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# Epidemiology and management of stem rot of chilli (*Capsicum annuum* L.) caused by *Sclerotium rolfsii* Sacc.

**Prem Naresh, Ved Ratan, Upesh Kumar, Traloni Singh and SK Biswas**

**Abstract**
The domesticated chilli (*Capsicum annuum* L.) is one of the important vegetables and spices crop among family Solanaceae. Most of the promising chilli cultivars are under a great threat for profitable cultivation due to the attack of several by fungal diseases. The important fungal diseases of chilli are root rot /stem rot. These diseases are responsible for lowering down the yield and quality both. The disease was widely occurring in Kanpur and its adjoining area with the incidence ranging from 12.6 to 59.8 percent (Av. 36.20%). Highest disease incidence (59.8%) was recorded in Sarsaul of dist. Kanpur and lowest in Badokhar, dist. Banda (12.6%) followed by Maudaha dist. Hamirpur (17.4%). The pathogen was able to survive along with diseased plant debris and to cause primary infection. The pathogen surviving in diseased plant debris stored in laboratory condition caused 17.1% infection in seedlings while it infected 29.41% seedlings when plant debris stored under field condition. The seedlings raised in sterilized soil from surface sterilized seeds without mixing plant debris remained healthy. Diseased symptoms were observed on 29.41% seedlings in case of naturally infected seeds while 34.28% seedlings were found infected when raised from artificially inoculated seeds. On the other hand, plants raised from healthy surface sterilized seeds did not develop any symptoms of the disease. This clearly indicated that the diseased seeds served as primary source of inoculums. To ascertain the role of infected soil as primary source of infection, it is revealed that the plants raised in the pots filled with naturally infested field soil and artificially inoculated soil produced stem rot. However, the percentage of plant infection was more in case of artificially inoculated soil than naturally infested field soil. To know the role of seeds in initiation of disease, it was observed that the disease was successfully reproduced from infected seeds sown in sterilized soil. Diseased symptoms were observed on 29.41% seedlings in case of naturally infected seeds while 34.28% seedlings were found infected when raised from artificially inoculated seeds. On the other hand, plants raised from healthy surface sterilized seeds did not developing symptoms of the disease. This clearly indicated that the diseased seeds served as a source of primary inoculums. The highest disease incidence (20-21%) was observed during first week of August, when the average temperature was 31.19 °C (2009-10) & 29.77 °C (2010-11) along with 70.0 and 81.50% relative humidity, respectively in both the year. The disease incidence declined with the decline average temperature along with decrease in average relative humidity. Probably rain fall helped in increasing the relative humidity and also the spread of the disease. To find out the disease resistance reaction, cultivars/ germplsms of chilli were screened under natural conditions and found that, Out of seventy varieties/germplasms screened 04 varieties/germplasms were found to be moderately resistant (MR), 07 moderately susceptible (MS), 23 varieties/germplasm susceptible (S) and remaining varieties/germplasm were found to be highly susceptible(S) under natural conditions. None of the varieties/germplasms was found immune (I) and resistant(R). But in pots experiment (artificial condition), eleven varieties, showing free, resistant and moderately resistant reaction were subjected to further testing under artificial condition of inoculation in the glass house and found that out of 11 varieties /germplasms none of the verieties/germplasm was immune (I) and resistant (R), while 2 varieties /germplasm (Chanchal and A M-1)were found to be moderately resistant (MR), 2 moderately susceptible (MS) and 3 were susceptible (S) and remaining 4 varieties /germplasm were found to be highly susceptible(HS). In pot condition out of 11 selected field trial tested in pots, none of the variety /germplasm was immune and resistant against the test pathogen. The two (Chanchal and AM-1) germplasms were moderately resistant and two (2013 and 8601) were moderately susceptible and rest were susceptible and highly susceptible against the disease. To know the impact of time of planting on disease incidence and yield, chilli seedlings were planted on different time during crop season (1st week of June to II$^{nd}$ week of August) and observed that when chilli seedlings were planted in the second week of August, the disease incidence was minimum during both the year. The maximum yield was obtained from the seedlings planted in August during both the years. This clearly indicated that with advancement in planting time disease as well as yield potential decreased.

**Keywords:** Stem rot, chilli (*Capsicum annuum* L.), *Sclerotium rolfsii*

## Introduction
The domesticated chilli (*Capsicum annuum* L.) is one of the important vegetables and spices crop in family Solanaceae. Out of four species of chilli (*viz*. *Capsicum pendulum, C. pubescence, C. annuum* and *C. frutescens*), only two *viz* C. *annuum* (Hot and sweet chilli

peppers) and *C. frutescens* (small sized hot and highly pungent)are under cultivated in our country are one of the most important and being a basic ingredient of the Indian diet. Chilli is also known as *Mircha* fruits have high nutritional value and are a good source of vitamins (vit. A, C, & E. (Thamburaj and Singh, 2001) [17]. The fruits of chilli are used to increase the palatability and taste of cooked food. (Rai, 2005).The chief constituent of chilli are *Capsacin or capsicutin* ($C_{18}H_2O_3N$) present in the pericarp (outer wall of the fruit) which is crystalline coluorless pungent chemical and is responsible for pungency. The *Capsacathin* is only colouring pigment and is non–pungent and the red colour in fruit at the ripening stage is due to this pigment. The green chilli also contain *rutin* ($C_{27}H_{30}O_{16}$) which has specific medicinal value.

The production of chilli in India contributes 25% share in total quantity of chilli exported in the world. India is the world's largest manufacturer of oleoresins and exporter of dry chilli. In India area, production and productivity of chilli were 767.23 million ha. 1202.94 million Tones and 1.6 MT/ha, respectively (Parthasarathy and Kandiannan, 2010) [12].

