 1L; pH, 7.0). To isolate the disease inciting bacterium, the infected leaves were washed in running tap water to remove dirt, dried in blotter

paper and the disease portion were cut in to 5 mm size pieces with the razor blade. These diseased pieces were disinfected with 0.1 % mercurial chloride solution for 2 to 3 minutes and subsequently washed with three washing of distilled sterile water. These pieces were grinded in 5 ml sterile water in sterile pastel and mortar and the sediments were allowed to settle down. The supernatant was pipetted out with sterile pipette and placed on sterile solidified nutrient agar media in the sterile petri-plate and spread with glass rod spreader. These isolation plates were incubated in BOD incubator at 28±1$^0$C temperature and were observed for the appearance of yellow pigmented bacterial colonies of Xanthomonas campestris pv.campestris (Xcc) which generally appears on the 3$^{rd}$ day onward of incubation.

Bacterial colonies of Xcc having translucent, yellow, smooth, raised growth were further purified by dilution plating technique and the pure culture of black rot pathogen Figure 2 was used in pathogenicity test and other studies.

**Figure-2.** Pure culture of black rot bacterium Xcc in petriplate.

### *2.2. Confirmation of Pathogenicity of Isolated Bacterium on Cabbage Seedlings*

The pathogenicity of the isolated bacterium was proved on cabbage seedlings. The seeds of cabbage were sown in plastic pot soil under *in vitro* condition. One month old seedlings were used for pathogenicity test. The 24 hrs young culture of the Xcc on nutrient agar slant was suspended in sterile distilled water and injected into dorsal side of cabbage seedling leaves by syringe infiltration technique [5] to develop the disease symptoms Figure 3.

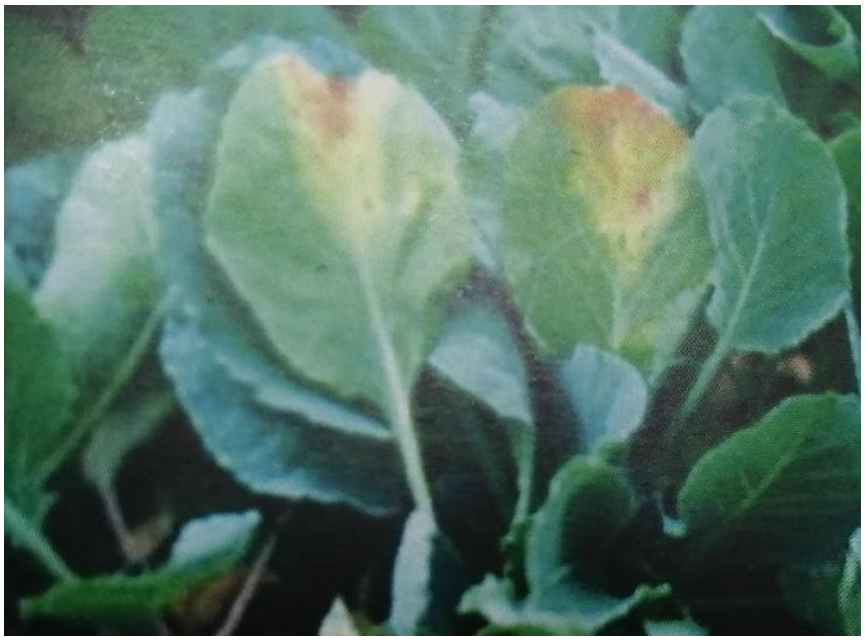

**Figure-3.** Pathogenicity of Xcc on cabbage seedlings.

### *2.3. Reaction of Cole Crop Seedlings to Black Rot Bacterium*

The 24 hrs young fresh culture of black rot bacterium was inoculated into the leaves of different cole crops seedling of 3 weeks aged viz. radish, mustard, beat, carrot and cabbage by syringe infiltration method. The reaction of infiltrated areas i.e. pathogenic susceptible reaction (SR) or resistant hypersensitive reaction (HR) was noted up to a month.

