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Survey and collection of isolates of *Colletotrichum capsici* from different chilli growing areas of erstwhile Khammam district

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Abstract
Chilli is susceptible to many foliar and soil borne fungal diseases of which fruit rot caused by *Colletotrichum capsici* is one of the most destructive disease which causes heavy yield loss in almost all chilli growing areas. A roving survey was conducted during the months of October- December 2021 in the chilli growing areas of *erstwhile* Khammam district *i.e*. Khammam, Sathupally and Bhadrachalam of Telangana and the disease incidence was assessed in different cultivars which are highly pungent, medium pungent and low pungent grown in these areas. The study revealed variations in per cent disease incidence of fruit rot in major chilli growing areas of *erstwhile* Khammam district. Highest disease incidence was recorded in Pinapaka village of Khammam area (89.0) followed by Mondikonta village of Sathupalli area (88.0). Of the 3 locations, minimum per cent disease incidence was observed in Erraguntapadu of Sathupalli (10.0). The results also shown that among the 19 isolates collected from the three chilli cultivars grown in the three mentioned chilli growing areas shown variations in the per cent disease incidence in the decreasing order of isolate C.c-3 (89) followed by C.c- 12 (88.0), C.c-13 (85.0), C.c-8 (83.0), C.c-18 (76.0), C.c-11 (74.0), C.c-16 (74.0), C.c-5 (72.0), C.c-4 (70.0), C.c-19 (68.0), C.c-10 (49.0), C.c-7 (43.0), C.c-1 (42.0), C.c-9 (26.0), C.c-14 (25.0), C.c-6 (24.0), C.c-17 (15.0), C.c-2 (12.0) and C.c-15 (10.0), respectively.

Keywords: Chilli, fruit rot, disease, survey and per cent disease incidence

Introduction
Chilli is considered as one of the most important commercial spice crops widely used and considered as wonder spice. Chilli (*Capsium annuum*) belonging to the family Solanaceae is most commonly cultivated and an indispensable source of vegetable and spice across the tropical and subtropical regions of the world. In 2019-20, Telangana ranked second in chilli area, production and productivity of 0.85 lakh hectares, 3.28 lakh tonnes and 3859 Kg ha^{-1} respectively. Out of all the chilli growing states in India, Telangana accounts for 11.59 per cent and 17 per cent in terms of area and production respectively (*https://www.pjtsau.edu.in*). The major chilli growing districts in Telangana are Khammam, Mahabubabad, Gadwal, Suryapet and Warangal (Rural). There is good demand for chilli hybrids like US-341 and Tejaswini in international market.

Chilli fruit rot caused by *Colletotrichum capsici* infects both unripe (green) and ripe (seed) chilli fruits and survives on seed as acervuli and micro sclerotia (Raj and Christopher, 2009) [14]. Infection of *Colletotrichum capsici* will be higher in mature stage than in the early stage of chilli plant (Raj and Christopher, 2009) [14]. Chilli fruit rot is a polycyclic pathogen, where the initial disease is induced by spores of *Colletotrichum capsici* which survive in and on seed in the form of acervuli and microsclerotia (Montri *et al*., 2009) [11]. Chilli fruit rot disease is seed and air borne and has a great effect on seed germination and its vigour (Saxena *et al*., 2016) [20]. Survival of mycelia in stomatal regions of chilli fruits had been observed (Manandhar *et al*., 1995) [9]. The symptoms of the disease appears on leaves, flowers and fruits. The disease incited as dark spot, water-soaked lesions that rapidly expand. In some cases, the lesions are brown, and then turn black due to the formation of setae and acervuli (Roberts, 2001) [17]. The disease is most common in almost all chilli growing areas and it is estimated to cause 25-48% loss in different parts of India (Datar, 1995; Ekbote, 2001) [3, 4] whereas some reported 8.0 to 60.0 per cent estimated loss in different parts of India (Raj and Christopher, 2009) [14] and also 10.0 per cent to 80.0 per cent reduction in fruit yield (Than *et al*., 2008) [21].