Most of the promising chilli cultivars are under a great threat for profitable cultivation due to the attack of several abiotic and biotic stresses likes fungi, bacteria, virus, nematode etc. The major losses of chilli are covered by fungal diseases. The important fungal diseases of chilli are fruit rot root rot stem rot. These diseases are responsible for lowering down the yield and quality both (Thamburaj and Singh, 2001) [17]. Among many fungal diseases in chilli, stem rot also known as foot rot/ Southern blight/ white stem rot/ stem rot in different places of the country caused by *Sclerotium rolfsii* Sacc. is an important disease.

*Sclerotium rolfsii* Sacc. is well known polyphagous, omnivorous, ubiquitous and most destructive soil borne fungus that causes leaf and stem blight of a large number of plants. Infrequently its teleomorph, *Aethalium rolfsii*, has been found in nature or induced to form under laboratory conditions (Tu *et al.*, 1992) [18]. *Sclerotium rolfsii* is generally distributed in tropical and subtropical countries where high temperature prevails during the rainy season (Weber, 1931) [19]. This disease appears from nursery to maturity of the crop. The plant parts affected by pathogen are leaves, fruit, twigs, stems, and even seeds. Southern blight/ stem rot currently has a wide geographical distribution in warm climate. Capsicum is highly susceptible to this disease and 50 to 60 percent mortality has been reported.

A severe mortality of chilli plants were observed during March-April near Jaipur in chilli growing areas. About 60 to 80 percent of fully grown, mature plants of chilli from the standing crop were collapsed down and dried suddenly (Mathur and Gurjar, 2001) [9].

The severe stem rot of chilli causing 30-40% seedling rot was observed in a 2.0 ha at farmer's field in Saurashtra (Gujrat) India. This is the first report of *S. rolfsii* causing collar rot in chilli from Gujrat (Lukose *et al.*, 2003) [8]. It produces oxalic acid for pathogenesis on many host plants (Bhoraniya *et al*., 2002) [3]. It is a destructive plant pathogen with an almost unlimited host range.

The disease is now day gradually increasing in different agro-climatic regions of Uttar Pradesh. Therefore, keeping in view the severity of the disease and its importance, there are several management techniques applied this disease control methods like chemical, biological and botanical.

In chemical control, it impossible because green chilli fruit direct consume and in these type fruit having pesticides residue while biological are not possible in poor farmer in village level because farmer not proper storage and maintained the bioagents and in botanical control somehow costly in field level therefore it is essential that management should be applied which possible farmer and environmentally safe. Using objectives likes to find out the source of perpetuation of pathogen, to determine the role of environmental factors in relation to disease development and management of the disease through Screening of available varieties /germplasms of chilli against pathogen under natural and artificial conditions and Cultural management and effect of time of planting on disease severity.

## Material and Methods

### Collection, isolation and purification of the fungus of diseased material

Natural Stem and root of chilli plants showing infection were collected at regular intervals during the survey of crop in different area of Uttar Pradesh. The disease incidence of stem of chilli was observed by randomly selecting four sub plots of four square meters in different field and counted the number of diseased and healthy plants. The percent disease incidence (PDI) was calculated according to fallowing procedure as given by Chestler (1950) [5].

$$\text{Percentage Disease Incidence (PDI)} = \frac{\text{No. of diseased plants in sub plot}}{\text{Total no. of plants in sub plot}} \times 100$$

The fungus isolation was making by two methods.

(a) Isolation from affected tissues.

(b) Isolation from sclerotia.

### Isolation from affected tissues (specially root and stem)

Infected plant roots and stems, showing distinct symptoms were selected for isolation of the pathogen. The selected stems were thoroughly washed with tap water, in order to remove dust and other surface contaminants. Small pieces from the affected stems just touching the healthy portion of stems were cut with a sterilized blade. The cut pieces were gently washed with running tap water and then dipped in 0.1% mercuric chloride solution for 30 second. These pieces were taken out and washed immediately with 3 to 4 changes of sterile water, to remove traces of mercuric chloride. The excess moisture was removed by drying the pieces in between the two folds of sterilized blotting paper. These sterilized pieces were then transferred into Petri dishes containing two percent potato dextrose agar (PDA) medium with the help of sterilized forceps in the inoculation chamber.

### Isolation from sclerotial bodies

Together with isolating fungus from diseased stem, the sclerotia on the roots was also used for isolation. These sclerotia were placed using as above procedure and inoculated in poured Petri-plates. Petri-plates were incubated at 28 $\pm$ 1 °C. After 24 hours different colony growth was observed near the planted sclerotia. These colonies, later on were obtained in pure form in culture tubes, previously poured and slanted. For pure culture of the fungus mycelia tips were used. The cultures were purified by transferring freshly grown hyphal tips method.

**Pathogenicity test**

The pathogenicity of isolated fungus obtained from stem, root and sclerotia were carried out and established according to Koch's postules. The pathogenicity was performed on chilli variety Kalyanpur Chaman which was found to be highly susceptible to the disease under natural condition. For testing the pathogenicity, the surface sterilized seeds were sown in 3 cm earthen pots filled with sterilized soil. Watering to the pots was done as and when required. The plants thus rose for using pathogenicity test with mycelial disc and soil inoculation with sclerotia as described below.

**Disc method**

The chilli seeds of a highly susceptible variety (Kalyanpur chaman) were grown in 3 cm earthen pots containing sterilized soil. Mycelial discs of 5.00 mm diameter were cut with the help of sterilized cork borer from the margin of 7 days old culture grown on 2 percent potato dextrose agar medium and were placed at the base of one month old injured and uninjured healthy plants of chilli. The inoculated plants were covered with polythene bags for 48 hrs to provide maximum humidity for infection. The un-inoculated set of plants washed with distilled water covered with polythene bags which served as control.

