KUVEMPU UNIVERSITY

EFFECT OF PHYTOFUNGAL PATHOGENS ON SOME SOLANACEOUS VEGETABLE CROPS OF CHITRADURGA DISTRICT, KARNATAKA.

Thesis submitted to Kuvempu University

for the award of Degree of

DOCTOR OF PHILOSOPHY

in

BOTANY

By

Ms. SOWMYA G H M.Sc

Research Guide

Dr. N. RAJESHWARI M.Sc., M.Phil., Ph.D.
Professor
Department of Botany and Seed Technology.
Sahyadri Science College.
Kuvempu University.
Shimoga-577203

Submitted to

The Department of P.G Studies and Research in Applied Botany
Kuvempu University, Jnana Sahyadri, Shankaraghatta – 577 451
Shivamogga District, Karnataka, INDIA

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Ms. Sowmya G. H. **M.Sc.**
Research Scholar
Department of Botany and Seed Technology
Sahyadri Science College
Kuvempu University
Shivamogga District, Karnataka, India

Declaration

I, **Ms. Sowmya G. H.,** hereby declare that the thesis entitled **"EFFECT OF PHYTOFUNGAL PATHOGENS ON SOME SOLANACEOUS VEGETABLE CROPS OF CHITRADURGA DISTRICT, KARNATAKA."** embodies the results of bonafide research work carried out by me under the guidance of **Dr. N. Rajeshwai,** Professor, Department of Botany and Seed Technology, Sahyadri Science College, Kuvempu University, Shimoga, Karnataka.

Further, I declare that this record or part thereof has not been the basis for the award of any other degree or diploma in either this or any other institution or university.

Date: 31.04.2023

Place: **Shankaraghatta**

Sowmya. G.H
(SOWMYA G. H.)

Kuvempu University

☎ (R) : 08182 240200
Mobile : 9480329762
E-mail : rajeshwaribabu02@gmail.com

Dr. N. Rajeshwari M.Sc., M.Phil., Ph.D.
Professor

Department of Botany and Seed Technology
Sahyadri Science College,
Kuvempu University, Shimoga
Karnataka, India

Certificate

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(Dr. N. RAJESHWARI)

Date: 31.04.2023

Place: **Shankaraghatta**

Kuvempu University

Ph : 08282 256254
Fax : 08282 256255
Mobile : 9845646821
E-mail : murthy_ylk@yahoo.co.in.

Dr. Y.L. Krishnamurthy
Professor and Chairman

Department of P.G. Studies and Research in
APPLIED BOTANY
Jnana Sahyadri, Shankaraghatta 577 451
Shivamogga District, Karnataka, India

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(Dr. Y.L. KRISHNAMURTHY)

Date: 21.04.2023

Place: **Shankaraghatta**

Kuvempu University

Ph : 08282 256254
Fax : 08282 256255
Mobile : 9845646821
E-mail : murthy_ylk@yahoo.co.in.

Dr. Y.L. Krishnamurthy
Professor and Chairman

Department of P.G. Studies and Research in
APPLIED BOTANY
Jnana Sahyadri, Shankaraghatta 577 451
Shivamogga District, Karnataka, INDIA

COURSE WORK COMPLETION CERTIFICATE

This is to certify that **Ms. Sowmya G. H.,** is a bonafide Research Scholar of this department, has satisfactorily completed the course work requirements, which is a part of his Ph.D. programme.

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Document Information

Analyzed document	KU-TH-BOT-SOWMYA-GH-23.pdf (D163815311)
Submitted	4/13/2023 10:19:00 AM
Submitted by	Walmiki R H
Submitter email	walmiki_rh@rediffmail.com
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Sources included in the report

SA	**Kuvempu University, Jnanasahyadri / KU-TH-BOT-MANJULA-T-21.pdf** Document KU-TH-BOT-MANJULA-T-21.pdf (D117210427) Submitted by: walmiki_rh@rediffmail.com Receiver: walmiki_rh.kuvempu@analysis.urkund.com	1
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Chapter-1 Introduction

The family Solanaceae or Nightshades is an economically important family of flowering plants. The family ranges from annual and perennial herbs to vines or shrubs and trees, including a number of important vegetable crops like Capsicum (Peppers), Lycopersicon (Tomato) and Solanum (Eggplant and Potato). Members of the family are characterized by solitary or clustered flowers with five fused sepals and petals, five stamens; and a superior ovary composed of two fused carpels and obliquely placed in the flower upon a basal disk of tissue. The style is simple and bears a two-lobed stigma, the pollen-receptive surface. The flowers are usually conspicuous and are visited by insects (Morris and Taylor -2017). The term vegetables refer to an edible part of a plant which can be consumed raw or cooked. Vegetables are very important ingredients in human diet. Eating vegetables is beneficial to one"s health – they are the main sources of nutrients (Table- 1.1). Solanaceous vegetable crops are important source of vitamin C, A, E, thiamine, niacin, pyridoxine, folacin, minerals and dietary fibres which play a significant role in human nutrition and help to cope with malnutrition (Shilpa and Arvind -2017). Vegetables are widely distributed in nature, one of the limiting factors that influence the vegetables economic value is the relatively short shelf-life period by pathogens attacked. The nutritive values of healthy vegetables are altered because of fungal attack and sometimes fungi produce certain mycotoxins in them and make them unsuitable for human consumption. At first, plants which grew locally would have been cultivated but as time went on, trade brought exotic crops from elsewhere to add to domestic types. Nowadays, most vegetables are grown all over the world as climate permits and crops may be cultivated in protected environments in less suitable location.

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Acknowledgements

This work is by far the most significant accomplishment in my life and it would not have been impossible without blessings of God and people who supported me and believe in my caliber. I take this opportunity to express sincere gratitude to all of them.

Words are inadequate to express my profound gratitude and sincere thanks to my honorable guide **Dr. N. Rajeshwari,** Professor, Department of Botany and Seed Technology, Sahyadri Science College, Kuvempu University, Shimoga. I honestly thank for her exemplary guidance, encouragement and financial assistance. Her trust and support inspired me in the most important moments of making right decisions in every juncture of my life and I am glad that I worked under her guidance. Thank you madam for all that you have taught me.

I am greatly indebted to **Dr. H.N. Ramesh Babu,** Professor, Department of Botany and Seed Technology, Sahyadri Science College, Kuvempu University, Shimoga, for his valuable suggestions, support and guidance.

With deep sense of gratitude, I would like to thank **Dr. Y.L. Krishnamurthy,** Professor and Chairman, **Dr. M. Krishnappa,** Professor (Rtd), **Dr. M.B. Shivanna,** Professor (Rtd), **Raja Naika,** Professor, **Dr. Somashekar G. Malammanavar,** Assistant Professor, **Dr. H.C. Shrishail,** Assistant Professor and Doctoral Committee for giving valuable suggestions and encouragements to refine this work.

I extend my gratitude to **Dr. Nataraja,** Associate Professor (Rtd), **Dr. Nafeesa Begum,** Associate Professor, **Dr. T. Parameshwar Naik,** Professor, **T. D. Gopal,** Assistant Professor, and all the Lecturers, Department of Botany and Seed Technology, Sahyadri Science College, Shimoga for their kind support during the work.

My humble and sincere thanks to my beloved parents **Hanumanthappa M.,** and **Shobha A. T.,** Brother **Ravikiran. G. H.,** Grand Mother Late **Lakkamma,** Woodbee **Mr. Chidananda. S.,** Uncle **Narappa. K.O.,** Aunty **Renuka. A. T.,** Sister **Pooja K. N.** and Brother **Darshan K. N.** for their unconditional love, prayers, blessings, moral support and financial assistance without which this work would not have been possible.

A special thanks to my friend **Dr. Kantharaja. R.,** for his support and help during the work. Without his support, it was difficult to complete the thesis work.

I am very much thankful to my dearest friends **Mrs. Shaila. M., Ms. Deepa. K. U., Mr. Vijay Kumar. S. P., Mr. Sandeep. T.,** for their valuable support, advice and financial support during the work.

I am thankful to my research Friends **Dr. Yogashree. G. D., Mr. Manjunath. K., Mr. Ashoka G. B., Ms. Savithra., Mrs. Vidhya Bhat., Ms. Pushpavathi., Mrs. Shashwathi., Ms. Rakshitha., Mr. Sharath., Ms. Thejashree. A. B., Mrs. Pallavi. M., Mrs. Pallavi. R., Mr. Sunil Kumar. T. V., Mrs. Archana Mesta** and all the research scholars for their cooperation and sincere help.

I also thanks to all the guest faculty of Department of Botany, Kuvempu University, and also **Mr. Jagadeesh Chandra, Mr. Sampath and Mr. Gaviraya** and all the Non-teaching Staff Members of the Department for their support.

My special thanks to the OBC Cell which has given financial assistance for the completion of this bonafide work.

I take this opportunity to recall all the persons who helped directly and indirectly to carry out this bonafide work.

Sowmya G.H.

Dedicated to my

Beloved Parents

ABBREVIATIONS

%	-	Percentage
℃	-	Degree Celsius
:	-	Ratio
±	-	Plus of Minus
µl	-	Microliter(s)
µm	-	Micro meter
BLASTn	-	Basic Local Alignment Search Tool
cm	-	Centimeter(s)
CTAB	-	Cetyltrimethylammonium bromide
DNA	-	Deoxyribonucleic acid
eg	-	Example
et al	-	And others (co-authors)
Fig.	-	Figure
i.e.,	-	That is
ITS	-	Internal transcribed spacer
Km	-	Kilometer(s)
MAFFT	-	Multiple Alignment using Fast Fourier Transform
MEGA X	-	Molecular Evolutionary Genetics Analysis
ml	-	Mililiter(s)
mm	-	Millimeter(s)
No.	-	Number
NCBI	-	National Center for Biotechnology Information
NaOCl	-	Sodium hypochlorite

PCR	-	Polymerase Chain Reaction
PDA	-	Potato Dextrose Agar
ppm	-	Parts per million
psi	-	Pounds per square inch
rpm	-	Revolution per minute
RAxML	-	Randomized Axelerated Maximum Likelihood
sp.	-	Species
viz.,	-	Namely

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The family Solanaceae or Nightshades is an economically important family of flowering plants. The family ranges from annual and perennial herbs to vines or shrubs and trees, including a number of important vegetable crops like Capsicum (Peppers), Lycopersicon (Tomato) and Solanum (Eggplant and Potato).

Members of the family are characterized by solitary or clustered flowers with five fused sepals and petals, five stamens; and a superior ovary composed of two fused carpels and obliquely placed in the flower upon a basal disk of tissue. The style is simple and bears a two-lobed stigma, the pollen-receptive surface. The flowers are usually conspicuous and are visited by insects (Morris and Taylor -2017).