### *2.4. Effect of Black Rot Bacterium on Germination of Cole Crop Seeds*

The seeds of different cole crops viz. radish, mustard, beet, carrot and cabbage was used to study the effect of black rot bacterium Xcc on the seed germination percentage, seedling vigour and disease symptoms on seedlings. The test seeds (100 seeds/test) were soaked in to bacterial suspension ($10^8$ cfu/mL) for 2 hours while control/check seeds were soaked in water. These soaked seeds were placed on the blotter paper which was pre-sterilized and then pre-soaked in to bacterial suspension (for test seed) and water (for check seed) respectively. The blotter paper was rolled and kept at ambient temperature of $28^0$C for 5 days to record the observation on germination percentage, seedling vigour and disease symptoms (if any).

### *2.5. Effect of Black Rot Bacterium Present In Soil on Germination of Cole Crop Seeds*

The seeds of different cole crops viz. radish, mustard, beet, carrot and cabbage were sown in the pot soil previously saturated with black rot bacterium. The germination rate and disease symptoms were observed after $5^{th}$ day of sowing at an alternate day. The appropriate control was kept for each cole crop. Comparison between germination percentage in controlled and bacterial inoculated soil was done to study the effect of soil borne Xcc on germination.

### *2.6. Detection of Black Rot Bacterium on Commercial Cole Crop Seeds*

The presence of internal/ external infection of black rot bacterium Xcc on the commercial cole crop seed was studied by using the nutrient agar plate assay method. For detection of the external presence of the bacterium, the seeds were placed on the NA plates. For detection of internal presence of the bacterium, the seed surface was

sterilized in 0.1% mercuric chloride solution, wash thrice in sterilized water and cut in to small pieces and kept on nutrient agar plates. The plates were incubated at ambient temperature for 3 days and observations were recorded for yellow Xanthomonas colonies formed around the seed on the NA plates.

### 2.7. Reaction and Survival of Black Rot Bacterium in Different Weeds

The leaves of different weeds around the cabbage field were inoculated with black rot bacterium Xcc (at concentration of 7 x $10^8$ cfu/mL) in the intercellular spaces of the leaf tissue by syringe infiltration method. Observation on pathogenic susceptible reaction (water-soaking reaction), resistant hypersensitive reaction/incompatible reaction (necrotic brown/yellow/greenish/grey papery) and immune reaction (no reaction) was noted at an interval of 2 days up to 8 days. The weed leaves inoculated areas showing disease reaction or hypersensitive reaction were used for re-isolation of the bacterium to study its survival in the alternate weed host and its pathogenic nature on re-isolation. The isolation was done at 8,15,30 and 60 days after inoculation. The bacterium re-isolated from these weed leaves was tested for its pathogenicity on cabbage head for development of black rot disease symptoms.

### 2.8. Survival of Black Rot Bacterium in Soil

The survival of black rot bacterium in soil was estimated under laboratory condition.

#### 2.8.1. Sterilization of Soil

The soil was air dried in hot air oven at 120 $^0$C for one hour. It was again steam sterilized for 3 consecutive days in the autoclave for 30 minutes. It was again steam sterilized in autoclave at 15 psi for 1 hour to obtain complete destruction of microbes and their spores through these different stages of sterilization.

#### 2.8.2. Soil Inoculation with Xcc Culture

The 24 hrs fresh Xcc culture was inoculated in to the autoclave sterilized nutrient broth (composition: Peptone, 5g; Beef extract, 3g; Sucrose, 20g; distilled water,1L, pH, 7). The inoculated broth was incubated in BOD incubator at 28±1$^0$C temperature for 3 days for the growth of the bacterium.

The sterile polypropylene cups were filled with 200 g sterilized soil in each cup. The soil in the cup was saturated with sterilized water as per requirement and treatment. Then these soils in the cup was inoculated with bacterial suspension ($10^7$cfu/mL, 50 ml/200 gm soil) as per treatment viz. Sterilized moist soil inoculated with bacterial culture, sterile dry soil inoculated with bacterial culture while sterilized moist soil and sterile dry soil was used as control. The same treatment was repeated in case of non- sterile soil. The moist treatment cups were moistened by the sterile water in the sterile condition on the alternate day up to field capacity.