**Soil inoculation**

Sclerotia harvested from 25 days old culture of pathogen grown on sand corn meal medium (250 g. corn or maize, 750 g. washed white sand and 250 ml. distilled water) were washed with sterilized water and mixed with the sterilized mixture of sand and soil (5:1) up to 2 cm depth at the rate of 45 sclerotia per pot. Ten healthy seeds of chilli variety (Kalyanpur Chaman) were sown in each pot, and allowed to grow naturally. The plants were examined regularly for the development of symptoms and final data on disease development were recorded after 15 days of inoculation.

**Losses in yield due to varying severity of stem rot in chilli**

The locations included for survey were Kalayanpur, Sarsaul (Kanpur Nagar) Ghatampur (Ramabai Nagar), Bindki (Fatehpur) Ajgain. (Unnao), Chamad (Aligarh), Mallanwa (Hardoi), Kucharia (Raebarelly), Maudaha (Hamirpur) and Barokhar (Banda). Extensive survey of different chilli growing areas of Uttar Pradesh was made for the assessment and evaluation of stem rot during June to March in the year 2009-2010 and 2010-11. Observations were recorded on field under natural conditions. Percent of stem rot was calculated for every location based on number of infected plant.

**Mode of perpetuation of pathogen- 1-mode of infection and perpetuation**

To study the primary mode of infection of the pathogen, the fallowing experiments were conducted.

**A. Role of diseased plant debris as a source of primary inoculum**

The study was conducted in a three sets. In one set of pots, diseased plant debris stored at room temperature (15-30 °C) was thoroughly mixed with sterilized soil and filled in earthen pots of 3 °C m diameter. In second set the plant debris kept in field condition were mixed with sterilized soil filled in earthen pots and another third set surface sterilized seeds were sown in autoclaved soil without plant debris served as control. Five healthy surface sterilized seeds of variety Kalyanpur chaman were sown in each pot and data on seedling emergence and disease development were recorded. Plants rose from surface sterilized healthy seeds in sterilized soil in pots without mixing any plant debris served as control. The observations about disease infection on seedlings were taken.

**B. Role of seed as a source of primary inoculum**

For assessing the role of seed as the primary source of inoculum in the next season, seeds were collected from the naturally infected plants displaying symptom of chilli in infected fields having partially and fully infected plants from farmers field during 2009. These seeds were stored under room condition in paper bags till the next sowing/planting season.

Healthy seeds were also collected which were artificially infected with the pathogens. For this purpose fresh culture of the fungus was taken and mycilial suspension (having $10^6$ /ml. C.F.U.) was prepared. The seeds were then heavily coated with this suspension and dried at 15-30 °C in laboratory. These artificially infected seeds were stored in paper bags till the next sowing season. These naturally and artificially infected seeds and surface sterilized healthy seeds were sown in autoclaved soil in pots during next crop season 2010. Seedling emergence and number of infected seedling were recorded.

**2. Environmental factors in relation to disease development**

To study the effect of weather factors *viz*. temperature, relative humidity (R.H.), rainfall, on disease development, the 25-30 days old chilli seedlings were planted during two consecutive crop years *viz*. 2008-2009 and 2009-2010. The experiment was conducted at Vegetable Research Farm Kalyanpur, Kanpur. Planting was done during first week of June at the distance of 3 cm X 2 cm with irrigation at an interval of 12-15 days as soon as plant required. The observations on disease occurrence, its further development and severity were recorded starting from the first appearance of the disease symptoms fallowed by the interval of seven days with a view to observe the relation with weather parameter *i.e. r*ainfall, temperature, and relative humidity. As soon as the disease was appeared, the number of infected plants was recorded and subsequently the disease intensity was recorded at fortnightly (weekly) interval and it was correlated with weather data. Thus the data on the maximum and minimum temperature, rainfall, relative humidity and disease intensity in each phase were tabulated and were critically analyzed to ascertain the most conductive temperature and Relative humidity for growth and development of disease. The information on atmospheric temperature and rainfall were collected from metrological station, Department of Agronomy, C. S. Azad University of Agriculture and Technology, Kanpur.

**Management of disease**

**1. Screening of available varieties/germplasms of chilli against pathogen under natural and artificial condition**

The use of resistant varieties is the best method for controlling any plant disease and the same holds good for this disease also. In order to find out the source of resistance against the

disease, cultivars/ germplsms of chilli were screened under natural conditions in breeder's trial laid out by the using of sick plot technique (Nene *et al*., 1981) [11] in four meters row distance at Vegetable Research Farm, kalyanpur. The seedlings having 25-30 days old age were planted in standard distance (30 x 2 cm.) apart. In each germplasm in one line, 10 plants were maintained. The experiment was carried out during 2008-09 and 2009-1 Crop season in order to locate the source of resistance. All the recommended agronomic practices were fallowed as and when required.

Subsequently, the varieties, showing free, resistant and moderately resistant reaction were subjected to further testing under artificial condition of inoculation in the glass house. For this purpose, each variety was raised in duplicate in 3 cm earthen pots containing sterilized soil. Five plants in each pot were maintained and after attaining the age of one month, the plants were inoculated with the sand corn meal medium @ 100 g per pot having 7 days old culture of the fungus. The inoculated plants were kept in humid chamber for 48 hrs and then transferred in open. Plants were watered as when required to maintain sufficient moisture. The disease incidence was recorded after every 15 days started from the 7 days after inoculation till the crop maturity of the plants with the help of the fallowing formula.

$$\text{Disease incidence (D.I.) \%} = \frac{\text{No of diseased plants in sub plot}}{\text{Total No of plants in sub plot}} \times 100$$

Reactions of different cultures / germplasms were noted after 7 days of inoculation and were placed in six categories from immune to high susptible.