In India, pre and post-harvest losses of chilli are more than 50.0 per cent (Sahitya *et al*., 2014) [18] and is known to reduce the marketable yield from 2.50 to 11.60 depending on the variety (Rahman *et al*., 2011) [13]. Fruit rot alone reduces the fruit yield by more than 50.0 per cent (Lakshmesha *et al*., 2005; Ramachandran *et al*., 2007) [8, 16] and substantial reduction in quality characters among different parts of India (Bosland and Votava, 2003; Pakdeevaraporn *et al*., 2005) [2, 12]. Chilli is an important commercial crop for Telangana state. Though the productivity is affected by this disease and the area is increasing. There is no systematic study taken up in Telangana on fruit rot disease and their control measures. Hence a survey would ultimately be helpful in indicating the areas with high disease incidence which can be managed timely to avoid any disease epidemic.

Material and Methods

A comprehensive roving survey was conducted during October to December 2021. Collection of the isolates were taken up in the chilli growing areas of *erstwhile* Khammam district *viz*., Khammam, Sathupally and Bhadrachalam of Telangana from the different cultivars *i.e*. highly pungent, medium pungent and low pungent cultivars grown in the areas mentioned respectively. The collection was done during the months of October to December 2021. A total of 19 isolates were collected randomly from the three chilli cultivars grown in the three mentioned chilli growing areas. Randomly, 5 plants were selected in an area of 1.00 acre on three chilli cultivars grown from above three chilli growing areas. The Per cent Disease Incidence (PDI) of fruit rot was calculated using the formula.

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of plants infected by a particular disease}}{\text{Total number of plants observed}} \times 100$$

The data on per cent disease incidence was collected and scoring was given based on common variables and characters. Principal Component Analysis of recorded survey data was done using SPSS software (Joliffe and Cadima, 2016). Survey data of *erstwhile* Khammam district was clustered into accurate selection of the most varied individuals based on Hierarchial analysis by using unweighted pair group method arithmetic mean (UPGMA) analysis of NTSYS –PC Software (Sattar *et al*., 2016) [19].

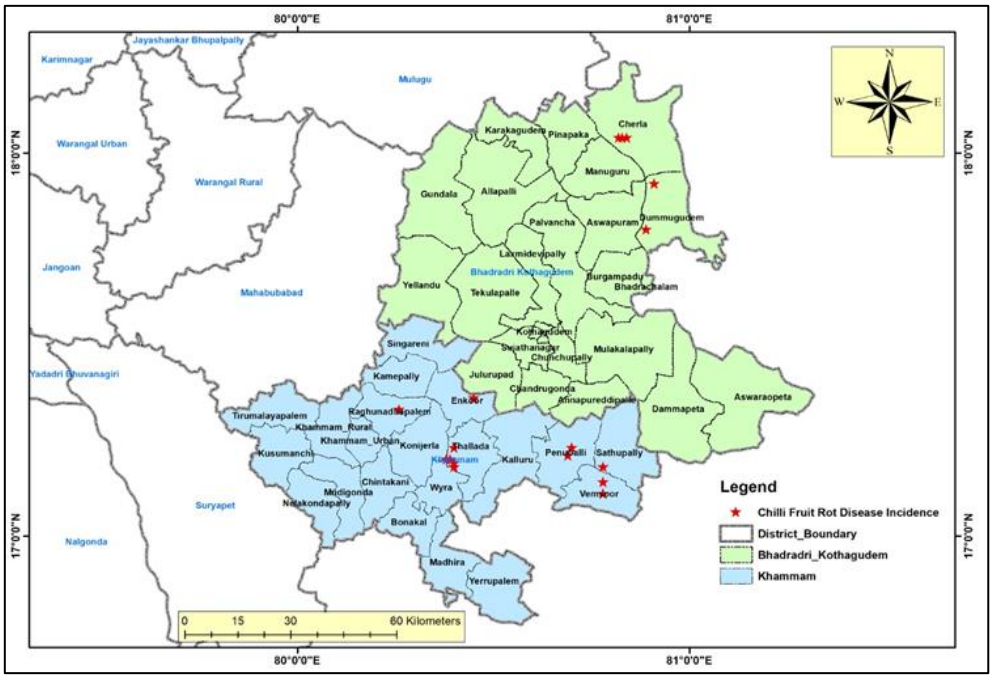

Fig 1: Arc GIS Map showing Chilli fruit rot disease incidence observed from major chill growing areas of *erstwhile* Khammam district during roving survey conducted in the year 2021 - 2022.