#### 2.8.3. Isolation of Xcc from Test Soil

The isolation of bacterium from test soil was done by serial dilution plating technique. For this, one gram of soil sample was suspended in 10 mL sterile distilled water, shaken well and kept for settlement of soil particles. 1 mL supernatant from this was used for serial dilution up to $10^{-5}$ dilution. 1 mL of test soil sample solution was poured in the sterile petri-plate followed by pouring of lukewarm NA medium and was thoroughly mixed by rotating the plated on the plain table surface. These plates were incubated at 28±1$^0$C temperature for 3 days and the observation of the Xcc colonies were taken. The isolation of Xcc bacterium from soil was done at 0 hr, 2 days, 8

days, 15 days, 30 days and 60 days after the inoculation of the bacterium into the soil. By this method, the survival of the Xcc in the soil and the population of black rot bacterium in the soil were studied.

## 3. RESULTS AND DISCUSSION

### 3.1. Susceptibility of Cole crops to X.c.pv.campestris (Xcc) bacterium

The bacterium infiltrated in to cabbage leaves produced typical blackening of leaf veins on 6th day and the infected area turned papery whitish within next 3 days. The bacterium infiltrated in to cabbage head caused typical blackening and rotting of inoculated area within 6 to 7 days and the entire cabbage head got rotten within 10-15 days under *in vitro* condition Figure 4. The rotten portion emitted foul smell.

**Figure-4.** Black rot in cabbage due to Xcc artificial inoculation.

Broccoli was more susceptible to black rot bacterium as compare to cabbage and cauliflower Table 1.

**Table-1.** Period required for induction of water-soaking disease reaction in different crop.

| Sr.No. | Black rot disease induced in | Disease water-soaking reaction induction period (in days) | | |
|---|---|---|---|---|
| | | 3 | 5 | 6 |
| 1. | Broccoli head | SR | | |
| 2. | Cabbage head | | | SR |
| 3. | Cauliflower head | | SR | |

**Note: SR=** Diseased water-soaking reaction.

### 3.2. Survival of Xcc in Different Weeds

The syringe infiltrated leaves of different weeds with Xcc suspension Table 2 indicated that the infiltrated area on the leaves of weed Calotropis gigantean, Euphorbia geniculate, Cassia tora, Corchorus acutungulas and Convolvulus arvensis produced HR within 24 hours while on leaves of Lactuca runcianata and Cardiospermum halicacabum a yellowing of the infiltrated areas was produced within 48 hrs. The yellow area shed, leaving a typical shot hole symptoms. Euphorbia hirta produced grayish reaction to the bacterium on 4th day.

**Table-2.** Reaction produced by Xcc on different weeds and survival of the bacterium in reaction areas.

| Sr.No | Farm Weeds (Botanical name) | Reaction induced by Xcc infiltration on weed leaves (at days) | | | Survival period of Xcc in reaction areas (in days) | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 8 | 15 | 30 |
| 1. | Itemanthera triandra | NR | NR | NR | - | - | - |
| 2. | Calotropis gigantean | BR | BR | BR | + | + | - |
| 3. | Cleome viscosa | NR | NR | NR | - | - | - |
| 4. | Parthenium hysterophorus | NR | NR | NR | - | - | - |
| 5. | Euphorbia geniculate | BR | BR | BR | - | - | - |
| 6. | Euphorbia hirta | NR | NR | GR | - | - | - |
| 7. | Euphorbia thymifolia | NR | NR | NR | - | - | - |
| 8. | Phyllanthus niruri | NR | NR | NR | - | - | - |
| 9. | Cassia tora | BR | BR | BR | + | + | - |
| 10. | Desmodium diffusium | NR | NR | NR | - | - | - |
| 11. | Portulaca oleracea | NR | NR | NR | - | - | - |
| 12. | Zyzyphus rotundifolia | NR | NR | NR | - | - | - |
| 13. | Physalis minima | NR | NR | NR | - | - | - |
| 14. | Sonchus oleracious | NR | NR | NR | - | - | - |
| 15. | Corchorus acutungulas | BR | BR | BR | - | - | - |
| 16. | Tridex procumbens | NR | NR | NR | - | - | - |
| 17. | Lactuca runcianata | NR | YR | YR | + | + | - |
| 18. | Ipomea purpurea | NR | NR | NR | - | - | - |
| 19. | Lantena camera | NR | NR | NR | - | - | - |
| 20. | Celosia argentea | NR | NR | NR | - | - | - |
| 21. | Eclipta erecta | NR | NR | NR | - | - | - |
| 22. | Convolvulus arvensis | BR | BR | BR | + | + | - |
| 23. | Cardiospermum halicacabum | NR | YR | YR | + | + | - |