The term vegetables refer to an edible part of a plant which can be consumed raw or cooked. Vegetables are very important ingredients in human diet. Eating vegetables is beneficial to one's health – they are the main sources of nutrients (Table- 1.1). Solanaceous vegetable crops are important source of vitamin C, A, E, thiamine, niacin, pyridoxine, folacin, minerals and dietary fibres which play a significant role in human nutrition and help to cope with malnutrition (Shilpa and Arvind -2017).

Vegetables are widely distributed in nature, one of the limiting factors that influence the vegetables economic value is the relatively short shelf-life period by pathogens attacked. The nutritive values of healthy vegetables are altered because of fungal attack and sometimes fungi produce certain mycotoxins in them and make them unsuitable for human consumption.

At first, plants which grew locally would have been cultivated but as time went on, trade brought exotic crops from elsewhere to add to domestic types.

Nowadays, most vegetables are grown all over the world as climate permits and crops may be cultivated in protected environments in less suitable location.

Botanical description:

1. Chilli

Chilli is also known as Hot pepper and one of the most important cash crops of India. It is also one of the oldest cultivated crops of the world and part of human diet since from 7500 BC.

Capsicum is native to southern North America. India ranks first among the chilli growing countries in the world. Total area cultivated in India varies between 0.816-0.982 million ha with annual production of around 1.1 million tonnes of dry chilli. China, Pakistan, Thailand, Peru, Mexico, Morocco and Turkey are the other chilli producing countries. In India chilli is cultivated almost throughout the country and major growing states are Andhra Pradesh, Karnataka, Maharashtra, Odisha, Tamil Nadu, Madhya Pradesh, West Bengal and Rajasthan (Dhaliwal M S -2017).

The species encompasses a wide variety of shapes and sizes. Chilli Plant is an annual sub-herb and the fruits vary in shape, size, colour and degree of pungency. Capsicum plants are herbaceous or semi-woody annuals or perennials. The leaves are ovate, tapering to a sharp point, measuring up to 15cm, dark green on the upper surface and pale green on the lower surface. The flowers are small, white and borne singly or in clusters of 2 or 3 in the axils of the leaves. The fruits are of diverse shapes and sizes depending upon the variety.

Pepper (*Capsicum annum*) comprises both nonpungent and pungent (chili) peppers. Four additional species (*Capsicum frutescens, Capsicum chinense, Capsicum pubescens* and *Capsicum baccatum*) are also cultivated for chili pepper production. Peppers are generally consumed fresh or processed for use as vegetables and spice (Morris and Taylor -2017).

Chilli is an important source of vitamins A, C and E and folic acid. Consumption of chilli clears the lungs, improves gastric emptying and blood circulation and also relieves the pain from the rheumatoid arthritis patients.

Pungency in chilli is due to the alkaloid "capsaicin" contained in the pericarp and placenta of fruits, it produces mild to intense spice when eaten. Medicinal uses of chilli include treatment of asthma, coughs and sore throats. Pungency compound is a strong antioxidant and used by the pharmaceutical industry.

This crop is affected by number of diseases caused by virus, Bacteria, Fungi and nematode. Among all the diseases fungal diseases loss accounts for 30-50%. It is due to effect of environmental factors like rainfall, temperature and relative humidity.

2. Tomato

The Tomato is the edible berry of the plant *Solanum lycopersicum* L. The species originated in western South America and Central America. The tomato was introduced to other parts of the European-colonized world during the 16th century.

Tomato is cultivated throughout the world and China, USA, India, Turkey and Egypt are the top five tomato producing countries. In India, Bihar, Karnataka, Uttar

Pradesh, Odisha, Andhra Pradesh, Maharashtra, Madhya Pradesh, Punjab, Haryana and Assam are the major growing states.

Tomato is the most popular horticultural crop. It is an autogamous (self-pollinating) diploid species, which is a model for plant genetics and fleshy fruit ripening, plant–pathogen interactions and advancing concepts of marker-assisted breeding. It is a perennial herbaceous plant and cultivated in tropical and temperate climates in open field or under greenhouse in temperate climate. The primary root may grow several metres in length. The stem is angular and covered by hairy and glandular trichomes that confer a characteristic smell. Leaves are alternately arranged on the stem with a 137.5° phyllotaxy. Leaves range in shape from lobed to compound, with segments arranged pinnately. Compound leaves are typically comprised of five to nine leaflets. Leaflets are petiolated and dentate. All leaves are covered by glandular, hairy trichomes. Their flowers are appearing on the apical meristem, anthers fused along the edge and fruit-berry and globular or ovoid in shape (Morris and Taylor -2017).

Tomato is rich in vitamin A and C hence it referred as Poor man's orange. Lycopene imparts the red colour to ripe tomatoes is reported to possess anticancer properties. It also rich in ascorbic acid and β-carotene. It also serves as an anti-oxidant as β-carotene function. It also acts as powerful natural anti-oxidant used in pharmaceuticals.

3. Brinjal

Brinjal or eggplant (*Solanum melongena* L.) is an important solanaceous crop of sub-tropics and tropics. In India, it is one of the most common, popular and

principal vegetable crops grown throughout the country except higher altitudes. A number of cultivars are grown in India, consumer preference being dependent upon fruit color, size and shape.

It is a major vegetable with world production is around 31 million tones. China, India, Egypt, Turkey, Japan and Italy are the leading producers. Odisha, West Bengal, Bihar, Karnataka, Maharashtra, Gujarat, Madhya Pradesh and Andhra Pradesh are the important states growing eggplant in India.

Brinjal or eggplant is an herbaceous annual with erect or semi spreading habits. It is a perennial plant but cultivated as annual. It develops into bushy plants with large, fuzzy leaves that grow to a height of about 60 to 120 centimeters. The plant is erect, compact and well branched. It has a rather fibrous or lignified root system. The leaves are large, simple, lobed and alternate on the stems. The stems, leaves and calyx of some cultivars are spined. The flowers are large, violet-colored and either solitary or in clusters of two or more. The fruit is pendent and is fleshy berry borne signally or in clusters. The shape of fruit varies from ovoid, oblong, ovoid or long cylindrical.

Eggplant has high nutrition, possesses excellent medicinal properties and good source of minerals like calcium, phosphorus, iron, vitamins especially B-complex. It contains high concentrations of antioxidant phenolic compounds and low fat and proteins. It helps to drop the cholesterol level in blood due to presence unsaturated fatty acids like linoleic and linolenic acids and minerals like magnesium and potassium. White eggplant is good for diabetic patients.

Table 1.1: Nutritional value of Solanaceous vegetable crops (per 100 g)

Content	**Brinjal**	**Tomato**	**Chilli**
Energy	24 Kcal	18 Kcal	31 Kcal
Carbohydrates	5.7 g	3.9 g	6.03 g
Protein	1 g	0.9 g	0.99 g
Total fat	0.19 g	0.2 g	0.30 g
Cholesterol	0 mg	0 mg	0 mg
Dietary Fiber	3.40 g	1.2 g	2.1 g
Folates	22 µg	15 µg	46 µg
Niacin	0.649 mg	0.594 mg	0.979 mg
Pyridoxine	0.084 mg	0.080 mg	0.291 mg
Riboflavin	0.037 mg	0.034 mg	0.085 mg
Thiamin	0.039 mg	0.037 mg	0.054 mg
Vitamin A	27 IU	833 IU	3131 IU
Vitamin C	2.2 mg	13 mg	127.7 mg
Vitamin E	0.30 mg	0.54 mg	1.58 mg
Vitamin K	3.5 µg	7.9 µg	4.9 µg
Sodium	2 mg	5 mg	4 mg
Potassium	230 mg	237 mg	211 mg
Calcium	9 mg	10 mg	7 mg
Iron	0.24 mg	0.3 mg	0.43 mg
Manganese	0.250 mg	0.15 mg	12 mg
Zinc	0.16 mg	0.17 mg	0.25 mg
Carotene-β	-	449 µg	1624 µg
Carotene-a	-	101 µg	20 µg
Lutein-zeaxanthin	-	123 µg	490 µg
Lycopene	-	2573 µg	51 µg

(Source: Shilpa Devi and Arvind Nagar, Nutritional and Medicinal Properties of Solanaceous Vegetables, IARI -2017)

Production of fresh vegetables:

The statistics shows the world's leading 10 producers of fresh vegetables in 2020. In that year, China was the leading producer with a production volume of nearly 594 million metric tons, followed by India with approximately 141.2 million metric tons of fresh vegetables (Table- 1.2). According to Shahbandeh-2020 statistical data, Tomatoes were the leading vegetables based on global production volume in that year.

Table 1.2: Leading producers of fresh vegetables worldwide during 2020

Sl No.	Countries	Production (In million metric tons)
1	China	594.05
2	India	141.2
3	United states of America	33.12
4	Turkey	25.96
5	Viet Nam	17
6	Egypt	16.14
7	Nigeria	15.71
8	Mexico	15.1
9	Russian Federation	13.95
10	Spain	12.67

(Source: Shahbandeh M-2020)

Global vegetable production

Between 2000 and 2020, the global production volume of vegetables increased significantly, from 682 million metric tons in 2000 to more than 1.15 billion metric tons in 2020.

India's diverse climate ensures availability of all varieties of fresh fruits and vegetables. It ranks second in fruits and vegetables production in the world after China. As per National Horticulture Database published by National Horticulture Board, India produced large Metric Tonnes of vegetables.

Area and production in India:

Among various states in India, West Bengal, Uttar Pradesh, Bihar, Madhya Pradesh, Odisha, Maharashtra, Gujarat and Karnataka are the major vegetable growing state (Table -1.3).

Table 1.3: Area and production of vegetables in India during 2019-20

Sl No	STATES	Area	Production
1.	Andhra pradesh	254.79	6758.85
2.	Arunachal pradesh	2.62	17.43
3.	Assam	318.97	4011.48
4.	Bihar	906.00	16939.38
5.	Chhatisgarh	521.55	7384.15
6.	Gujarat	640.33	12608.48
7.	Haryana	447.53	8461.74
8.	Himachal pradesh	88.51	1773.62
9.	Jammu & Kashmir	60.12	1337.12
10.	Jharkhand	295.88	3561.14
11.	Karnataka	418.68	7195.0
12.	Kerala	58.88	1694.25
13.	Madhya Pradesh	943.98	18761.70
14.	Maharashtra	691.52	12173.55
15.	Manipur	45.67	356.07
16.	Meghalaya	49.09	515.88
17.	Mizoram	34.65	200.47

18.	Nagaland	41.10	455.17
19.	Odisha	632.59	8670.60
20.	Punjab	273.36	5491.34
21.	Rajasthan	194.28	2131.42
22.	Sikkim	38.80	231.40
23.	Tamil nadu	324.46	7442.26
24.	Telangana	99.03	1605.13
25.	Tripura	47.98	838.26
26.	Uttar pradesh	1251.31	27496.32
27.	Uttarakhand	97.84	1010.13
28.	West bengal	1474.37	28354.15
29.	Others	38.36	532.20
	Total	10292.26	188008.73

(Source: https://agricoop.nic.in)

Note: Area : '000 Ha

Production : '000 MT

Karnataka state has congenial agro-climatic conditions, rich natural resources and skilled farming community required for horticultural development. The geographical area of Karnataka is 190.50 lakh hectares, of which an area of 104.89 lakh hectare comes under the cultivable area constituting 55% of the geographical area. Out of the total cultivated area, 15.84 lakh hectare of is covered under horticulture (2001-12). Horticulture area in the state, accounts for about 8% of the total geographic area, forming about 15% of the total cultivable area. Out of 15.84 lakh hectares of horticultural crops area, 3.69 lakh hectares comes under vegetables.