Fig 2a: Infected fruits showing dark spots, water-soaked lesions that expand into brown and black lesions due to formation of acervuli and setae.

Fig 2b: Chilli plants infected with fruit rot disease showing die back symptom with pericarp of fruit covered by a fruiting bodies which turns rusty in colour.

Fig 2: Symptoms of chilli fruit rot disease observed under field conditions during the roving survey conducted in the year 2021-2022.

Fig 3: Pure cultures of different isolates of *Colletotrichum capsici* collected during survey conducted in *erstwhile* Khammam district during 2021-2022

Results and Discussion

Survey on incidence of *Colletotrichum capsici* in chilli in Erstwhile Khammam District

A roving survey was conducted during October to December 2021 in major chilli growing areas of erstwhile Khammam district *viz*., Khammam, Sathupally and Bhadrachalam areas of Telangana from different cultivars which were highly pungent, medium pungent and low pungent respectively to know the occurrence of chilli fruit rot disease caused by *Colletotrichum capsici*. A total of nineteen locations were covered in sixteen villages of Khammam, Sathupally and Bhadrachalam areas during the survey. The information on latitude, longitude, variety/ hybrid, soil type, previous crop, source of irrigation and Per cent Disease Incidence in these areas were collected. Based on number of fruits infected and total number of fruits per plant, per cent disease incidence was calculated and the details are given in Table.1.

Khammam: Seven villages of five mandals of Khammam area *viz*., Mallavarm, Kodavatimetta, Pinapaka villages of Thallada mandal, Immamnagar village of Enkoor mandal, Earlapudi village of Khammam mandal were surveyed in the month of November-2021 and Medepelli village of Mudigonda mandal, Chandrupatla village of Kallur mandal were surveyed in the month of December-2021. Chilli crop is cultivated in red soils in most of these villages. Major sources of irrigation are canal irrigation and bore wells. Hybrids Yashaswini and Tejaswini are the major hybrids grown in

Mallavaram, Mudigonda, Earlapudi and Kallur villages. Kaveri, AGRO-VST-9 and Little heart are the hybrids grown in Kodavatimetta, Pinapaka and Imamnagar villages. The maximum per cent disease incidence was observed in Pinapaka village (89.0) followed by Medepelli village (76.0), Khammam (72.0), Enkoor (70.0), Kallur (68.0), Mallavaram (42.0), Kodavatimetta (12.0).

Bhadrachalam: Five villages of two mandals of Bhadrachalam area *viz*., Kothapalli, Gumpenagudem, Dondipeta villages of Charla mandal and Bandirevu, Seetharamapuram villages of Dummugudem mandal were surveyed in the month of December-2021. The crop was grown majorly in red and black soils. Major sources of irrigation are tube wells and bore wells. US-341 is the major chilli hybrid grown in Gumpenagudem and Dondipeta village. Bioindica, Armour, Syngenta–4884 are the hybrids grown in Kothapalli, Bandirevu and Seetharamapuram villages respectively. The maximum per cent disease Incidence was observed in Bandirevu village (83.0) followed by Seetharamapuram village (49.0), Gumpenagudem (43.0), Dondipeta (26.0) and Kothapalli villages (24.0).