**Note: NR=** No visible reaction in infiltrated area; BR= Browning hypersensitive reaction in infiltrated area; YR = Yellowing reaction in infiltrated area, and GR= Grayish reaction in infiltrated area. - = Xcc bacterium absent; + = Xcc bacterium present.

The survival and presence of bacterium in the infiltrated areas showing no visible reaction, browning hypersensitive reaction, yellowing reaction or greyish reaction studied up to 60 days by making isolation from the infiltrated areas revealed that the weeds which showed BR and YR Figure 5 had the presence of the bacterium Xcc up to 15 days indicating that the bacterium can survive in these weeds up to 15 days.

**Figure-5.** Reaction of Xcc on weed Cassia tora and Euphorbia geniculate

Weeds showing no visible reaction of infiltrated areas did not have the presence of bacterium by a week meaning that the bacterium does not survive in these weeds. Similarly, in the GR areas of Euphorbia hirta the bacterium did not survive.

These results are indicative that the bacterium can survive in certain weeds for at least 2 weeks and thus can serve as a source of inoculum. The Xcc re-isolated from HR areas of these weeds after 2 weeks and re- inoculated on cabbage head produced typical black rot disease symptoms.

### 3.3. Reaction of Black Rot Bacterium on Seedling Leaves of Cole Crops

Different cole crop leaves viz. of cabbage, radish, carrot, beet and mustard inoculated with Xcc produced either Hypersensitive reaction (HR) or Susceptible water soaked reaction SR Figure 6. Only the cabbage leaves produced SR with blackening of the leaf vein on 6th day whereas other cole crop leaves produced HR of different types. The production of HR varied according to the sensitivity of crop to the inoculated Xcc bacterium. The mustard leaves were very sensitive to the bacterium and produced HR within 24 hrs followed by beet leaves which required 48 hrs for production of HR followed by radish and carrot which required 72 hrs for HR production Table 3. The HR reaction was either brownish area, Yellowish area, papery white area, greening area.

**Figure-6.** Reaction of Xcc on Radish, on Mustard and on beet leaf respectively.

**Table-3.** Different types of incompatible Reaction of Cole crop seedling leaves to X.c.pv.campestris.

| Sr.No | Name of cole crop | Types of Reaction developed (in days) | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 6 |
| 1. | Cabbage | - | - | - | SR |
| 2. | Radish | - | - | HR ( Y) | |
| 3. | Carrot | - | - | HR (Br) | |
| 4. | Beet | - | HR (G) | | |
| 5. | Mustard | HR (P) | | | |

**Note: HR=** hypersensitive reaction developed into Xcc infiltrated areas (Y= Yellowish, Br= Brownish, G= Greenish, P = Papery white); SR= susceptible water-soaking reaction.

### 3.4. Survival of Xcc in Soil

The survival of Xcc in soil particularly in dry soil, in moist soil, in dry soil with infected cabbage stumps and in moist soil with infected cabbage stumps indicated that the bacterium survived up to 15 days in dry soil and up to 30 days in moist soil. However, the population of Xcc was more in dry soil as compare to moist soil at 15 days Table 4. The bacteria survived in the infected cabbage stumps in soil up to 3 months Table 5 irrespective of the soil moisture condition and thus act as a source of inoculum for infection to the succeeding cabbage crop.