**2. Time of planting (In field)**

To study the effect of alteration in planting time on disease incidence, susceptible variety Kalyanpur Chaman was planted in sick plot (4.0 x 2.0 m) at fortnightly interval under natural condition. Ten seedlings per plot were planted. The planting of 25-30 days old seedlings of chilli was done in six treatment at first week of June, second week of June, first week of July, second week of July, first week of August and second week of August in the year 2009 and 2010 with four replications for each treatment. Time to time water, fertilizer and agronomic practices were adopted as per requirement. Disease incidence was recorded after two months from date of planting and average disease incidence was calculated in both the years. The yield per hectare was also recorded in both the years.

## Result and Discussion

**1. Prevalence and incidence of the disease**

**Table 1:** Incidence of stem rot of chilli caused by *S. rolfsii* at different locations of Uttar Pradesh

| S. No. | Locations of U.P. | Average diseases severity% |
|---|---|---|
| 1. | Farmer's field Sarsaul, District Kanpur | 59.8 |
| 2. | Farmer's field Ghatampur, District Ramabai Nagar | 41.8 |
| 3. | Farmer's field Bindki, District Fatehpur | 36.2 |
| 4. | Vegetable Research Farm, Kalyanpur, District Kanpur | 32.6 |
| 5. | Farmer's field Mallawa, District Hardoi | 31.2 |
| 6. | Farmer's field Kucharia, District RaeBareli | 30.4 |
| 7. | Farmer's field Ajgain, District Unnao | 26.4 |
| 8. | Farmer's field Chamad, District Aligarh | 24.8 |
| 9. | Farmer's field Maudaha, District Hamirpur | 17.4 |
| 10. | Farmer's field Badokhar, District Banda | 12.6 |

The results presented in Table-1 revealed that the disease was widely occurring in Kanpur and its adjoining area with the incidence ranging from 12.6 to 59.8 percent (Av. 36.20%). Highest disease incidence (59.8%) was recorded in Sarsaul of dist. Kanpur and lowest in Badokhar, dist. Banda (12.6%) followed by Maudaha dist. Hamirpur (17.4%). The disease incidence was highest in early sown varieties and lowest in late sown varieties of chilli

**Perpetuation of the pathogen-a-role of diseased plant debris as a source of primary inoculums**

Study was conducted in a three sets. In one set diseased plant debris were stored at room temperature (15-30 °C) and thoroughly mixed with sterilized soil and filled in earthen pots of 3 cm dia. In second set the plant debris kept in field condition were mixed with sterilized soil filled in earthen pots and in third set surface sterilized seeds were sown in autoclaved soil without plant debris served as control. Five healthy surface sterilized seeds of veriety Kalyanpur Chaman were sown in each pot and data on seedling emergence and disease development were recorded.

**Table 2:** Role of diseased Plant debris as source of primary inoculums

| S.N. | Treatments | No. of seeds sown | No. of plants obtained | No. of plants infected | Percent disease incidence |
|---|---|---|---|---|---|
| 1 | Diseased plant debris kept in laboratory condition +Autoclaved soil +surface sterlized seeds | 40 | 35 | 6 | 17.1 |
| 2 | Diseased plant debris kept in field condition+ Autoclaved soil +surface sterlized seeds | 40 | 34 | 10 | 29.41 |
| 3 | Autoclaved soil without plant debris+ surface sterlized seeds (control) | 40 | 38 | Nil | Nil |

The results presented in Table 2 indicated that the pathogen was able to survive along with diseased plant debris and to cause primary infection. The pathogen surviving in diseased plant debris stored in laboratory condition caused 17.1% infection in seedlings while it infected 29.41% seedlings when plant debris stored under field condition. The seedlings

raised in sterilized soil from surface sterilized seeds without mixing plant debris remained healthy.

To know the role of diseased plant debris as a source of primary inoculum, the results obtained from experiment indicated that the pathogen was able to survive for a long period with diseased plant debris and served as a source of primary infection. The pathogen survived in diseased plant debris up to six month when it was stored in laboratory condition and caused 17.1% infection in seedlings while it infected 29.41% seedlings when plant debris stored under field condition up to six month. The seedlings raised in sterilized soil from healthy, surface sterilized seeds without mixing plant debris remained healthy. The similar result were also reported by Mishra *et al*. (2000) [10]. Pathogen perpetuates on seeds and plant debris so studies were taken in laboratory condition to know the pathogenic behavior.

**B. The role of seeds as a source of primary inoculums**

Experiments were conducted in three sets. In first set, seeds were collected from naturally infected plants of farmer's field and kept under room condition (25 °C) in paper bags till the next season. In another set, healthy seeds collected from healthy plants were artificially infected with the pathogens. For this purpose, fresh culture of the fungus was taken and mycilial suspension (having $10^6$ /ml. C.F.U.) was prepared. The seeds were then heavily coated with this suspension and dried at 15-30 °C in laboratory. These artificially infected seeds were stored in paper bags till the next sowing season. In third set, healthy seeds were also collected for experiment which served as control. These naturally and artificially infected seeds and surface sterilized healthy seeds were sown in autoclaved soil in pots during next crop season 2010 and the results are given in Table 3.

**Table 3:** The role of seeds as source of primary inoculum

| S.N. | Treatments | No. of seeds sown/pot | No. of seedlings/pot | No. of seedlings infected/pot | Percent of infected seedling |
|---|---|---|---|---|---|
| 1 | Naturally infected seeds sown in autoclaved soil | 40 | 34 | 10 | 29.41 |
| 2 | Artificially infected seeds(seeds mixed with the mycelia suspension and sown in autoclaved soil) | 40 | 35 | 12 | 34.28 |
| 3 | Only surface sterlized healthy seeds (control) | 40 | 37 | Nil | Nil |

The disease was successfully reproduced from infected seeds sown in sterilized soil. Diseased symptoms were observed on 29.41% seedlings in case of naturally infected seeds while 34.28% seedlings were found infected when raised from artificially inoculated seeds. On the other hand, plants raised from healthy surface sterilized seeds did not develop any symptoms of the disease**.** This clearly indicated that the diseased seeds served as primary source of inoculums.