Sathupally: Four villages of two mandals of Sathupalli area *viz*., Mondikonta and Chowdavaram villages of Penuballi mandal and Erraguntapadu and Marlapadu villages of Vemsoor mandal were surveyed in the month of December. In Mondikonta village, 3 fields were surveyed and Erraguntapadu village, 2 fields were surveyed. Chilli crop was grown majorily in red soils. Major sources of irrigation are tube wells and bore wells. Local variety is the major chilli variety grown in two fields of Mondikonta village, two fields of Erraguntapadu village and Marlapadu village. Byadgi and Tejaswini are the hybrids grown in Mondikonta and Chowdavaram respectively. The maximum per cent disease incidence observed was 88.0 in one of the three locations of the Mondikonta village followed by 85.0 and 74.0 in another two locations. In case of the two locations of Erraguntapadu village, the per cent disease incidence observed was 74.0 and 10.0 whereas in Chowdavaram and Marlapdu, it was 25.0 and 15.0. Similar findings reported by Rao *et al*. (2020) [15] that the per cent incidence of fruit disease in chilli ranged from 36.0 to 53.6 in different locations during the survey conducted in Khammam District. Badgujar *et al*. (2019) [1] reported that the roving survey conducted in the eight districts of the Marthwada region on the fruit rot of chilli cultivars during 2017-2018 and 2018-2019 found the per cent disease incidence of 31.29 during 2017-2018 and 36.11 during 2018-2019. Whereas Mishra *et al*. (2018) [7] reported that the survey conducted during the year 2015-16 in different locations of Uttar Pradesh found the maximum per cent disease incidence of fruit rot as 54.91. Similarly, Koppad and Mesta (2017) [7] reported that the per cent disease incidence of fruit rot ranged from 19.21 to 59.14 during the roving survey conducted in Belagavi, Dharwad, Gadag and Haveri districts of Karanataka.

Comparison of Per cent Disease Incidence of 19 different isolates of *Colletotrichum capsici* pathogen collected from different chilli growing areas of *erstwhile* Khammam district

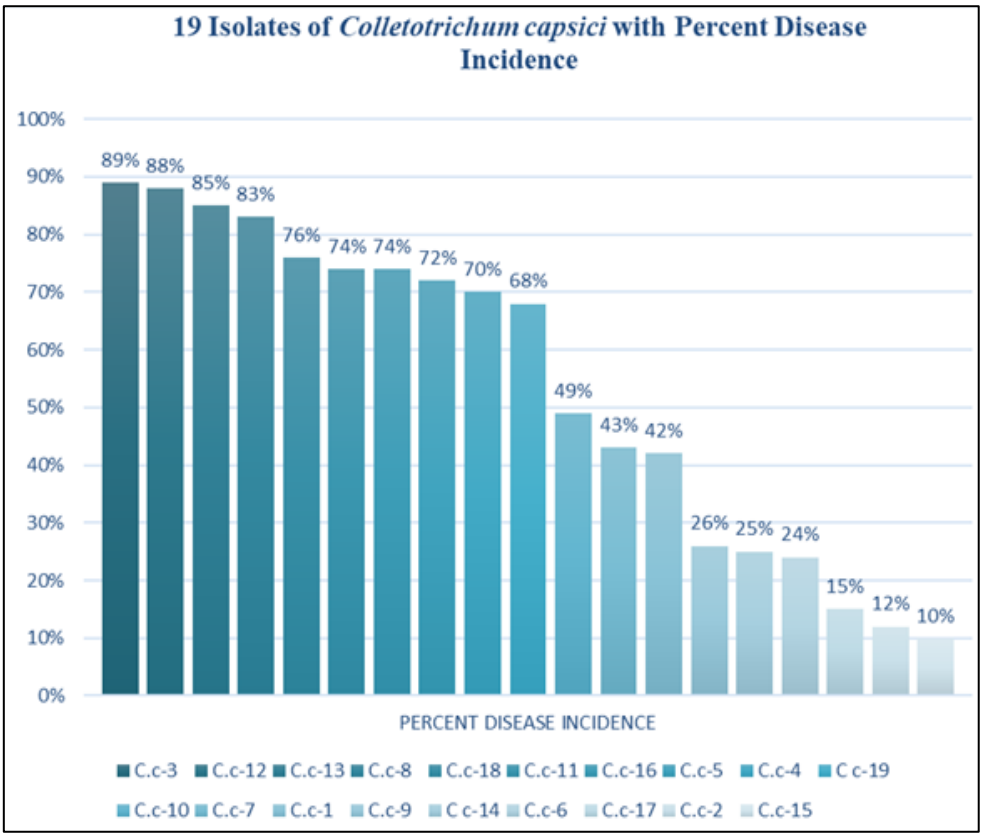

Fig 5: Graph representing the comparison of Per cent Disease Incidence of 19 different isolates of *Colletotrichum capsici* pathogen collected from different chilli growing areas of *erstwhile* Khammam district.

The findings from the results of the survey was represented in form of chart which shows the decreasing order of Per cent Disease Incidence of 19 different isolates collected during the survey.