**Table-4.** Survival of X.c.pv.campestris in soil.

| Sr.No | Soil | Survival period (in days) and population of Xcc (cfu/g) in soil | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 8 | 15 | 30 |
| 1 | Dry soil | 4.4 x $10^8$ | 4.2 x $10^8$ | 5.2 x $10^7$ | 4 x $10^7$ | |
| 2 | Moist soil | 5.5 x $10^7$ | 5.4 x $10^8$ | 1.1 x $10^8$ | 5 x $10^6$ | 11 x $10^6$ |

**Table-5.** Survival of X.c.pv.campestris in cabbage stump in soil.

| Sr.No | Soil | Survival period (in days) of Xcc (cfu/g) in soils having Xcc infected cabbage stumps | | | | |
|---|---|---|---|---|---|---|
| | | 8 | 15 | 30 | 60 | 90 |
| 1 | Dry soil having Xcc infected cabbage stumps | + | + | + | + | + |
| 2 | Moist soil having Xcc infected cabbage stupms | + | + | + | + | + |

**Note:** + = Survival of X.c.pv.campestris in soil.

### *3.5. Effect of Xcc on Germination of Cabbage Seeds*

The effect of Xcc on germination of cabbage seeds under *in vitro* test indicated Table 6 that there was 13.64 percent reduction in germination in cabbage seeds Figure 7. Similarly, the seedling vigour (seedling growth in cm) was also found to be affected by the black rot bacterium. The percent decrease in seedling vigour was 28.5 percent due to presence of bacterium as seed borne infection.

**Table-6.** Effect of seed borne Xcc on seed germination and seedling vigour of cabbage.

| Percent seed germination in cabbage seeds | | Percent decrease in germination in | Seedling vigour( growth in cm) | | Percent decrease in seedling vigour |
|---|---|---|---|---|---|
| Xcc treated seeds | Untreated seeds | | Xcc treated seeds | Untreated seeds | |
| 76 | 88 | 13.64 | 2.5 | 3.5 | 28.57 |