Agro-climatic features and vegetable production in Chitradurga district:

Chitradurga district falls in central eastern parts of the state and covers a total geographical area of 8388 sq. kms. The district is divided into 6 Taluks, namely Chitradurga, Hiriyur, Hosadurga, Holalkere, challakere and Molakalmuru.

Chitradurga district lies in the central dry agro climatic zone. The average temperature during the summer reaches up to 42ºC and minimum during winter can be 12ºC. Major part of the land is utilized for the agricultural purpose which includes rabi, kharif and other agricultural plantation. The water bodies cover an area of 384.9 sq. km which is comparatively low area with agricultural land, hence the people of this district depend on rainfall for growing the crops.

It is a dry region which normal annual rainfall occurs is 668mm (varies between 668mm in Holalkere in western part to 457mm in Challakere). The major soil type is black soil and red soil. Chitradurga is an agriculture dominant economy with over 50% of the net area under cultivation. It cultivates major crops like Ragi, Jowar, Maize and pulse varieties. The commercial crops like Groundnut, Sunflower, Cotton, Tobacco and some vegetables and fruits. Details of cultivation area, production, yield and values of solanaceous vegetable crops from 2014-19 were recorded in **table 1.4.**

The district produces numbers of vegetables and the major vegetables are Tomato, Chilli, Brinjal, Okra, Beans, Onion, Bitter gourd and some leafy vegetables. Most of the solanaceous vegetables remain in the field for a period of 90 days. During these days, they are pruned to the attack of various microorganisms like fungi, bacteria, virus and mycoplasma like organisms. Also, exposed to different environmental factors like rain, wind, temperature and R^H. Both these factors influence the production of the crop. However, the microorganism causes severe toll in the production as well as storage.

According to Salau 2015 Fungi constitute a major problem in the production, storage and processing of agricultural products especially vegetable crops. Vegetable belonging to the families Cucurbitaceae, Brassicaceae and Solanaceae are important due to their nutritional as well as economic values. However, the farmers face heavy yield loss both in quality and quantity of these crops due to damage as a result of various diseases caused by fungal pathogens.

Fungi are universally present in all types of natural habitats and from one of the most important components of an eco-system as decomposers. The limiting factors that influence the vegetable economic value is the relatively short shelf-life period by pathogens attack. Fungal vegetable infection may occur during the growing season, harvesting, handling, transport, post-harvest storage, marketing conditions and after purchasing by the consumer. Vegetables are containing high level of nutrient elements and sugars and their low p^H values make them particularly desirable to fungal decaying (Mohamed -2013).

Table 1.4: Annual Report of Horticultural crops (Solanaceous Vegetables) in Chitradurga District from 2014-2019

Sl. No	Year	Vegetables	Chitradurga				Challakere				Hiriyur				Holalkere				Hosadurga				Molakalmuru				Total			
			A	P	Y	V	A	P	Y	V	A	P	Y	V	A	P	Y	V	A	P	Y	V	A	P	Y	V	A	P	Y	V
1.	2014-15	**Tomato**	243	2916	12	249.0	153	1836	12	173	70	840	12	73.20	704	8448	12	615.60	581	116.20	20	994.00	130	2517	18	183.15	1881	27319.00	14	2187
2.		**Brinjal**	97	2482	25	24.20	34	850	25	85	39	975	25	97.50	39	975	25	97.50	66	1335	30	133.50	80	2240	28	224.00	355	9348.33	26.33	935
3.		**Chilli**	192	1920	10	288.00	86	860	10	129	370	3700	10	555.00	1021	10210	10	1531.50	156	1248	8	187.20	61	1098	18	164.70	1886	20746.00	11.00	3112
1.	2015-16	**Tomato**	170	4200	20	630.00	153	1836	12	158	70	840	12	120.60	704	8448	12	845.52	581	11620	20	587.00	157	3021	18	400.65	1835	29159		2817
2.		**Brinjal**	89	2258	25	180.64	34	850	25	85	38	950	100	76.00	39	975	25	97.50	66	1335	30	66.75	62	1736	28	347.20	328	12737	38.83	1274
3.		**Chilli**	267	4806	18	720.90	86	860	10	172	285	2850	10	427.50	1241	12410	10	1985.60	156	1248	8	74.88	84	1512	18	231.00	2119	26134	12.33	3136
1.	2016-17	**Tomato**	221	2652	12	358.8	193	2316		230.4	75	900	0	126.6	495	5940		604.8	565	11300		2992.8	117	2193		283.65	1666	24881.92	44.83	5060.20
2.		**Brinjal**	94	2400.5	25.75	190.64	34	850	25	85.00	46	1150	25	92.00	40	1000	25	100.00	63	1890	30	756.00	62	1736	28	347.20	339	8969.26	26.45	1801.80
3.		**Chilli**	235	76492.5	10	252.50	86	860	10	172.00	317	3170	10	475.5	1543	15430	10	2468.80	170	13920	8	4.76	50	900	18	137.50	2401	26411	11	7221.00

1.	**2017-18**	**Tomato**	530	6360	48	-	201	2412	36	-	277	3264	36	-	391	4692	36	-	567	11340	60	-	122	2316	54	-	2088	30384	270	-
2.		**Brinjal**	190	4831	103	-	34	850	25	-	118	2950	3	-	44	1100	25	-	63	1890	30	-	89	2492	28	-	538	14113	214	-
3.		**Chilli**	557	5570	40	-	86	860	10	-	618	6180	10	-	1323	13230	10	-	170	1360	8	-	85	1530	18	-	2839	28730	96	-
1.	**2018-19**	**Tomato**	152	1824	20	264	1248.6	24972.6	60	4480.52	360.12	3961.44	24	551.0	187.15	2245.8	36	228.69	60.18	1203.6	20	4.62	112	2142	54	277.95	2120.08	36349.44		-
2.		**Brinjal**	44	1117	25	89.36	110.78	2769.5	25	276.95	70.91	1772.75	100	141.82	36.05	901.25	25	90.13	6.48	194.4	30	1166.40	90	2520	28	504	358.22	9274.9	38.83	-
3.		**Chilli**	286	2860	10	429	361.64	3616.4	10	723.28	1337.9	13379	10	2006.8	1182.2	11822.1	10	1891.55	191.82	1534.56	8	5.37	85	935	11	233.75	3444.57	34147.06	9.83	-

(Source: District Horticultural Department, Chitradurga)

Note: A-Area (In Hectares), P-Production (In Tonnes), Y-Yield (In Tonnes/ Hectares), V-Value (In Lakhs) and – No records

Increased vegetables productivity can be achieved by using high yielding varieties/hybrids and improved crop management practices. Many high yielding vegetable cultivars were released in recent years of cultivation. But many diseases have become a limiting factor to realize their high yielding genetic potentiality. Among all the diseases, fungal diseases are important and major disease in vegetable crops and they cause up to 30% - 50% of yield loss. The disease symptoms at various growth stages of crop appeared as rots, leaf spots, blight, wilts, die-back, discoloration, collar rot or brown lesion spots, damping-off and fruit infection are the major fungal diseases seen in vegetables. The fungal pathogens affect the market value as well as nutritive value of the product.

According to Datar and Mayee (1981) the vegetable crops suffer more during kharif season than other seasons. *Alternaria solani* affects the tomato crops at all the stages in severe epidemic, reducing yield upto 78.51%. Whereas naturally infected crop is reduced to 46.26%.

Early blight of tomato caused by *Alternaria solani* was the most destructive, widespread disease in temperate, tropical and subtropical regions of the world. It severely attacks the crop and losses the yield up to 50%- 80% on susceptible hybrid varieties (Hijmans *et al* -2000). *A. solani* infect all the parts of the plants like leaf blight, fruit lesions, stem and collar rot results in severe damage in all stages of plant development (Abada *et al*-2008). It also causes disease in Potato, Pepper (Chilli) and eggplant (Brinjal) (Najibullah *et al* -2016)

According to Manoj Kumar *et al* (2015) *Alternaria* leaf spot was the wide spread, highly destructive disease in chilli and production was completely loss due to fungal infection under congenial environmental condition.

Chilli was affected by number of plant pathogens. Plant parasitic pathogens causes several diseases like wilt and root rot by *Fusarium* species, Powdery mildew by *Leveillula taurica*, Damping off and Wilt by *Pythium aphanidermatum* (Hafeez-1986, Saleem *et al*-1996, Mushtaq and Hashmi-1997, Hussain and Abid-2011). Root rot by *Macrophomina phaseolina* and *Rhizoctonia* root rot by *Rhizoctonia solani* (Faisal *et al*-2013).

Fusarium wilt of Brinjal was a destructive disease of brinjal. Fusarium species causes severe wilt and death of upper parts of plants (Banu and Sharada-2018).

The pathogenicity test is the main criterion for the identification of pathogens suspected of being the etiological agents of a plant disease and to determine the suspected pathogen may cause disease symptoms in host plant which it was isolated. This involves reproduction of certain symptoms following artificial infection of suitable hosts under greenhouse conditions.

In today's scenario, management of fungal diseases is the major issues in plant disease management because fungal pathogens are gained resistance to all fungicide which is a big challenge to us. The chemical based products are used in the control of pathogens for survival of life for a longer period under adverse environmental conditions (Cook -1903). Chemical control has been the most effective method adopted by farmers to protect the crops from fungal pathogens. Many strategies have been employed for the management of diseases in crop, among those use of fungicides have recorded better control for the spread of pathogens than the use of botanicals or biocontrol agents (Amrita Saxena *et al* -2016).

The biology, epidemiology, severity of the disease, pathogenicity and their control have not been studied in detail with reference to the different agro climatic region of Chitradurga district and with the cultivars grown. It is a dry place, the annual rainfall and moisture is low. But the vegetable crops are attacked by fungal disease in severe condition and lead to reduce quality and quantity of vegetables and crop yields hence the investigation is undertaken.

Keeping this in view, an attempt was made to review available literature regarding fungal diseases, their pathogenicity and disease control of vegetable crops from various Journals, articles, reports and conference proceedings to cover wide range of information. Present investigations were carried out to understand the following objectives:

1. To isolate and characterize the fungal pathogens of some Solanaceous vegetable crops.
2. To screen fungal pathogens for pathogenicity against selected Solanaceous crop plants.
3. To study the control of certain fungal pathogens *in vitro.*

2.1 STUDIES ON SCREENING OF INFECTED MATEIALS IN FIELD:

Bhale (2011) reported on market storage and Post-Harvest fungal diseases of some important fruits in market of Osmunabad district. Fungal diseases of 9 selected fruits were studied and in all 11 fungal pathogens were observed. Among these *Aspergillus niger, Rhizoctonia solani, Geotrichum candidum* and *Penicillium* species are the major.