Table 1: Details of survey on incidence of *Colletotrichum capsici* in chilli in *erstwhile* Khammam District

S.no	Date of survey	Area	Village	Mandal	Latitude	Longitude	Variety/ hybrid	Soil type	Previous crop	Source of irrigation	Per cent disease incidence
C.c-1	17-11-2021	Khammam	Mallavaram	Thallada	17.23°	80.4°	Yashaswini	Red soil	Maize	Bore wells	42.0
C.c-2	17-11-2021	Khammam	Kodavatimetta	Thallada	17.19°	80.4°	Kaveri	Black soil	Cotton	Canal irrigation	12.0
C.c-3	17-11-2021	Khammam	Pinapaka	Thallada	17.18°	80.4°	AGRO-VST-9	Red soil	Chilli	Canal irrigation	89.0
C.c-4	17-11-2021	Khammam	Immamnagar	Enkoor	17.36°	80.45°	Little heart	Red soil	Chilli	Canal irrigation	70.0
C.c-5	17-11-2021	Khammam	Earlapudi	Khammam	17.33°	80.26°	Tejaswini	Red soil	Maize	Bore wells	72.0
C.c-6	08-12-2021	Bhadrachalam	Kothapalli	Charla	18.04°	80.829°	Bioindica	Black soil	Cotton	Bore well	24.0
C.c-7	08-12-2021	Bhadrachalam	Gumpenagudem	Charla	18.04°	80.84°	US-341	Red soil	Chilli	Tube wells	43.0
C.c-8	08-12-2021	Bhadrachalam	Bandirevu	Dummugudem	17.92°	80.91°	Armour	Black soil	Chilli	Tube wells	83.0
C.c-9	08-12-2021	Bhadrachalam	Dondipeta	Charla	18.04°	80.82°	US-341	Red soil	Chilli	Tube wells	26.0
C.c-10	08-12-2021	Bhadrachalam	Seetharamapuram	Dummugudem	17.80°	80.89°	Syngenta-4884	Red soil	Cotton	Bore well	49.0
C.c-11	29-12-2021	Sathupally	Mondikonta	Penuballi	17.21°	80.69°	Local variety	Red soil	Chilli	Bore wells	74.0
C.c-12	29-12-2021	Sathupally	Mondikonta	Penuballi	17.23°	80.7°	Local variety	Black soil	Cotton	Tube wells	88.0
C.c-13	29-12-2021	Sathupally	Mondikonta	Penuballi	17.23°	80.7°	Byadgi	Red soil	Chilli	Bore well	85.0
C c-14	29-12-2021	Sathupally	Chowdavaram	Penuballi	17.11°	80.78°	Tejaswini	Red soil	Chilli	Bore wells	25.0
C.c-15	29-12-2021	Sathupally	Erraguntapadu	Vemsoor	17.18°	80.78°	Local variety	Red soil	Chilli	Bore wells	10.0
C.c-16	29-12-2021	Sathupally	Erraguntapadu	Vemsoor	17.11°	80.78°	Local variety	Red soil	Chilli	Bore wells	74.0
C.c-17	29-12-2021	Sathupally	Marlapadu	Vemsoor	17.14°	80.78°	Local variety	Red soil	Cotton	Bore wells	15.0
C.c-18	29-12-2021	Khammam	Medepelli	Mudigonda	17.20°	80.38°	Yashaswini	Black soil	Cotton	Canal irrigation	76.0
C c-19	29-12-2021	Khammam	Chandrupatla	Kallur	17.20°	80.39°	Tejaswini	Red soil	Chilli	Bore wells	68.0
C.D.											1.599
SE(m)											0.567
SE(d)											0.801
C.V.											2.349

Among the 19 isolates, the highest per cent disease incidence was recorded in C.c-3 (89.0) followed by C.c- 12 (88.0), C.c-13 (85.0), C.c-8 (83.0), C.c-18 (76.0), C.c-11 (74.0), C.c-16 (74.0), C.c-5 (72.0), C.c-4 (70.0), C.c-19 (68.0), C.c-10 (49.0), C.c-7 (43.0), C.c-1 (42.0), C.c-9 (26.0), C.c-14 (25.0), C.c-6 (24.0), C.c-17 (15.0), C.c-2 (12.0) and C.c-15 (10.0) in the decreasing order of per cent disease incidence, respectively.