To ascertain the role of infected soil as primary source of infection, it is revealed that the plants raised in the pots filled with naturally infested field soil and artificially inoculated soil produced stem rot. However, the percentage of plant infection was more in case of artificially inoculated soil than naturally infested field soil. Similar results were also reported by Singh, *et al.*, (2010) [15] on survival of *S. rolfsii* causing color rot of chick pea in soil. Pant and Mukhopadhyay (2002) [13] observed maximum soybean seed rot with mix inoculums of four fungi. This also resulted in significant seedling mortality.

To know the role of seeds in initiation of disease, it was observed that the disease was successfully reproduced from infected seeds sown in sterilized soil. Diseased symptoms were observed on 29.41% seedlings in case of naturally infected seeds while 34.28% seedlings were found infected when raised from artificially inoculated seeds. On the other hand, plants raised from healthy surface sterilized seeds did not developing symptoms of the disease**.** This clearly indicated that the diseased seeds served as a source of primary inoculums. The finding was closely resembled with the finding of Singh *et al.* (2010) [15].

**Role of environmental factors in relation to disease development**

Environmental factors *viz.* temp., relative humidity and rainfall etc., play on important role not only in infection but also in plant disease development. Therefore, the present investigation was carried out during 2009-10 and 2010-11 to study the effect of these factors on the development of stem rot of chilli under natural condition as per technique described under "Material and Method" at experimental plots of Vegetable Farm, C.S. Azad Uni. of Agriculture and Technology, Kanpur. The data were recorded at weekly interval starting from crop planting till crop harvesting. The prevailing atmospheric temperature, Relative Humidity (R.H.) and Rainfall were also noted from the observatory, Department of Agronomy at the University and these factors were co-related with disease severity/intensity as summarized in Table-4 and Fig and found that atmospheric temperature and relative humidity played in an important role in disease development and a significant correlation was also observed between the environmental conditions and disease incidence. The disease appeared in the first week of June which was gradually increased up to August; and disappeared from October on wards in both the year (2009-10 &2010-11).

The highest disease incidence (20-21%) was observed during first week of August 2009-10 and 2010-11 when the average temperature was 31.19 °C (2009-10) & 29.77 °C (2010-11) along with 70.0 and 81.50 percent relative humidity (R.H.), respectively in both the year. The disease incidence declined with the decline average temperature along with decrease in average relative humidity. Probably rain fall helped in increasing the relative humidity and also the spread of the disease.

Environmental factors play an important role in disease development. The highest disease incidence of 21% percent was observed during first week of August in both the year, when the average temperature was 31.19 °C and 29.77 °C and relative humidity 70.00% and 81.50 percent, respectively. The disease incidence declined with the decrease in average temperature (26.40 °C) and decrease in average relative humidity below 70%. Probably rain fall helped in increasing the relative humidity and also the spread of the disease resulting in comparatively higher disease incidence in the season. The present findings are in close conformity with the finding of Ayocock (1966), who have reported that the

maximum disease occurrence at 25-35 °C, which is also the optimum range for mycelial growth and sclerotial germination of the fungus. Similarly, Hari *et al*. (1991) [7] have reported that growth of *Sclerotium rolfsii* was best at 30 °C.