Wani (2011) reported on overview of the fungal rot of tomato and gave inclusive information regarding various pathological aspects on the fungal rot of tomato and management strategies opted for post-harvest diseases of tomato.

Mohamed (2013) worked on survey of fungal diseases of some vegetables and fruits in Aswan, EGYPT. They isolated fifteen species of 9 terrestrial fungal genera from diseased fruit and vegetables on PDA media during investigation. Aspergillus came in high incidence genera and represented by three species namely *A. flavus, A. niger* and *A. ochraceus*. Another four fungal genera were came in the second position after *Aspergillus* and represented as *Acremonium*, *Alternaria*, *Fusarium* and *Penicillium*. *Solanum lycopersicum* was yielded the highest number and Psidium guava was yield the lowest numbers of fungal genera and species. *Aspergillus flavus* and *Fusarium Proliferatum* was the highest fungal isolates produced clear zone.

Muhammad *et al* (2013) studied on the important fungal diseases of potato and their management- a brief review. This brief review paper demonstrates the symptoms and management strategies against important fungal diseases of potato.

Rinkey Pallavi *et al* (2014) studied on survey of Post-harvest fungal diseases of fruits and vegetables in the market of Nagpur. They observed fungal diseases of 17 selectable fruits and vegetables and their fungal pathogen. Among all *Aspergillus, Alternaria* sp, *Fusarium* sp, *Mucor* sp, *Penicillium* sp and *Rhizopus* sp are the major disease causing organisms. They revealed that fungal infection is mainly due to injury during storage and handling.

Syed *et al* (2014) surveyed on economical important fungal diseases of Tomato in sub-zoba Hamemalo of Eritrea. They undertake the survey for incidence of early blight and powdery mildew of tomato caused by *Alternaria solani and Oidium neolycopersici* respectively. They reported maximum disease incidence due to early blight were 56.28% and minimum were 19.05% in seven days. Whereas in case of powdery mildew the maximum and minimum disease incidence were 38.96% and 13.43% respectively. Overall average for higher leaf infection in early blight and powdery mildew were recorded 41.85% and 34.63% respectively.

Mari Bhat and Anushree (2015) investigated on phylloplane mycoflora of some vegetable crops. They used Blotting Paper Technique (BPT) and Potato Dextrose Agar (PDA) method for isolation and observed 15 fungal organisms in PDA viz; *Cladosporium cladosporoides* (98.8%), *Penicillium funiculosum* (74.4%), *Aspergillus flavus* (57.6%), *P. notatum* (46.8%), *A. niger* (40.4%), *Fusarium oxysporum* (35.2%), *Penicillium sp* (34.4%), *A. fumigatus* (28.4%), *P. frequentans* (20%), *Cercospora sp* (15.6%), *Rhizopus stolanifer* (2.4%), *Helminthosporium sp* (1.6%), *Alternaria alternata* (1.6%), *Curvularia lunata* (0.8%) and *Rhizopus sp* (0.4%). In other hand 11 fungal species were reported in BPT in varied level of incidence viz; *Cladosporium cladosporoides* (26.4%), *Fusarium oxysporum* (24.4%),

Cercospora sp (23.6%), *Alternaria alternata* (9.2%), *Curvularia lunata* (5.6%), *A. niger* (4.8%), *Rhizopus sp* (2.8%), *Helminthosporium sp* (4.8%), *Penicillium sp* (1.2%), *Rhizopus stolanifer* (0.4%) and *Penicillium funiculosum* (0.4%)

Salau *et al* (2015) worked on the fungal diseases of vegetables in Sokoto state, Nigeria. This study reviews the inclusive information regarding various pathological aspects of the fungal disease, cause and management strategies opted for pre and post-harvest diseases of vegetables in Sokoto.

Chilli is one of the most important spices and vegetable crop of India and it was susceptible to various fungal diseases like Anthracnose, Damping–off, Fusarium wilt, collar rot, dry root rot, stem rot. Out of these Anthracnose and *Fusarium* wilt are the most common widespread and important disease. Total 36 locations of Pratapgarh, Amethi, Sulatanpur, Kanpur, Etawah, Allahabad, Faizabad, Jaunpur, and Mirzapur districts of Uttar Pradesh was surveyed during the year 2015-16. Maximum anthracnose severity recorded in Jaunpur (54.91%) and Mirzapur (54.00%) district. They reported *Fusarium oxysporum* f. sp. capsici was the predominant pathogen and its average recovery percent were 53.30% in all locations. It caused considerable loss in all chilli growing regions. *Rhizoctonia solani* was the second most prominant pathogen found in the surveyed region of Uttar Pradesh (Abhishek *et al* -2018).

Mahanthesh *et al* (2017) studied status of tomato early blight in Shivamogga and Davanagere districts. They explained tomato crop is vulnerable to infection by bacterial, viral, nematode and fungal diseases. Among the fungal diseases, early blight of tomato caused by *A.solani* causing loss from 50-86% in fruit yield. They conducted survey during kharif season in 2015 in Shivamogga and Davanagere districts of Karnataka revealed that range of percent disease index from 22.35 to 47.25. The

maximum percent disease index (PDI) was recorded in Nyamati (47.25) and Kommanal (42.50) in Davanagere and Shivamogga district respectively and the minimum PDI 22.35 and 39.75 was recorded in Avarekoppa (Shivamogga) and Kenchikoppa (Davanagere) respectively.

Sajad *et al* (2017) surveyed of local tomato growing field of Jabalpur. They used potato dextrose agar media for identification of fungi. They observed most of the tomato fruit suffered by fruit rot caused by *Alternaria alternata, Aspergillus niger, Geotrichum candidum, Alternaria solani, Mucor racemosus, Aspergillus flavus, Fusarium oxysporum, Fusarium moniliforme, Penicillum digitatum, Rhizopus stolanifer, Colletotrichum lycopersici, Sclerotium rolfsii, Myrothecium roridum, Phoma destructiva* and *Trichothecium roseum.* Highest frequency of occurrence occurred in *Alternaria alternata* 16.51% followed by *Alternaria solani* 12.43%, *Geotrichum candidum* 10.66%, *Aspergillus niger* 8.82%, *Colletotrichum lycoperssici* 7.53%, and lowest frequency in *Sclerotium rolfsii, Mucor racemosus, Penicillium italicum* and *Cladosporium fulvum,* Maximum occurrence found in *Alternaria alternata* (16.51) hence it selected for pathogenicity test.

Yadav *et al* (2017) conducted the survey to assess the fruit rot incidence of chilli in four locations of Jaipur district. Overall, 60.33 per cent fruit were found infected at surveyed four locations of Jaipur district during 2015 and ranges from 51.75% to 66.70%. Therefore, they reveal that the fruit rot incidence was predominance and the presence of fruit rot is a major constraint to profitable of chilli in Jaipur district.

Priya *et al* (2018) surveyed for Wilt of chilli and threat to chilli crop in Northern Karnataka. They conducted survey on 2014-15 in three districts (Belagavi,

Gadag and Haveri) and surveyed total 22 locations. The disease severities were assessed in percentages at green stage and percentage of the diseases were recorded. The overall disease severities were ranged from 5.45 to 95.00 percent. The highest incidence of wilt disease was noticed in fields of Hirehalli village (95.00%) in Haveri district whereas least incidence of the disease was recorded at Nandikurli village (5.45%) in Belagavi district. The highest district mean of the disease incidence were recorded in Haveri (73.50%) followed by Gadag (53.00%) and Belagavi (41.57%).

Zakir *et al* (2018) reported on Severity of Alternaria Leaf Spot of Brinjal caused by Alternaria alternata in Kashmir, India. They conducted survey in three districts of Kashmir valley viz., Anantnag, Baramulla, and Budgam revealed that disease was prevalent in all the three districts with mean disease incidence and intensity of 30.76 and 9.77 per cent, respectively. The maximum disease incidence of 38.68 and intensity of 14.07 per cent was observed in district Budgam and minimum disease incidence of 21.73 and intensity of 5.88 per cent was observed in district Anantnag.

2.2 ISOLATION AND IDENTIFICATION:

Ukeh and Chiejina (2012) investigated on preliminary cause of post-harvest fungal rot of Tomato. They collected tomato fruits from local market in Nsukka and isolated the fungal organism by using PDA medium. Identified the organism based on cultural characters and microscopic examinations of the cultures. *Helminthosporium solani, Aspergillus niger, Penicillium digitatum* and *Mucor piriformis* were identified and *A. niger* had the highest percentage frequency of occurrence followed by *M. piriformis*.

Isolation and characterization of *Fusarium oxysporum* for its pathogenic and non-pathogenic nature in tomato (*Solanum lycopersicum*) was studied by Mamta Joshi *et al* (2013). They collected soil and plant samples from nine different geographical locations in Uttar Pradesh, India. They recovered total sixty isolates of *Fusarium* species from the soil and plant samples. Among those isolates, thirty nine were identified as *Fusarium oxysporum* on the basis morphological and molecular identification and conducted pathogenicity test on Pant T-3 tomato variety. The disease incidence was recorded range from 0 to 78.74%. They recorded among the isolates of *F. oxysporum*, five were nonpathogenic and three were found strongly pathogenic and tested Non-pathogenic isolates for their antagonistic effect against most pathogenic isolates of *F. oxysporum*. They concluded that the Isolate no. 40 showed highest antagonistic activity in inhibiting the radial growth of pathogenic isolates.

Jagadeesh *et al* (2015) worked on Image processing based detection of fungal diseases in Plants. They recorded on to detect, to identify and to accurately quantify the first symptoms of diseases. Plant diseases are caused by bacteria, fungi, virus, nematode etc. of which fungi is the main disease causing organism. They focused on early detection of fungal disease based on the symptoms.

Brunda Devi *et al* (2016) reported the occurrence and distribution of fungi associated with four tuber vegetables like carrot, beetroot, sweet potato and corm during storage in five districts of Telangana. They followed standard method to isolate and identify the fungi and observed total 41 fungal species of 22 genera. Among four root vegetables, fungi were found predominantly on carrots while sweet potato had lesser dominance. *Fusarium solani* was found most dominant and common

fungus isolated from all four vegetables in all districts. And they reported total 8 plant fungal species viz., *Byssochlamys nivea, Conifera sp, Cunnighamella echinulata, Chaetomium mollicellum, Monilina fructicola, Monodictys fluctuate, Trichoderma hargianumand,* and *Trichothecium roseum* were found for the first time to be associated with tuber vegetables during storage.