Principal Component Analysis of *Colletotrichum capsici* population of different survey variables

The data collected during the survey was scored based on common variables and characters. Further, Principal Component Analysis of recorded survey data was done using SPSS software and the results are shown in the Table.2.

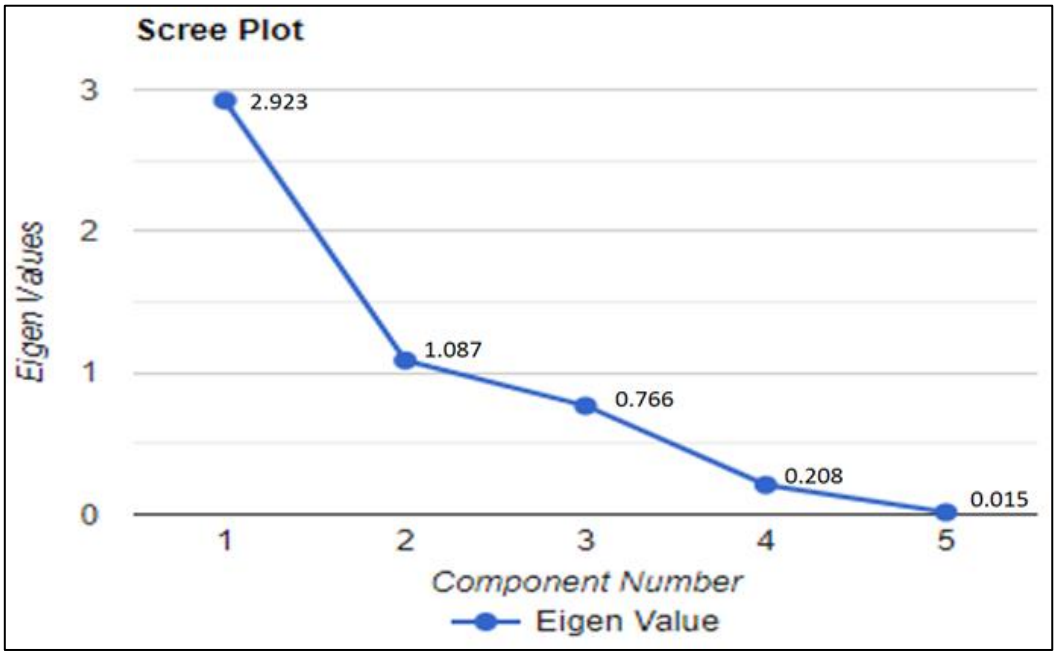

Fig 4: Scree plot for survey data of *erstwhile* Khammam district by using Principal Component Analysis.

Table 2: Principal Component Analysis of *Colletotrichum capsici* population of different survey variables

Component	Eigen value	Proportion	Cumulative (%)
Area	**2.923**	0.585	0.585
Village	1.087	0.217	0.802
Mandal	0.766	0.153	0.955
Variety	0.208	0.042	0.997
Per cent disease incidence	0.015	0.003	1.000

According to Principal Component Analysis, Eigen value ≥ 1 *i.e.*, Area and Village components was considered for existence of variability among 19 different isolates of *Colletotrichum capsici* pathogen. The results from the principal component analysis of recorded survey data was shown in the form of Eigen values, which shows that the highest Eigen value was recorded at area level indicates greater variability with regard to geographical location.

Dendrogram of 19 isolates of *Colletotrichum capsici* generated by unweighted pair group method arithmetic mean (UPGMA) analysis of survey data of erstwhile Khammam district

The data collected during the survey data in erstwhile Khammam district was clustered into accurate selection of the most varied individuals based on Hierarchial analysis by using unweighted pair group method arithmetic mean (UPGMA) analysis of NTSYS –PC Software and a dendrogram was prepared and the phylogenic classification revealed existence of diverse isolates within the same species. Scores were derived from survey profile showed 61.7% similarity within the isolates of *Colletotrichum capsici*. Based on UPGMA clustering, 19 isolates grouped into 10 clusters.