**Table 4:** Effect of temperature, humidity and rainfall on disease incidence

| S. N. | Date | 2009-10 | | | | | | | 2009-10 | Date | 2010-11 | | | | | | | 2010-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Temperature ($C^0$) | | | Humidity (%) | | | Rainfall (mm) | Disease incidence (%) | | Temperature ($C^0$) | | | Humidity (%) | | | Rainfall (mm) | Disease incidence |
| | | Avg. Max. | Avg. Min. | Avg. | Avg. max. | Avg. Min. | Avg. | | | | Avg. Max. | Avg. Min. | Avg. | Avg. max. | Avg. Min. | Avg. | | |
| 1. | 7 June 2009 | 40.30 | 25.74 | 37.45 | 67.70 | 30.20 | 48.85 | 2.71 | 6.2 | 7 June 2010 | 42,34 | 29.02 | 34.60 | 55.42 | 23.71 | 39.57 | 00.00 | 5.00 |
| 2. | 14 | 42.92 | 25.85. | 34.39 | 43.00 | 17.85 | 26.14 | 00.00 | 6.00 | 14 | 40.14 | 26.88 | 33.51 | 56.71 | 29.85 | 43.28 | 00.00 | 4.00 |
| 3. | 21 | 42.21 | 26.24 | 34.23 | 51.85 | 30.00 | 40.92 | 00.00 | 7.00 | 21 | 40.31 | 29.34 | 34.82 | 60.85 | 36.28 | 48.57 | 2.97 | 6.20 |
| 4. | 28 | 42.18 | 28.22 | 35.09 | 62.85 | 33.42 | 48.14 | 00.00 | 7.80 | 28 | 34,57 | 29.14 | 34.12 | 70.85 | 49.28 | 60.07 | 2.85 | 7.00 |
| 5. | 5 July | 38.42 | 27.07 | 32.75 | 79.28 | 49.57 | 64.42 | 00.43 | 10.00 | 5 July | 37.62 | 28.18 | 32.90 | 77.00 | 48.71 | 62.85 | 3.65 | 9.25 |
| 6. | 12 | 35.64 | 26.72 | 31.18 | 84.42 | 63.28 | 73.92 | 7.90 | 10.40 | 12 | 34.94 | 27.34 | 31.14 | 82.71 | 65.00 | 86.57 | 13.91 | 14.30 |
| 7. | 19 | 34.65 | 26.71 | 30.68 | 88.00 | 71.71 | 79.85 | 3.78 | 11.00 | 19 | 34.31 | 26.77 | 30.54 | 90.85 | 74.14 | 82.5 | 10.81 | 15.25 |
| 8. | 26 | 34.45 | 26.21 | 30.33 | 85.28 | 71.57 | 78.42 | 18.06 | 20.00 | 26 | 32.40 | 26.60 | 29.50 | 92.14 | 74.14 | 83.14 | 27.20 | 19.50 |
| 9. | 2 Aug | 35.42 | 26.95 | 31.19 | 78.28 | 61.85 | 70.00 | 3.15 | 21.00 | 2 Aug | 32.85 | 26.70 | 29.77 | 90.71 | 72.28 | 81.50 | 2.42 | 20.15 |
| 10. | 9 | 37.48 | 27.68 | 32.58 | 68.28 | 49.28 | 58.84 | 1.51 | 10.00 | 9 | 33.48 | 26.97 | 34.22 | 87.42 | 71.00 | 79.21 | 7.12 | 18.15 |
| 11. | 16 | 33.27 | 26.55 | 30.01 | 83.85 | 74.28 | 79.97 | 23.35 | 18.20 | 16 | 33.91 | 27.00 | 30.45 | 86.00 | 71.85 | 78.92 | 3.80 | 10.50 |
| 12. | 23 | 34.22 | 25.34 | 29.42 | 87.00 | 65.00 | 76.00 | 5.31 | 19.00 | 23 | 32.05 | 26.51 | 29.28 | 94.57 | 83.71 | 89.14 | 11.00 | 11.80 |
| 13. | 30 | 32.80 | 25.37 | 29.08 | 86.00 | 69.42 | 77.71 | 0.77 | 20.50 | 30 | 32.82 | 26.62 | 29.72 | 92.14 | 78.14 | 85.14 | 03.80 | 12.50 |
| 14. | 6 Sept | 32.22 | 25.12 | 28.67 | 88.71 | 69.85 | 79.28 | 0.20 | 20.00 | 6 Sept | 33.14 | 26.71 | 29.92 | 91.42 | 75.00 | 83.21 | 13.91 | 13.0 |
| 15. | 13 | 30.14 | 23.97 | 27.06 | 89.28 | 72.71 | 81.00 | 02.60 | 16.00 | 13 | 33.40 | 26.37 | 29.88 | 92.42 | 73.00 | 82.71 | 4,64 | 14.20 |
| 16. | 20 | 34.25 | 24.07 | 29.15 | 85.42 | 54.57 | 70.00 | 00.00 | 12.60 | 20 | 30.97 | 25.45 | 28.21 | 94.42 | 89.71 | 92.02 | 4.77 | 14.00 |
| 17. | 27 | 35.11 | 24.98 | 30.05 | 80.42 | 57.71 | 70.14 | 00 | 11.20 | 27 | 31.91 | 24.48 | 28.20 | 93.57 | 74.57 | 84.07 | 6.71 | 14.40 |
| 18. | 4 Oct | 33.08 | 25.04 | 28.99 | 84.28 | 65.57 | 74.92 | 0.57 | 9.00 | 4 Oct | 33.54 | 22.77 | 28.15 | 86.71 | 63.71 | 75.21 | 00.00 | 10.00 |
| 19. | 11 | 31.25 | 21.55 | 26.40 | 91.57 | 59.85 | 75.64 | 16.17 | - | 11 | 33.02 | 22.31 | 27.67 | 85.71 | 59.42 | 72.57 | 2.37 | - |
| 20. | 18 | 32.45 | 18.37 | 25.41 | 91.71 | 45.14 | 68.42 | 00 | - | 18 | 32.48 | 21.85 | 27.17 | 86.28 | 54.57 | 70.42 | 00.00 | - |
| 21. | 25 | 31.57 | 13.85 | 22.71 | 78.71 | 25.57 | 52.14 | 00 | - | 25 | 32.04 | 21.77 | 26.90 | 91.71 | 52.28 | 72.00 | 0.20 | - |
| 22. | 1 Nov | 30.98 | 12.22 | 21.60 | 78.14 | 28.85 | 53.50 | 00 | - | 1 Nov. | 30.40 | 14.37 | 22.38 | 90.42 | 28.71 | 64.92 | 00.00 | - |
| 23. | 8 | 30.65 | 13.62 | 22.14 | 90.14 | 38.85 | 64.50 | 00 | - | 8 | 30.05 | 14.81 | 22.43 | 92.28 | 45.57 | 68.92 | 00.00 | - |
| 24. | 15 | 27.27 | 16.90 | 22.09 | 87.57 | 57.28 | 72.42 | 0.42 | - | 15 | 30.18 | 18.50 | 24.09 | 89.85 | 47.71 | 68.78 | 00.00 | - |
| 25. | 22 | 24.84 | 12.55 | 18.70 | 82.71 | 47.57 | 65.14 | 00 | - | 22 | 25.45 | 16.45 | 20.95 | 91.14 | 74.71 | 82.92 | 3.45 | - |
| 26. | 29 | 26.17 | 8.94 | 17.56 | 85.85 | 30.71 | 56.14 | 00 | - | 29 | 24.82 | 16.54 | 19.97 | 96.14 | 69.00 | 82.57 | 2.52 | - |
| 27. | 6 Dec | 25.31 | 8.90 | 17.11 | 91.57 | 42.14 | 62.57 | 00 | - | 6 Dec | 24.02 | 8.45 | 16.24 | 85.28 | 62.57 | 73.92 | 00.00 | - |
| 28. | 13 | 25.74 | 10.74 | 18.24 | 90.00 | 42.28 | 66.14 | 00 | - | 13 | 24.37 | 11.54 | 18.52 | 83.14 | 50.42 | 66.78 | 00.00 | - |
| 29. | 20 | 24.28 | 10.6 | 18.08 | 89.28 | 43.42 | 66.35 | 00 | - | 20 | 23.65 | 7.92 | 15.79 | 83.85 | 34.57 | 59.21 | 00.00 | - |
| 30. | 27 | 22.10 | 6.70 | 14.40 | 89.57 | 41.28 | 65.42 | 00 | - | 27 | 23.88 | 7.0 | 15.44 | 86.85 | 37.14 | 60.78 | 00.00 | - |
| 31. | 3 Jan 2010 | 18.78 | 8.02 | 13.40 | 94.28 | 69.57 | 81.92 | 1.40 | - | 3 Jan 2011 | 20.45 | 9.2 | 14.82 | 92.71 | 54.57 | 73.64 | 00.00 | - |
| 32. | 10 | 16.04 | 7.55 | 11.81 | 95.57 | 82.42 | 89.00 | 00 | - | 10 | 11.55 | 4.54 | 8.06 | 95.71 | 77.42 | 86.57 | 00.00 | - |
| 33. | 17 | 13.88 | 8.54 | 11.21 | 95.57 | 77.28 | 86.42 | 0.45 | - | 17 | 21.91 | 6.82 | 14.37 | 86.28 | 42.28 | 64.28 | 00.00 | - |
| 34. | 24 | 15.94 | 6.62 | 11.28 | 93.57 | 71.85 | 82.71 | 00 | - | 24 | 23.37 | 7.14 | 15.25 | 86.57 | 32,85 | 59.71 | 00.00 | - |
| 35. | 31 | 24.11 | 8.02 | 16.07 | 91.57 | 43.42 | 67.50 | 00 | - | 31 | 23.02 | 8.02 | 15.52 | 86.71 | 51.0 | 68.85 | 00.00 | - |
| 36. | 7 Feb | 25.17 | 9.28 | 17.22 | 90.57 | 39.28 | 64.92 | 00 | - | 7 Feb | 26.14 | 10.02 | 18.10 | 90.42 | 44.42 | 67.42 | 00.00 | - |
| 37. | 14 | 32.10 | 13.71 | 18.40 | 95.14 | 69.28 | 80.00 | 2.14 | - | 14 | 26.07 | 12.31 | 19.20 | 85.00 | 41.42 | 63.21 | 00.00 | - |
| 38. | 21 | 25.22 | 10.57 | 18.10 | 85.28 | 54.85 | 70.07 | 00 | - | 21 | 22.77 | 11.45 | 17.14 | 92.42 | 53.57 | 73.00 | 00.00 | - |
| 39. | 28 | 28.94 | 13.90 | 21.42 | 86.14 | 43.85 | 65.00 | 0.03 | - | 28 | 25.42 | 11.20 | 18.34 | 87.00 | 46.28 | 66.64 | 00.26 | - |
| 40. | 7 March | 31.85 | 16.15 | 24.00 | 81.42 | 36.57 | 58.92 | 00 | - | 7 march | 28.65 | 14.10 | 21.38 | 76.85 | 44.85 | 60.85 | 00.00 | - |
| 41. | 14 | 30.82 | 14.10 | 22.46 | 76.71 | 29.71 | 53.21 | 00 | - | 14 | 29.60 | 14.88 | 20.95 | 74.42 | 37.85 | 57.42 | 00.00 | - |
| 42. | 21 | 34.22 | 17.37 | 25.68 | 80.14 | 28.00 | 54.07 | 00 | - | 21 | 33.91 | 16.85 | 25.38 | 76.42 | 43.71 | 60.07 | 00.00 | - |
| 43. | 28 | 39.14 | 19.02 | 29.09 | 74.14 | 20.71 | 47.42 | 00 | - | 28 | 34.97 | 17.37 | 26.17 | 74.71 | 46.71 | 60.71 | 00.00 | - |
| CD. at 5% | | | | | | | | | | | | | | | | | | |