Abu-Al-Islam *et al* (2016) investigated on eco-friendly management of mycoflora associated with *Trichosanthes Anguina* L. and *Trichosanthes Dioica* Roxb. They collected fresh vegetables from five local markets and isolate the fungi associated with sample by Tissue Planting method on PDA medium. They identified seven species of fungi namely *Aspergillus flavus, A. fumigatus, A. niger, Fusarium sp, Penicillum sp, Rhizopus stolonifer* and *Trichoderma viride.* Among all the *Aspergillus niger* is the predominating fungi. To control the fungi, they selected *Allium cepa, Allium sativum* and *zingiber officinale* plants extract and sodium bicarbonate and sodium chloride for evaluating their effect on the growth of fungi. They showed *Allium sativum* extract and both chemicals show 100% radial growth inhibition of isolated fungi at 20% concentration.

Mahadevakumar *et al* (2016) studied on leaf blight and fruit rot disease of brinjal caused by *Diaporthe vexans* (*Phomopsis vexans*) in six agro-ecological regions of south west India. They isolate the *D. vexans* and grown a potato dextrose agar medium and identified based on morphological and cultural characteristics. They recorded high severity of leaf blight in northern transition zone (NTZ: 10.6- 25.3%) followed by central dry zone (CDZ: 10-17%) and southern dry zone (SDZ: 8.3-18%) and the maximum severity of fruit rot in CDZ (29-39%) followed by SDZ (22.3-62%)

and NTZ (21-33.3%). They concluded that D.vexans is a serious constraint to brinjal production in six brinjal growing regions of south west India.

Leaf Spot of Brinjal: Epidemiological Aspects was studied by Premila and Sophiarani (2016). They monitored fungal airspora over Brinjal field for two consecutive cropping season using Tilak's Rotorod Air Sampler. Total 25 fungal types were identified and assigned to 5 different sub divisions of fungi. Dominant fungal types were *Aspergilli, Pencilli, Alternaria, Cercospora, Curvularia, Cladosporium*. They observed monthly variation of *Alternaria melongena* in both cropping season and reported as occurrence of leaf spot disease of brinjal depend on weather parameters. Disease incidence and percent contribution of *Alternaria Melongena* were correlated with meteorological parameters like relative humidity, temperature and rainfall.

Alternaria alternata was an important, widely distributed pathogen which caused early blight of tomato (Najibullah *et al*-2016). They investigated on morphological, pathogenic, cultural and physiological variability of *A. solani.* Maximum mycelial growth was recorded in Sabouraud's Agar medium followed by Host agar medium and PDA Medium. Pigmentation, sporulation, mycelial growth surface, margin and zonation were varied from one media or other media they used. Temperature 30℃ and P^H 6.5 with 12h light and 12h darkness recorded the maximum colony growth. In pathogenicity test, the isolates were successfully infect the tomato foliage appearing infection symptoms of early blight but degree of infection was varied from one isolate to other.

Zainab *et al* (2016) carried an investigation on the incidence of fungal leaf spots disease of mango (*Mangifera indica*) in Sokoto state. Diseased plant leaves

were identified using disease symptoms and taken to laboratory for culture, isolation and identification of the pathogens. They determined the plant disease incidence by using disease index and severity scale of 0-4 rating. A total 11 fungal pathogens are isolate and identified as *Alternaria longipes, Aspergillus fumigatus, Aspergillus niger, Colletotrichum gloesporiodes, Fusarium oxysporum, Fusarium mangifera, Pestalotiopsis mangiferae, Phoma mangiferae, Phomopsis mangiferae, Pseudofusicoccum spp* and *Rhizopus oryzae* and concluded that leaf spots intensity was more influenced by environmental conditions and cultural practices rather than climatic factors in the areas.

Bilal Ahmed *et al* (2017) worked on occurrence and distribution of vegetable seed borne mycoflora in Punjab Pakistan. In this research they used standard blotter paper and agar plate technique for isolation of seed mycoflora. They collected major vegetable seeds in summer and winter from regional local markets of Punjab province. They identified 15 fungal genera and 18 different species. The highest incidence of fungal pathogens was *Aspergillus niger, A.flavus, Penicillium camemberti* and *Bipolaris spp*. The low incidence are *Stemphylium spp, Cladosporium spp, Fusarium semitectum, Curvularia lunata, Trichoderma spp, Rhizopus nigricans, Paccilomyces lilacinus, Fusarium oxysporum, Drechslera australiensis, Ascochyta spp, A.fumigatus, Rhizoctonia spp, Alternaria alternata* and *Chactomium globosum*. They concluded that Agar plate method is most suitable technique for detection of seed borne fungi in vegetable seed. This study helps for the management of seed borne fungal pathogen and treatment before sowing with appropriate fungicide to overcome losses.

Patekar *et al* (2017) used Standard blotter and Glucose Nutrient Agar technique for the study. Tomato and Brinjal seed samples were collected from various shops of Ahmednagar as treated sample and local farmer's seed as untreated samples. This study confirmed that vegetable seeds confirmed that untreated seeds deteriorated by fungi like *Aspergillus, Rhizopus, Fusarium, Cladosporium* and *Monilia sp.* and treated seeds with various pesticides show general saprophyte like *Rhizopus, Aspergillus* and *Mucor*. They concluded Seed germination rate was higher in treated seeds as compared to untreated seeds.

Isolation and identification of phytopathogenic fungi from infected plant parts was studied by Thilagam *et al* (2018). They are isolated from infected plant parts and are identified on colony morphology and lactophenol cotton blue stain for the microscopic identification and spore structure. Pure culture of the isolates were subcultured and transferred on to differential media for species identification. The morphological characteristics of these fungal elements show various spores have identified upto genus or species level.

Brown Spot of *Bipolaris oryzae* cause yield loss in paddy. Isolates was collected from nine growing regions of India. Culture was grown and maintained on PDA slants at 4℃. Based on colony morphology and growth characters they isolated 17 isolates and categorized into four groups. They were black-fluffy growth, grey – fluffy growth with white spot, grey-fluffy growth and grey with suppressed growth. They also studied the morphological characterization on different media and spectral values of the isolates (Valarmathi and Ladhalakshmi-2018).

Association of *Bipolaris* and *Drechslera* species with Bipolaris leaf blight (BpLB) infected wheat leaves were studied by Selina *et al* (2019). They isolated the fungi by using Tissue planting method on PDA. Morphological and microscopic characters were recorded for the identification and the species identified based on the Camera Lucida drawing. A total five species of *Bipolaris* and two species of *Drechslera* have been isolated and described.

Wagner *et al* (2019) first reported *Corynespora cassiicola* causing leaf spot on *Solanum americanum* in Brazil. They were observed Leaf spots in *S. americanum* in four hectares of tomato crop in Brazil. The plants were distributed throughout the area around 50% of the leaves were infected. Isolation was performed by transferring little samples of superficially disinfected plant tissues from symptomatic leaves onto Petriplates containing PDA. The resulting colonies were dark gray, circular with dense and velvety mycelial growth. The conidia were straight to curved, cylindrical, brown with 3 to 14 pseudosepta. These characteristics are similar to those described for *C. cassiicola* (Ellis and Holliday 1971).

Isolation and Identification of Different Fungal Species from Major Kharif Vegetables of Sindh Province, Pakistan was studied by Pahnwar *et al* (2021). They collected major Kharif vegetables like tomato, chilli and eggplant showing typical symptoms of fruit rot and leaf spots from the field and the pathogen was isolated and identified based on standard procedure and manuals. They isolated seven fungal species (*Alternaria alternata, A. solani, Aspergillus flavus, A. niger, Fusarium oxysporum, Pencillium sp.* and *Rhizopus stolonifer*) from fruit rot of Tomato and seven species (*A. alternata, A. tenuissima, A. flavus, A. niger, Colletotrichum capisi, Penicillium sp. and R. stolonifer*) from Chilli fruit rot and six fungal species (*A.*

alternata, A. flavus, A. niger, F. solani, Penicillium sp., and *R. stolonifer*) from leaf spot of Brinjal. They recorded highest infection frequency in *A. solani* (48.83%) and *A. tenuissima* (44%) from tomato and chilli fruit rot respectively. In leaf spot of eggplant were showed 34.5% in *A. alternata* and finally concluded that *A. solani, A. tenuissima* and *A. alternata* were more dominant in tomato and chilli fruits and leaves of eggplant.

2.3 MOLECULAR IDENTIFICATION:

Baysal *et al* (2010) worked on Molecular characterization of *Fusarium oxysporum f.melongenae* by ISSR and RAPD Markers on eggplant. They used ISSR and RAPD Markers to characterize *Fusarium oxysporum f. melongenae* isolates collected from eggplant field in Southern Turkey. Pathogens were identified by their morphology and their identity was confirmed by PCR Amplification using the specific primer PFO2-3. ISSR and RAPD fingerprints showed a level of genetic specificity and Diversity. The primers selected to characterize *Fusarium oxysporum f. melongenae* may be used to determine genetic differences and pathogen virulence. This study is the first to characterize eggplant *F.oxysporum* species using ISSR and RAPD.

PCR based detection assay to detect the pathogen from DNA samples obtained from fungal isolates was carried by Jayaramaiah *et al* (2013). Universal primer pairs designed from internal transcribed spacer regions ITS1 and ITS4 of the ribosomal DNA (rDNA) of the genus *Phomopsis* species were used for PCR. They revealed that the amplification of expected 553 bp PCR products in all the DNA products in all the DNA samples isolated from different isolates of *Phomopsis vexans* confirming their association in leaf blight and fruit rot disease of Brinjal.

Snezana *et al* (2016) studied the Morphology, pathogenicity and Molecular Identification of Fusarium spp. Associated with Anise Seeds in Serbia. They isolate and identified the strains of Fusarium species present on Anise seed sample. Based on the morphological, microscopic, characteristics and a molecular identification by sequencing of TEF gene, *F. tricinctum, F. proliferatum, F. equiseti, F. oxysporum, F. sporotrichoides, F. incarnatum* and *F. verticilliodes* were confirmed. According to their research *F. tricinctum* and *F. sporotrichoides* were the first report as pathogenic to Anise seeds in the world. All the seven *Fusarium* species were pathogenic and *F. oxysporum, F. tricinctum* and *F. incarnatum* were most virulent species.

Adam *et al* (2018) investigated on Target leaf spot disease of tomato caused by *Corynespora cassiicola*, a serious and emerging disease in Gangetic alluvial region of West Bengal, India. They reported this pathogen was the natural barrier for tomato production with a disease severity ranged between 35% and 58% which causes tremendous loss of tomato foliage and fruits. *C. cassiicola* was identified on basis of morpho-cultural and molecular characterization.

Rosangkima *et al* (2018) worked on isolation and molecular characterization of ginger soft rot pathogenic fungi in Aizawl district of Mizoram, India. They collected ginger soft rot diseased material from five different villages of Aizawl district, Mizoram. They isolated the fungi using tissue transplanting technique, cultured in a potato dextrose agar medium then morphologically identified based on colony colour, pigmentation, size and shape of macroconidia and molecular identification were done using ITS of rDNA. *Fusarium oxysporum, Fusarium solani* and *Plectosphaerella cucumerina* were identified. *Fusarium spp* were the most common and major causative agent for ginger soft rot.