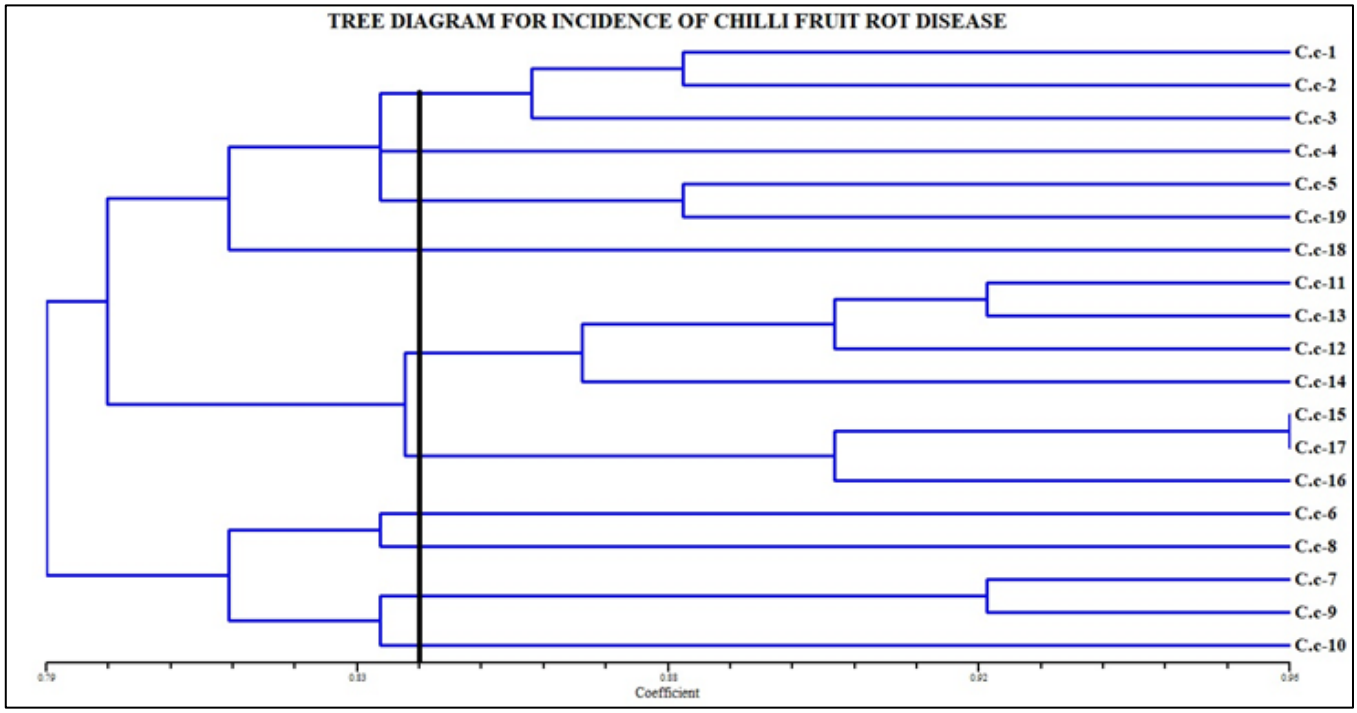

Fig 6: Dendrogram of 19 isolates of *Colletotrichum capsici* generated by unweighted pair group method arithmetic mean (UPGMA) analysis of survey data of *erstwhile* Khammam district.

Among the 10 clusters, cluster-1 having three isolates collected from Thallada mandal of Khammam area comprises of isolates C.c-1, C.c-2 and C.c-3 which in turn categorized into two subgroups. First sub group constitute isolates C.c-1 and C.c-2 collected from Mallavaram and Kodavatimetta villages having the percent disease incidence of 42.0 and 12.0, respectively. Second sub group comprised of isolate C.c-3 from Pinapaka village having 89.0 per cent disease incidence. Cluster-2 consisting of isolate C.c-4 collected from Imamnagar village of Enkoor mandal of Khammaam area having 70.0 per cent disease incidence. Cluster -3 consisting of isolates C.c-5 and C.c-19 collected from Earlapudi village of Khammam district and Chandrupatla village of Kallur mandal of Khammam district having 72.0 and 68.0 per cent disease incidence, respectively. Isolate C.c -18 was grouped in Cluster-4 collected from Medepelli village of Mudigonda mandal of Khammam area recorded 76.0 per cent disease incidence.