**Management-a-screening of available varieties/ germ plasms of chilli under natural and artificial condition**

Disease management with varietal screening is safe and sound method; therefore, study was under taken in field as well as pot condition for further breeding programmes. The use of resistance varieties/germplasms is the cheapest and environmentally safe method for management of any plant disease. Screening of chilli's varieties/germplasms, consisting of released varieties and some local varieties from different places were carried out under natural condition for determining the source of resistance to the stem rot disease caused by *Sclerotium rolfsii*. Chilli varieties/germplasms grown at the Vegetable Research Farm Kalyanpur of the University were screened for disease incidence during crop season (2009-10 and 2010-11). The highest disease incidence was recorded in any of two consecutive years' accounts for grouping the varieties/cultures in different categories. The seventy varieties/cultures were grouped in various categories of resistance and susceptible on the basis of number of stem rotted plants. The data, thus obtained were represented in the Table.

**Table 5:** Reaction of varieties/germplasms against *S. rolfsii* under natural and artificial condition during crop season (2009-10 and 2010-11)

| S.N. | Categories | Scale | Varieties/Cultures | |
|---|---|---|---|---|
| | | | Natural condition | Artificial condition |
| 1. | Immune (I) | No infection (0.0%) | Nil | Nil |
| 2. | Resistant (R) | Infection up to (0.1-5%) | Nil | Nil |
| 3. | Moderately resistant (MR) | Disease intensity (5.1-10%) | Chanchal, AM-1, 2013, 8601 | Chanchal and A M-1 |
| 4. | Moderately susceptible (MS) | Disease intensity (10.1-25.0%) | Pusa Jwala, AM-2, A-36, Kalyanpur-7, 810-47, M-2-1 and NA-11, | 2013 and 8601 |
| 5. | Susceptible (S) | Disease intensity (25.1-40%) | Chaman, 2014, 2024, 2025, 2026, Selection A-4, 7701, 13-6-1, 13-8, 13-6, New Sel-2010, New Sel-2009, New Sel-2008, 2031, M-2-1-1, M-7-1-1, M-7-2-1, M-7-1, M-5-1, SPS Sel-5, Anti-74, Sel-60 and Sel-62 | AM-2, A-36 and Kalyanpur-7 |
| 6. | Highly susceptible(HS) | Disease intensity more than (40%) | 2027,2028, 2029, 2031, 810-45, 810-5, 910-70, 910-2, 910-1, 810-55, 9301, 2019-1, 2016, 2016-1,2016-2, 410-2, G-4,8304-A,890B-2, 810-211, 810-16, 810-15, 48-8, 810-46, 810-49, 810-45-1, 810-42, 810-18, 810-40, 810-44, 810-66-1, 810-65-1, Achar-1-3, Achar-1-4, Achar-1-1 and Raj-1, | Pusa Jwala, 810-47, M-2-1 and NA-11 |