2.4 PATHOGENICITY:

Literature revealed that several methods of inoculations have been adopted by different workers for confirming the pathogenicity of the pathogenic fungi isolated from different vegetables.

Jin-Hyeuk Kwon and Hyeong-Jin Jee (2005) studied Soft rot on fruit of eggplant (*Solanum melongena*) caused by *Choanephora cucurbitarum* in the experimental fields at Gyeongnam Agricultural Research and Extension Services in Korea from 2002-2003. The disease initiated with water-soaking and dark-green lesions and later the infected tissues were rotten rapidly. It is grown well on potato dextrose agar between 15 to 40℃ and its optimum growth temperature was 30℃. Based on morphological characteristics, *C. cucurbitarum* were identified as the causal organism of the fruit soft rot of eggplant. This is the first report on the soft rot of *S. melongena* caused by *C. cucurbitarum* in Korea. Pathogenicity test were proved by artificially wounded method on eggplant fruits.

Fayzalla *et al* (2008) tested the effect of Environmental conditions on wilting and root rot fungi Pathogenic to solanaceous plants. They isolated twenty *Fusarium oxysporum*, eight *F. solani* two *Verticillium dahlia* and four *Rhizoctonia solani* from tomato plants showing wilt symptoms. These isolates varied in their aggressiveness against tomato plants. They used soil infestation method for pathogenicity test and plastic pots were filled with 500 g of clay:sand (3:1) mixture. Soil was infested with fungal isolates at the rate of 1% of soil weight. Pots were irrigated to ensure the establishment of tested isolates in the soil. Tomato seedlings were directly transferred to the infested pots and noun-infested pots served as control.

Than *et al* (2008) worked on Characterization and pathogenicity of *Colletotrichum* species associated with anthracnose on chilli (*Capsicum* spp.) in Thailand. They isolated and identified as *Colletotrichum acutatum, C. capsici and C. gloeosporioides* in chilli showing Anthrocnose symptoms based on morphology and molecular basis. They proved Pathogenicity tests of all three isolated species which causing Anthracnose in Chilli when inoculated onto fruits of the susceptible Thai elite cultivar *Capsicum annuum* cv. Bangchang by using wounding method.

Faisal *et al* (2013) conducted experiment on pathogenicity of some important root rot fungi to the Chilli crop and their biological control. Diseased plant specimens were collected and brought to the laboratory and the fungi *Rhizoctonia solani, Macrophomina phaseolina, Fusarium oxysporum, F. solani* and *Pythium sp*. were isolated. Pathogenicity tests were carried out under greenhouse conditions using isolated fungi on chilli and colonization, and infection percentages were determined. Among the isolated fungi *Pythium sp*. and *R. solani* severely affected the plants compared to other fungi tested for their pathogenicity. In biological control, four antagonistic fungi *Aspergillus flavus, A. niger, Pencillium commune* and *Trichoderma harzianum* were used against the mentioned pathogenic fungi which successfully suppressed the activity of pathogenic fungi. *T. harzianum* was highly antagonistic towards all the pathogen and showed strong inhibitory effect on growth and mycelial development.

Mbadianya *et al* (2013) carried out the study of leaf spot disease of eggplant (*Solanum aethiopicum* L.) in a derived savannah zone. They isolated *Helminthosporium infestans, Cladophialophora carrionii, Aspergillus niger, Rhizopus nigricans* and *Neurospora Africana* from the diseased plants. *Helminthosporium*

infestans (61.11%) was the most frequently isolated organism and high frequency of occurrence than A. niger (5.56%), C. carrionii (11.11%), R. nigricans (5.56%) and N. Africana (16.67%). The pathogenicity tests showed that only H. infestans was pathogenic on the test crop and it produces characteristic symptoms of dark brown spots with concentric rings on the leaves after 28th day of inoculation. Re-isolation of the pathogen from the infected leaves confirmed that H. infestans incited the leaf spot disease on the leaves.

Narendra Kumar and Swati Sharma (2015) worked on Fusarial Wilt of *Solanum lycopersicum* L. (Tomato) at Panchgao. They isolated the pathogen from rhizospheric soils, rhizoplane, infected stem and infected collar region of wilted tomato in order to know the dominance of the pathogen and isolated total of 19 fungal species belonging to 13 genera and two sterile mycelia. They showed maximum percentage occurrence of *Fusarium* in rhizosphere soil (73.1) and minimum in rhizoplane (40.1) while *Fusarium oxysporum* showed 58.6 in infected stem and 51.6 in collar region. The pathogenicity was performed to confirm the pathogen responsible for wilting in tomato through artificial inoculation to the stem of 20 days old seedlings.

Gholve *et al* (2016) isolated the fungus *P. ultimum* from Brinjal which produces non-septate, well branched, colourless to whitish mycelium, sporangia on indeterminate sporangiophores observed under the microscope. They proved Pathogenicity of *Pythium ultimum Trow* by sick soil method in pot culture, by using brinjal cv. hadgaon local variety under screen house condition. The pathogen was reisolated and compared its cultural and morphological characteristics with the naturally damping off diseased brinjal plant for the confirmation. They revealed that

out of of 13 brinjal cultivar lines, EPM-564, Ajay, Kranti seed, Brinjal MG and Puneri Kateri were moderately susceptible with disease incidence (11.10 to 16.66) and Vishal, Arnav, Local Pingali, Local Kinwat, Local Hadgaon were susceptible with the disease incidence (22.21 to 44.44).

Nirmaladevi *et al* (2016) studied the molecular characterization of pathogenic and nonpathogenic *F. oxysporum* f. sp. *lycopersici* strains isolated from tomato. They isolated the pathogen from symptomatic plants and soil samples and identified based on morphological and molecular analyses. They tested the pathogenicity of 69 strains on five susceptible tomato varieties. It showed 45% of the strains were highly virulent and 30% were moderately virulent. Molecular based analysis indicated the presence of wide genetic diversity among the strains and Phylogenetic based analysis showed evolutionary lineages of the pathogen. Among the pathogenic strains they tested, toxigenic strains harbored the Fum1 gene clearly indicated that the strains infecting tomato crops have the potential to produce Fumonisin.

Nurul *et al* (2016) worked on Pathogenicity of *Fusarium semitectum* and *Fusarium chlamydosporum* associated with pineapple fusariosis. They identified the organism based on morphological characters and subjected for pathogenicity by using Agar plug technique for leaves and pricking technique for fruits on three pineapple varieties viz., Gandul, Josapine and Moris. They reported *Fusarium semitectum* isolates appeared to be more virulent (D.S.I= 38.89-50.00) compared to *F. chlamydosporum* on both pineapple and leaves and and fruits.

Tavga Sulaiman et al (2016) assessed the pathogenicity and Molecular Identification of Fungi and Bacteria Associated with Diseases of Tomato in Malaysia. The fungi which have been isolated and detected from tomato plants were *Fusarium oxysporum,*

F. solani, F. acuminatum, Rhizoctonia solani, Colletotrichum boninense, C. acutatum and *Phoma destructiva*. The bacteria which have been isolated and detected from tomato plants were *Ralstonia solanacearum, Xanthomonas vesicatoria, X. gardneri* and *Pseudomonas syringae*. While the most pathogenic fungi were *C. boninense, P. destructive* and *F. oxysporum* with the disease incidence (89.6%, 86.6%, 85.6%) respectively, the most pathogenic bacteria were *X. vesicatoria* and *R. solanacearum* with the disease incidence (96.6% and 87.6%) respectively.

Veera Suresh *et al* (2017) first reported on *Corynespora* Leaf spot caused by *Corynespora cassiicola* on Chilli in West Bengal. They surveyed and observed the disease showing symptoms as dark brown spot on leaf, stem and fruits. They collected, isolated and identified as *C. cassiicola* on the basis of morphology and cultural characters. Koch's postulates were proved by conducting the pathogenicity test by detached leaf Technique. Finally, they reported as first report of *Corynespora* spot caused by *C. cassicola* on Chilli in West Bengal.

Inci Guler Guney and Mehmet Ertugrul Guldur (2018) evaluate the effect of different inoculation methods (root dip, soil infestation with wheat bran and soil infestation with rice grain) on pathogenicities of *R. solani, M. phaseolina, F. oxysporum* and *F. solani* on pepper seedlings. Inoculated pepper seedlings were left to grow for three months after transplanting under growth chamber condition. Inoculation of infective rice-grain was used to test pathogenicity of all four fungi. Root dip inoculation method was used for *F. solani* and *F. oxysporum* and soil infested with wheat bran for *R. solani* and *M. phaseolina*. All tested fungi induced similar foliar symptoms, root rot severity and caused a similar reduction in dry root weights when rice-grain inoculums were used. *F. oxysporum* was least virulent

pathogen and *R. solani, M. phaseolina* and *F. solani* were similarly virulent. They concluded and recommended rice-grain inoculation was best to test pathogenicity of fungi in pepper.

Sukanya Gogoi and Daisy Senapoty (2018) conducted survey on some districts of Upper Brahmaputra Valley Zone of Assam during 2015-16. They observed new pathogen *Phoma exigua* caused fruit rot of brinjal and recorded initial symptom developed on the fruits viz., minute, slightly sunken spots, which later produced minute black bodies (pycnidia) scattered and immersed in the infected host tissues. The isolated pathogen was identified as *Phoma exigua* on the basis of morphological and cultural characteristics. The pathogenicity test was proved by detached leaf and fruit technique. They reported as this is the first report of Fruit rot of Brinjal caused by *Phoma exigua* on Brinjal in Assam, India.

Silva *et al* (2019) carried out an Identification, prevalence and pathogenicity of *Colletotrichum* species causing anthracnose of *Capsicum annuum* in Asia. They isolated and identified total of 260 *Colletotrichum* isolates. The isolates were associated with necrotic lesions of chilli leaves and fruit collected from chilli producing areas of Indonesia, Malaysia, Sri Lanka, Thailand and Taiwan. Among all *Colletotrichum truncatum* were the most commonly isolated species. Other species were identified based on multi-gene phylogenetic analyses which were difficult to identify based on morphology. Results revealed a further seven *Colletotrichum* species viz., *C. endophyticum, C. fructicola, C. karsti, C. plurivorum, C. scovillei, C. siamense and C. tropicale*. Pathogenicity tests revealed that *C. javanense* (Novel sps) and *C. scovillei* were highly aggressive when inoculated on non-wounded fruit compared to all other species.

Raghu *et al* (2019) studied the morphological, pathogenic and molecular variability of the isolates collected from different geographical locations based on disease intensity. The maximum disease incidence was recorded from Kurnool district of Andhra Pradesh (34.90%) followed by Bellary district of Karnataka. The least disease incidence was recorded at Chickmagaluru district (6.08%). The disease incidence was more during 2013-14 compared to 2012-13 in all surveyed locations. Pathogenicity of 44 isolates on highly susceptible varieties like Sitara and Byadgi dabbi indicated that 29(65.90%) were highly virulent, 11(25%) were moderately virulent and 4(9.09%) isolates less virulent.