Six isolates of *Colletotrichum capsici viz*., isolate 11, isolate 13, isolate 12, isolate 14, isolate 15, isolate 17 and isolate 16 collected from Sathupally area were clustered into 5 and 6 which were in turn categorized into three sub groups with Cluster -5 and Cluster -6 as one of the sub group. In Cluster -5, first two sub groups of isolates of *Colletotrichum capsici* - isolate 11, isolate 13 & isolate 12 collected from Mondikonta village of Penuballi mandal recorded 74.0, 85.0, 88.0 per cent disease incidence, respectively in which isolate C.c-12 recorded highest per cent disease incidence than isolates C.c-13 and C.c -11. Cluster -6 having isolates of *Colletotrichum capsici* - isolate 15, isolate 17, isolate 16 collected from Erraguntapadu, Marlapadu, Erraguntapadu village of Vemsoor Mandal in which isolates C.c-15 & 17 are similar in nature having the least per cent disease incidence of 10.0 and 15.0, respectively and while in isolate C.c-6 recorded 74.0 per cent disease incidence.

Cluster- 7, 8, 9, 10 are having isolates of *Colletotrichum capsici* - isolate 6, isolate 8, isolate 7, isolate 9 and isolate 10 collected from Bhadrachalam area. In which, cluster -7 having isolate C.c-6 collected from Kothapalli village of Charla mandal recorded 24.0 per cent disease incidence whereas Cluster -8 having isolate C.c-8 collected from Bandirevu village of Dummugudem mandal recorded 83.0 per cent disease incidence. In case of cluster-9, which are having isolates C.c-7, C.c-9 collected from Gumpenagudam and Dondipeta village of Charla mandal recorded 43.0 and 26.0 per cent disease incidence whereas cluster-10 having isolate C.c-10 collected from Seetharamapuram village of Dummagudem mandal recorded 49.0 per cent disease incidence.

The reports of Sattar *et al*. (2016) [19] which represented the average disease incidence as a dendrogram, indicating the formation of two major clusters. Cluster –1 is made up of several sub-clusters and comprises of 21 places in Kot Radha Kishan with per cent disease incidence of more than 65.0 and a high of 99.0. Cluster-2 is made up of seven sub divisions: Gujjar Khan, Taxila, Haroonbad, Rawapindi, Kotlisatian, Kahuta, and Murre, with disease incidence ranging from 20 per cent to 50 per cent.

Conclusion

The findings from the survey conducted and collection of 19 isolates done during the months of October- December 2021 in the chilli growing areas of *erstwhile* Khammam district *viz*., Khammam, Sathupally and Bhadrachalam of Telangana from the different cultivars i.e. highly pungent, medium pungent and low pungent cultivars grown in this areas respectively to record the disease incidence of fruit rot in chilli revealed the variations in per cent disease incidence in major chilli growing areas of *erstwhile* Khammam district. The per cent disease incidence was recorded highest in Pinapaka village of Khammam district (89.0) followed by Mondikonta village of Sathupalli district (88.0). Of the 3 locations, minimum per cent disease Incidence was observed in Erraguntapadu of Sathupalli district (10.0). The results also shown that among the 19 isolates collected from the three chilli cultivars grown in the three mentioned chilli growing areas shown variations in the per cent disease incidence in the decreasing order of isolate C.c-3 (89.0) followed by isolates C.c- 12 (88.0), C.c-13 (85.0), C.c-8 (83.0), C.c-18 (76.0), C.c-11 (74.0), C.c-16 (74.0), C.c-5 (72.0), C.c-4 (70.0), C.c-19 (68.0), C.c-10 (49.0), C.c-7 (43.0), C.c-1 (42.0), C.c-9 (26.0), C.c-14 (25.0), C.c-6 (24.0), C.c-17 (15.0), C.c-2 (12.0) and C.c-15 (10.0), respectively. Tha data generated will help in identification and application of suitable control methods based of the per cent disease incidence recorded in different cultivars and different locations.

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