The observations made and recorded in Table 05 clearly indicated that none of the varieties/germplasms was found immune (I) and resistant(R). Out of seventy varieties/germplasms screened four varieties/germplasms were found to be moderately resistant (MR), seven moderately susceptible (MS), 23 varieties/germplasm susceptible (S) and remaining varieties/germplasm were found to be highly susceptible(S) under natural conditions.

In pots experiment (artificial condition), eleven varieties, showing free, resistant and moderately resistant reaction were subjected to further testing under artificial condition of inoculation in the glass house. For this purpose, each variety was raised in duplicate in 3 cm earthen pots containing sterilized soil.

Out of eleven varieties /germplasms screened in pot condition (Table05) and found that none of the verieties/germplasm was immune (I) and resistant (R), while 2 varieties /germplasm (Chanchal and A M-1)were found to be moderately resistant (MR), two moderately susceptible (MS) and three were susceptible (S) and remaining four varieties /germplasm were found to be highly susceptible (HS).

Screening of some varieties/germplasm was carried out under natural/pot conditions in crop season two consecutive years *i.e.* 2009-10 and 2010-11 during Kharif season. The observation on disease intensity revealed that none of the varieties / germplsms were found to be immune and resistant to disease in both condition. Under natural condition out of 70, veriety / germplsms screened, four (Chanchal, AM-1, 2013 and 8601) veriety / germplasms were appeared to be moderately resistant (MR) seven veriety / germplsms were found moderately susceptible (MS) and 23 were varieties susceptible. However, 36 veriety/cultures were highly susceptible to the disease in both the year.

In pot condition out of 11 selected field trial tested in pots, none of the variety /germplasm was immune and resistant against the test pathogen. The two (Chanchal and AM-1) variety /germplasm were moderately resistant and two (2013 and 8601) were moderately susceptible and rest were susceptible and highly susceptible against the disease. The findings of the present study are more or less similar to the observations made by Castellano G. (1999) [4] and Dukes *et al.*, (1983) [6] on stem rot of chilli. These varieties / germplsms are much important and may be used in breeding programme for stem rot of chilli in combination with their yield potential.

**B. Effect of time of planting on disease severity under field condition**

In order to find out the suitable time of planting of chilli for minimizing losses from the disease, the chilli seedlings were planted at different times during crop season (from 1 June to 16 August) of 2009-10 and 2010-11.

**Table 6:** Effect of time of planting on disease severity in field condition

| S.N. | Time of planting | Average Disease incidence (%) | | | | | | | | Avg. disease incidence (%) (2009-10 &2010-11) | Avg. Yield plot (gm. (2009-10 &2010-11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2009-10 | | | | 2010-11 | | | | | |
| | | No. of healthy plants | No. of affected plants | Disease incidence (%) | Avg. Yield. per plot (gm) | No. of healthy plant | No. of affected plants | Disease incidence (%) | Avg. Yield per plot (gm) | (%) | (gm) |
| 1. | I week of June | 17 | 23 | 57.5 | 425 | 19 | 21 | 52.5 | 525 | 55.00 (47.86) | 475 |
| 2. | II week of June | 20 | 20 | 50.0 | 500 | 22 | 18 | 45.0 | 550 | 47.50 (43.54) | 525.00 |
| 3. | I week of July | 23 | 17 | 42.5 | 575 | 24 | 16 | 40.0 | 600 | 41.25 (39.93) | 587.50 |
| 4. | II week of July | 25 | 15 | 37.5 | 625 | 26 | 14 | 35.0 | 650 | 36.25 (36.98) | 637.50 |
| 5. | I week of August | 30 | 10 | 25.0 | 750 | 30 | 10 | 25.0 | 750 | 25.00 (29.94) | 750.00 |
| 6. | II week of August | 32 | 8 | 20.0 | 800 | 32 | 8 | 20.0 | 800 | 20.00 (26.39) | 800.00 |
| CD. SEm | | | | | | | | | | 4.110, 1.351 | 20.9646.892 |

It is clear from the Table 6 and its corresponding Fig. that the minimum disease incidence (20.00 percent) during 2009-10 and (20.00 percent) during 2010-11 were observed when chilli seedlings were planted on 2nd week of August followed by crop planted on 1st week of June. Maximum diseases incidence (57.5 percent during 2009-10 and 52.5 percent during 2010-11) was recorded on early planted chilli seedlings. The rate of disease spread in a plant population and the disease incidence were much influenced by planting period of the crop.

To know the impact of time of planting on disease incidence and yield, chilli seedlings were planted on different time during crop season (1st week of June to IInd week of August) of 20009-10 and 2010-11. It was observed that when chilli seedlings were planted in the second week of August, the disease incidence was minimum during both the year. The maximum yield was obtained from the seedlings planted in August during both the years. This clearly indicated that with advancement in planting time disease as well as yield potential decreased. The results of the present study are more or less similar to the findings as reported by Awurum, A.N. (2000) [1] who has reported that planting date had significantly higher disease incidence in the crop sown on 1 June and 12 July than those on 2 and 23 August.

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