Satyadev *et al* (2020) worked on Isolation, identification and pathogenicity of *Sclerotinia sclerotiorum* causing *Sclerotinia* rot of chillii. They collected infected chilli plant samples and isolated the fungus on PDA medium and purified by using hyphal tip method. Pathogen was identified based on the morphologic and microscopic observation. They proved Pathogenicity on chilli plants in three methods viz., seed, soil and seed + soil inoculation method. Among the all the three inoculation methods they recorded seed + soil inoculation method showed maximum disease incidence (72.66%) followed by soil inoculation method (64.00%). The isolated fungus *Sclerotinia sclerotiorum* were confirmed based on the basis of cultural, morphological and pathogenicity test.

Wanjiku *et al* (2020) identified the fungal pathogens associated with avocado Stem End Rots (SER) in Kenya and evaluated its pathogenicity. Fungal isolates were collected from symptomatic avocado fruits from randomly selected orchards and major markets in Kenya during 2017 and March 2018. They identified total of 207 and 125 fungal isolates from orchards and major markets, respectively, on the basis of

morphological characters and conformed through molecular techniques. The identified isolates were *Lasiodiplodia theobromae* (39.8%), *Neofusicoccum parvum* (24.4%), *Nectria pseudotrichia* (18.4%), *Fusarium solani* (7.2%), *F. oxysporum* (5.1%), *F. equiseti* (3.9%), and *Geotricum candidum* (1.2%). In the pathogenicity test, they reported as *L. theobromae, N. parvum,* and *N. pseudotrichia* caused the most severe SER symptoms.

2.5 DISEASE MANAGEMENT/ IN *VITRO* CONTROL MEASURES:

Prasannath (2011) carried out research on Control of Fusarium Wilt of Chilli (*Capsicum annum* L.) by crude plant extracts. They isolated pathogenic fungi *F. oxysporum* f. sp. capsci from infected plant parts and identified based on morphological and cultural features. *Azadirachta indica, Ocimum sanctum, Zingiber officinale, Allium sativam* and *Allium cepa* were used to test the antifungal activity against the pathogen by using poisoned food technique. The result revealed that all the extract showed better inhibition of the fungal growth at 10% than 5% concentration. Among that *Allium sativum* was most effective followed by *Azadirachta indica* and *Ocimum sanctum*. The least inhibition was found in *Zingiber officinale*.

In *vitro* screening methods using chemical fungicides against canola black spot pathogen was carried out by Aqsa Aftab *et al* (2012). Brown and black spot diseases of canola plants caused by *Alternaria* species are the major threat and leads ultimately economic loss. They used two chemical fungicides with trade name Triton and Benedict contains active ingredients validamycin and iprobenfos respectively. The Fungus was grown on growth media and incorporated with fungicides by three different methods viz., well diffusion, disc diffusion and food poisoning. The Maximum inhibition was recorded by food poisoning method using either of

fungicide and recorded Benedict was more effective against *Alternaria sp*. as compared to Triton. They suggested food poisoning method for researchers to test the efficacy of fungicides in laboratory assays.

Ramadan Agamy *et al* (2013) isolated *Alternaria tenuissima* from leaf spot disease of Tomato cultivated under greenhouse condition. The ability of salicylic acid and newly prepared bioactive matter "Agrileen" were used to evaluate the suppression of leaf spot of Tomato. Exogenous application of SA (0.5 and 1.0mM) or AG (2.5 and 5%) enhanced the growth and plant yield of tomato in addition to the reduction of infection of *A. tenuissima*. Photosynthetic pigments, total proteins, free proline and the relative water content of leaves were also enhanced when SA or AG were applied. They confirmed application of SA or AG protects the tomato plants against *A. tenuissima* infection either direct strength defense or reduce the severity of infection.

Bhaliya and Jadeja (2014) recorded the evaluation of different contact, systemic and combination of fungicides *in vitro* against *Fusarium solani*. Among contact fungicides Mancozeb, Zineb showed 100% inhibition in all concentration followed by Chlorothalonil (80.28%) and copper oxychloride (79.25%) at 2500 ppm concentration. Out of six systemic fungicides, Carbendazim found best with 98.68% inhibition followed by Propiconazole (85.27%) and Difenoconazole (75.53%). In fungicide combination, cymoxanil+mancozeb, carbendazim+Mancozeb and tricyclazole+mancozeb gave 100% growth inhibition followed by carboxin+thirum with 98.79% mean growth and least inhibition was recorded in Zineb+Hexaconazol (72.19%).

Pramod Kumar Singh *et al* (2014) investigate on effect of leaf extract in spore germination of some major fungal diseases of *Daucus carota* in vitro condition. Leaf

extracts use of strychnos nux – vomica I, *Allium cepa*, *Azadirachta indica*, *Occimum sanctum* and *Allium sativum*, 50, 75 and 100ppm concentration antifungal activity against of different fungi in root vegetable viz., *Alternaria dauci, A. radicina, Botrytis cinerea, Cercospora carotae* and *Sclerotium rolfsii*. They reported leaf extract of some medicinal plants which were found effective during spore germination were also tried for controlling the wilt of plants at the seedlings stage.

Bashar *et al* (2015) worked on potential fungicides and plant extracts against Fusarial wilt of Brinjal. They tested antifungal potentials of nine fungicides and eight plant parts extracts were tested in opposition to *Fusarium oxysporum* Schlecht. and *F. solani* (Mart.) Sacc. the two pathogens, isolated from wilted roots of brinjal plants. Efficiency gradients observed that Bavistin and Tall was the best inhibiting agent against the invitro growth of the test pathogenic fungi. Among aqueous extracts of eight plant parts significant inhibition of the growth of the pathogens was observed with *Azadiracta indica* (leaf), *Zingiber officinale* (rhizome) and *Asparagus racemosus* (root) at 20% concentration.

Manoj Kumar *et al* (2015) evaluated the efficacy of different fungicide for the Management of Alternaria Leaf Spot disease in Chilli. Captol, Captan, Ziram, Captofol, Thiram Indofil Z78 and Indofil Z45 were used for assess the ability to reduce the growth of Alternaria alternata under laboratory conditions. Maximum inhibition (100%) was reported in Captol and Captan followed by Captofol (89.5%) in 0.1% dose. While in 0.2% dose Captol, Captan and Ziram also showed 100% inhibition.

Singh *et al* (2015) reported on Alternaia diseases of vegetable crops and its management control to reduce the low production. They selected mainly three

vegetable crop family like Cucurbitaceae, Brassicaceae and Solanaceae for their nutritional value. These three family crops are inflicted serious damage as early blight diseases caused by fungal pathogen *Alternaria* spp. They reported *A. tenuissima, A. cucumerina* on cucurbitaceous, *A. brassicae, A. brassicicola* and *A. raphani* on brassicaceous and *A. solani, A. longipes and A. crassa* on solanaceous plants are the most infectious pathogen. They suggested different chemical and biological control agents to control *Alternaria* diseases.

Two azoxystrobin based fungicides ONESTAR 23% SC and AMISTAR 23% SC were used against blight disease of tomato fruit rot and powdery mildew of chilli in Varanasi for 2 years. Maximum disease reduction was observed in plants treated with Onestar 23% SC and Amistar 23% SC in both chilli and tomato (70-78% reduction recorded in case of chilli while 69-71% recorded in case of tomato) with enhanced yield (1.29 fold increment in chilli and 1.39 fold increment in tomato) in both seasons Amrita Saxena *et al* (2016).

Biological management of wilt disease on chilli caused by *Fusarium solani* was studied by Nagendran *et al* (2016). They screened fifteen *Trichoderma* isolates against *F. solani in vitro* and recorded more than 50% inhibition over the mycelial growth. Maximum and minimum inhibition observed in phyto-4 (66.08%) and phyto-7 (52.42%) respectively.

Jaywant *et al* (2017) tested the efficacy of fungicides and antagonists under *in vitro* for the mycelial growth inhibition and reduction in sporulation of *Fusarium oxysporum.* The fungicides carbendazim 50% and carbendazim 12%+Mancozeb 63% were completely inhibited the mycelial growth and sporulation at all concentration 50 ppm to 1000 ppm); other fungicides viz., propiconazole 25%, captan

70%+hexaconazole 5%, carboxin 37.5%+thiram 37.5% showed effect at high concentration (1000 ppm) and capton 50% showed less effect. The rate of sporulation decreased linearly with increase in fungicide concentration. Complete inhibition in sporulation was revealed by carbendazim 50% and carbendazim 12%+Mancozeb 63% and minimum inhibition observed in captan 50%. Among the antagonists *Trichoderma harzianum* (45.9%) was better followed by *T. viride* (31.9%), whereas, the bacterial antagonist's viz., *Pseudomonas fluorescens* and *Bacillus subtilis* were ineffective.

Evaluation of Different Fungicides against Alternaria Leaf Blight of Tomato (*Alternaria solani*) was studied by Vijay kumar *et al* (2017). A total of six fungicides were evaluated under in *vitro* conditions against *A. solani* through food poisoned technique and using PDA as basal medium. Among the fungicides they used, the fungicide Score was most effective and it inhibits the mycelial growth upto 78.61 percent followed by 76.67 percent of Carbendazim and Antracol of 62.69 percent. Kavach showed Minimum inhibition of the mycelial growth and it recorded 50.74% of inhibition. Under in *vivo* (pots) condition the highest efficacy were recorded in Score when sprayed at 0.05 percent concentration with disease severity of 16.33% and disease control of 74.89% followed by Carbendazim fungicide of 18.00% disease severity and 72.30% disease control when compared with control while the least efficacy was observed in fungicides Kavach (33.67%, 48.22%) and Insignia (26.00%, 60.00%).

Dahal and Shrestha (2018) studied the efficacy of fungicides *in vitro* by poisoned food technique was studied in PDA medium against *Fusarium oxysporum* f. sp. lentis at Lamjung, Nepal. They tested fungicides were Carbendazim (50%WP),

Chlorothalonil (75%WP) and Dithane M-45 (75%WP) at three concentrations (100, 150 and 200ppm). All the fungicides inhibited the fungal growth significantly, among which Carbendazim was highly effective in all concentrations reducing 100% of mycelial growth followed by Chlorothalonil. Dithane M-45 showed least inhibition i.e., 26.62% in 200ppm and concluded the chemicals exhibited increased tendency of inhibition with increased concentration.

GulBahar *et al* (2018) conducted the survey to record disease intensity, confirm etiology and record the potential of different botanical pesticides and commercially available fungicides for managing *Fusarium oxysporum* f. sp *lycopersici*. The experiments were done in complete randomized block design with three replications and the results showed with the range of 8-47 % incidence. The predominantly isolated pathogen was *F. oxysporum* f.sp. *lycopersici* and its pathogenicity test were conducted on the Golo variety of tomato through soil drenching method. The disease incidence was recorded in inoculated tomato plants i.e., 30 and 42 % at 20 and 40 DAI, respectively. The Maximum (67%) inhibition of the fungal growth was recorded in neem seed extracts (8% conc.), 63% in neem seeds at 6% conc. and Eucalyptus at 8% conc. respectively. In other side, the Nativo 75 WG fungicide was found most effective followed by Topsin-M at 1000 ppm. The fungicide Aliette and Melodedue were found least effective under in-vitro conditions.