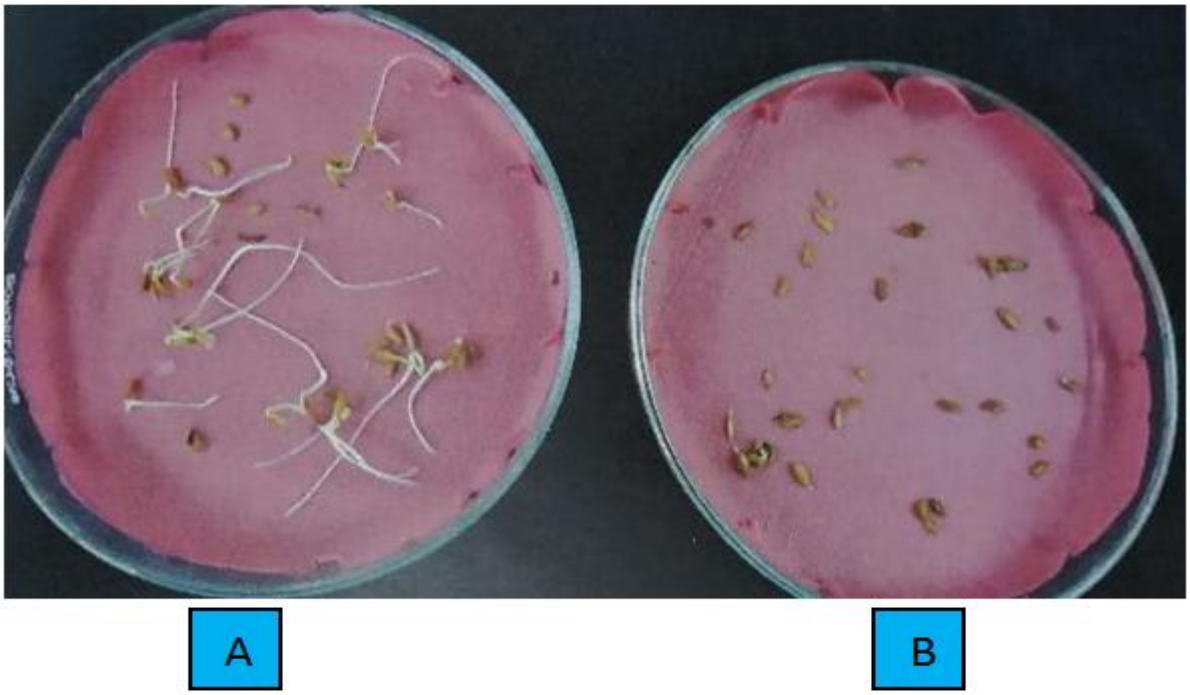


**Figure-7.** Effect of Xcc on seed germination. A. Seeds without Xcc treatment, B. Seeds with Xcc treatment.

### *3.6. Detection of Xcc in Cabbage Seeds to be Used for Raising the Seedlings*

The seeds of cabbage crop purchased from the market for raising the seedlings were subjected for the detection of black rot bacterium Xcc as external/ internal seed borne pathogen. The results indicated that the black rot bacterium was present in the cabbage seed bought from market for raising the cabbage seedlings as an external and internally seed borne pathogen.

### 3.7. Effect of Soil Borne Xcc on Germination of Cabbage Seeds

The presence and effect of soil borne Xcc on the seed germination for raising cabbage seedling indicated Table 7 that the presence of bacterium in the soil reduce the seed germination and seedling stand by around 26 percent.

**Table-7.** Effect of soil borne X.c.pv. campestris on germination of cabbage seeds.

| Percent germination of cabbage seeds | | Reducing in germination due to X.c.pv. campestris in soil |
|---|---|---|
| **Soil harbouring X.c.pv.campestris** | Sterile soil withoutX.c.pv.campestris | |
| **50** | 68 | 26.47 |

Thus various factors like presence of black rot bacterium Xcc on cabbage seed, in the planting fields, in infected cabbage stumps in preceding crop and on weed plants around the field determine the source of infection of the black rot pathogen on the cabbage seedling and its development in to black rot disease.

The black rot bacterium is a very serious pathogen on cabbage in Nashik areas in western Maharashtra, India, where this bacterial disease was first reported from Bombay province by Patwardhan [6] as early as 1928 on cabbage and subsequently on cauliflower by Patel, et al. [7]. It is also reported from katrain in Himachal Pradesh by Rao and Srivastava [8] in 1964 and the disease outbreak from Udaipur, Rajasthan by Chakravarti, et al. [9] in 1969 and by Rangaswami and Rajagopalan [10] in 1973. From other parts of the country the disease was reported by Gupta and Choudhary [11] with 50 % disease severity on some of the susceptible cabbage cultivars. Raju and Sivaprakasam [12] reported it in around 40 villages surveyed in South India and incidence of the disease increased from the vegetative to pre-heading and heading stages.

William [13] considered black rot as the most important disease worldwide of crucifers, attacking all cultivated brassicas, radishes and numerous cruciferous weeds while Liu [14] reported it on greenhouses cabbages in Taiwan. Catara, et al. [15] reported a serious epidemic of black rot on Brassica species in Sicily during the autum of 1997. Azevedo, et al. [16] reported the impaired production of cabbage by the occurrence of black rot in Brazil.

Scortichini, et al. [17] reported the black rot symptoms on broccoli and cauliflower in central-southern Italy. Caponero and Iacobellis [18] observed cauliflower plants with typical symptoms of black rot in Basilicata in Italy in 1992. Obradovic, et al. [19] reported black rot symptoms on diseased cauliflower plants in Yugoslavia. Ignatov, et al. [20] reported X.c pv. Campestris to infect large number of cruciferous plants including weeds in California. Wechter, et al. [21] reported severe outbreak of lead spot disease of leafy vegetable brassica by X.c.pv.campestris in South Carolina. Ram and Ramesh [22] reported the natural outbreak of the bacterium on radish for the first time in India where the bacterial infection caused cracking in roots and death of plant. Thus besides Cabbage the bacterium occurs on various brassica and cruciferous plants.

The cole crop seeds of radish, carrot, beet and mustard collected from market did not show presence of the black rot bacterium in seed samples while the cabbage seeds were found infected with the black rot bacterium. Kim [23] tested 29 commercial seed lots and observed that only one cabbage seed lot was found to carry X.c.pv.campestris while rest were free.

Bandyopadhyay and Chattopadhyay [24] reported that Xcc survive for 35 days in soil with 50% moisture content compared with 14 days in soil at 10-25% moisture content under sterilized conditions. Schultz and Gabrielson [25] recovered the black rot bacterium from buried, artificially infected cabbage residues as long as the residues persisted. Their data indicated that Xcc could survive for 507 days in cabbage stem residues. The bacterium colonized and persist in association with leaves on inoculated cabbage, radish and wild turnip internally and externally under field condition, although plants generally remained symptomless. Dzhalilov and Tiwari [26] reported that the black rot bacterium survived for 20 days at 20°C and 47 days at 5°C. Further, in stem debris, the

survival was for 493 days and on soil surface and at a depth of 20cm it was 551 days. Kocks, et al. [27] studied the carryover of inoculum for 3 years in cabbage field and reported the mean recovery rate from artificially infested soil was 58%. Extinction of Xcc in soil infested with infected plant debris proceeded exponentially and extinction rates depended on temperature and the decomposition of plant debris.

The survival of Xcc in different weeds showing browning or yellowing reaction due to infiltration of the bacterium Xcc, indicated that the bacterium survived in these reaction area up to 15 days. Thus, the bacterium can infect and survive in certain weeds and these can act as a source of inoculum. Young [28] reported that all Brassica species and some other members of cruciferae e.g. Boerhaavia erecta, Mathiola incana, Raphanus sativus and Lepidium sativum were the host for this bacterium. Schaad and Dianese [29] reported that cruciferous weeds serve as source of inoculums of Xcc to cause black rot of crucifers. They also reported that Xcc disseminated up to 12 m from infected weed to cabbage. Kuan, et al. [30] also reported the importance of cruciferous weeds as a reservoir of the inoculum. Aerosol dispersal of Xcc from cruciferous weeds could be an important primary source of inoculum. Kishun and Chandra [31] reported that Xcc occurred symptomless and epiphytically on the weed Centella asiatica in Banglore, India. They further reported that Xcc were able to survive and multiply on C. asiatica leaves and concluded that this weed may play an important role in the disease cycle of black rot of cruciferous. Tsuji and Somerville [32] reported the infection of cruciferous weed Arabidopsis thaliana by Xcc in USA. The bacterium produced semi oval necrotic and chlorotic lesions on the leaf margin of the weeds. Thus the bacterium has got the ability to infect and survive on the weeds.

## 4. CONCLUSION AND RECOMMENDATION

Black rot/Black leg caused by bacterial plant pathogen Xanthomonas campestris pv. campestris (Xcc) is a serious disease of cruciferous/cole crops in many parts of the world. The disease initiation, damage, spread, perpetuation and losses depends on various parameters associated with the disease pathogen which are to be considered in the threat perception for this disease. The presence of bacterium particularly on the seed purchased, in affected fields soils /or on diseased plant stumps in soil or on the field bunds, on/in the asymptomatic/ hypersensitive weeds around the cole crop fields, other black rot diseased cole crops available in the cultivation area are the main component in determining the threat perception for this disease. Once the threat perception is known, it becomes easier to manage the disease. Therefore, the management strategies must consider the number of threat component and for each threat component a relevant recommended strategy of disease control or a combination of strategies are to be applied.

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