Mallaiah *et al* (2018) conducted the study on most suitable and available fungicides to control the crossandra wilt caused by *Fusarium incarnatum*. They tested six fungicides, among them Bavistin (carbendazim) and Nativo (Trifloxystrobin 25%+Tebuconazole 50%WG) was recorded maximum inhibition fungal growth at all the tested concentration and complete inhibition observed at 300ppm and above

concentration. The minimum inhibition (90.7%) was recorded in copper oxychloride 50WP at 500ppm.

Manju Adhikari *et al* (2018) studied *In vitro* evaluation of different chemicals against *Rhizoctonia solani* by Poisoned Food Technique. They used fungicides namely SAAF (Carbendazim 12%+Mancozeb 63%), Allcop (Copper oxychloride 50 w/w), Protector (Chlorothalonil 75% wp) and Vitavax power (Carboxin 37.5% + Thiram 37.5%) were added in the PDA medium at 10ppm, 50ppm and 100ppm. All three concentrations of four fungicides significantly inhibited mycelial growth as compared to control. Vitavax was more effective at 10ppm and copper oxychloride at 50ppm and 100ppm. Hence, they recommended Vitavax is better for the management of *Rhizoctonia solani* in the field.

Ramji Lal Meena *et al* (2018) evaluated the Efficacy of Different Bioagents and Fungicides against *Rhizoctonia solani*. They assessed the Efficacy of tebuconazole 50% + trifloxystrobin 25% WG, carbendazim 12% + mancozeb 63% WP, *T. harzianum* and *P. fluorescens* under in *vitro* and in *vivo* conditions against *R. solani*. Among the treatments, the treatment consisting with tebuconazole 50% + trifloxystrobin 25% WG seed treatment (1.5 g/kg-1 seed) and soil drenching (1.5g/ lt-1 water) was found most effective in minimizing the foliar blight incidence (10.76%), disease inhibition (83.70%) and gave highest seed yield (14.20 q/ha-1) in mungbean followed by treatment consisting with seed treatment of carbendazim 12% + mancozeb 63% WP @ 2 g/kg-1 and soil drenching of carbendazim 12% + mancozeb 63% WP @ 2g lt-1 water (12.60%), (80.91%) and (13.50 q/ha-1) as compared to control (66.00% and 5.70 q/ha-1) respectively. while, in case of bioagents, seed treatment with *T. harzianum* @ 10 g/kg-1 and combination with soil application @ 10

kg ha-1 found most effective in minimizing the foliar blight incidence (25.13%) and disease inhibition (61.92%) followed by seed treatment with *P. fluorescens* @ 10 g/kg-1 and combination with soil application 10 kg ha-1 (33.10%) and (49.85%) respectively, as compared to untreated control.

Ullah *et al* (2018) isolated the three fungal plant pathogens from different host plants in District Mansehra, KP, and Pakistan. They isolated Fusarium oxysporum f. sp. capsici from wilted chilies, F. oxysporum f.sp. lentis from wilted lentils and Rhizoctonia solani from black scurf of potatoes. Five fungicides, Helonil (chlorothalonil), Clipper (copper oxychloride), Antracol (propineb), Ridomil gold (metalyxyl M + Mancozeb) and Desomile platinum (cymoxanil + Mancozeb) were evaluated for in vitro efficacy at concentrations of 100, 200, 300, 400, 500 and 1000ppm. Helonil was recorded most effective fungicide followed by Clipper and Antracol.

Chapol *et al* (2019) tested the six plant extracts viz., *Adhatoda vasica, Azadirachta indica, Ocimum sanctum, Allium sativum, Datura metal* and *Zingeber officinale* at 5%, 10% and 20% concentration *in vitro* against *A. solani*. They reported *Allium sativum* was the most effective against *A. solani* followed by *Azadirachta indica*. They also tested the efficacy of fungicide namely at 100, 200 and 400ppm. Tall 25EC was the most effective fungicide followed by Mancozeb 80WP against *A. solani*. causing early blight of Tomato.

Hussein S and Al Zubaidi L (2019) Studied on Biological control for crown and root disease of tomato caused by *Drechslera halodes* in Iraq. *Drechslera halodes were* isolated from infected Tomato's plants causing leaf spot, crown and root rot disease. Results of pathogenicity test under greenhouse condition indicate *Drechslera*

halodes were pathogenic to tomato plants. *Bacillus subtiles, Enterococcus columbae* and *Pseudomonas putida* were exhibited 100% antagonism efficiency against the pathogen on to the potato dextrose agar medium (PDA) *invitro*. All the biocontrol agents promoted plant growth.

Naznin Nahar (2019) studied the Disease management in eggplant (*Solanum melongena* L.) nurseries also reduces wilt and fruit rot in subsequent plantings. They conducted 2-year participatory study to compare yield and disease severity of plants that originated from preceding nursery studies. They raised the Seedlings according to farmers' practice or in nursery soil treated with *Trichoderma harzianum* from seed treated either with hot water or Carbendazim were transplanted on fields either with or without soil application of *T. harzianum*. They showed Laboratory tests of nursery raised seedlings from screenhouse experiments were found infected with R. solanacearum, but soil application of *T. harzianum* alone or combined with hot water treatment of seed substantially reduced the infection.

Zakawa *et al* (2019) carried out the study to evaluate the efficacy of *Azadirachta indica* crude/aqueous leaf extracts against post-harvest fungal rot pathogens of tomato fruit (in *vivo*). They randomly collected the sample from three different markets in Kasuwa kuturu, Tsohon kasuwa and Sabon kasuwa region. The fungal pathogen *Rhizopus stolonifer* and *Aspergillus niger* were identified and confirmed through pathogenicity test. They proved *A. indica* gave the best results in 60% of crude extracts with 1.39 mm in *Aspergillus niger* and in *Rhizopus stolonifer* 1.43 mm as rot diameter.

Endriyas Gabrekiristos and Getachew Ayana (2020) conducted to evaluate the efficacy of some selected fungicides for the management of Wilt Disease in Hot

Pepper (*Capsicum annum* L.) in one of the major hot pepper production regions in Ethiopia, the Central Rift Valley. They used 4DGK Isolate as the most virulent isolate with 100% wilt incidence to Mareko fana variety. As a result, it was used to evaluate the efficacy of fungicides by using poisoned food technique. Among tested 5 fungicides, URGI 75% WP, Nativo SC 300, Twinstar 75 WG led to 98.8%, 94.0% and 92.3% mycelia growth inhibition, respectively. Mancodex Super 72 WP (2.9%) and Agro Laxyl MZ 63.5 WP (6.5%), that was not effective in inhibiting the mycelial growth of hot pepper *Fusarium* wilt.

3.1 Study area

Chitradurga district is located on the valley of the Vedavati River in the central part of the Karnataka. It is located at 14.23°N to 76.4°E. It has an average elevation of 732 metres (2401 ft) and covers a total geographical area of 8388 sq. kms. The district is divided into 6 Taluks, namely Chitradurga, Hiriyur, Hosadurga, Holalkere, challakere and Molakalmuru. The average temperature during the summer reaches up to 42ºC and minimum during winter can be 12ºC and the annual rainfall occurs is 668mm (varies between 668mm in Holalkere in western part to 457mm in Challakere). The major soil type is black soil and red soil. Chitradurga is an agriculture dominant economy with over 50% of the net area under cultivation.

The study was done in all the six taluks of Chitradurga district namely Chitradurga, Hiriyur, Hosadurga, Holalkere, Challakere and Molakalmuru.

3.2 Field Survey and Collection of Samples

A field survey was done during 2019-2021 in major vegetable growing region of the Chitradurga district to estimate the fungal diseases. During the period a repeated field visit was made randomly to the farms in Chitradurga District. The minimum two to three villages of each taluk were selected for the collection of the samples based on symptoms like wilt, leaf spot, anthracnose, Blight, fruit rot etc.

The plant parts such as leaves and fruits showing disease symptoms were collected and cut in to pieces to accommodate in polythene cover using alcohol sterilized scissors, kept in new polythene bags, sealed, details of collected samples recorded and transported to the laboratory (Prasannath *et al* 2011). The samples were stored in refrigerator till the further processing.

Fig: 3.1 Location of Chitradurga district in Karnataka Map

Fig: 3.2 Map revealing the Surveyed Area

3.3 General procedures

3.3a Glassware cleaning and sterilization

In all the experimental studies borosil glass wares were used for the studies. They were washed with vim powder followed by washing in running tap water and rinsing in distilled water. Then all the glass wares were sterilized in hot air oven at 160℃ for one hour followed by autoclave in 15lb/psi (121℃) for 15 minutes.

3.3b Preparation of medium (PDA)

For isolation and identification of fungi in laboratory Potato Dextrose Agar (PDA) medium were used. Boil 200g of sliced unpeeled potatoes in 1 liter of water for 30 minutes. Filter through cheesecloth, saving effluent, which is potato infusion. Add 20g of each dextrose and agar were added to effluent and make up to 1 litre by adding distilled water. Sterilize media by autoclaving at 121ºC for 15 minutes (Digambar and Sahera-2016).

3.4 Isolation and Identification of the pathogen

The collected specimen exhibiting diseased symptom was washed thoroughly in running tap water. A portion of the infected tissue along with adjacent small unaffected tissue were cut into small pieces (2-5mm) and they were transferred to sterile Petridishes containing 1% Sodium hypo chlorite (NaOCl) solution for surface sterilization of plant tissue for 1 minute and washed repeatedly with sterile distilled water to remove disinfectants and dried on sterile filter paper.

The sterilized pieces were aseptically transferred to Petridishes containing Potato Dextrose Agar (PDA) medium added with ampicillin to check bacterial contamination. The plates were incubated at room temperature (25±2ºC) for 7-10 days for the growth of mycelium and were sub cultured on PDA slants for pure culture maintenance (Nagendran *et al* -2016).

3.4a Microscopic identification and Characterization:

The culture plate showing the growth of the fungus was observed for the colony morphology and growth characteristics. For microscopic observation fungal structure like mycelia, spore bearing structure and spores were picked up with a needle. Semi-permanent mounts were prepared using lactophenol cotton blue and the slides were observed under microscope for the mycelial and spore bearing structures.

Based on the observations, the fungal pathogens were identified up to species level based on morphology, colony colour, size and shape of the spores and conidia and confirmed using standard manual (Barnett and Hunter 1972; Booth 1971; Nagamani *et al* 2006; Nelson *et al* 1927).

The percentage of occurrence was calculated by using the formula (Hata and Futai -1995).

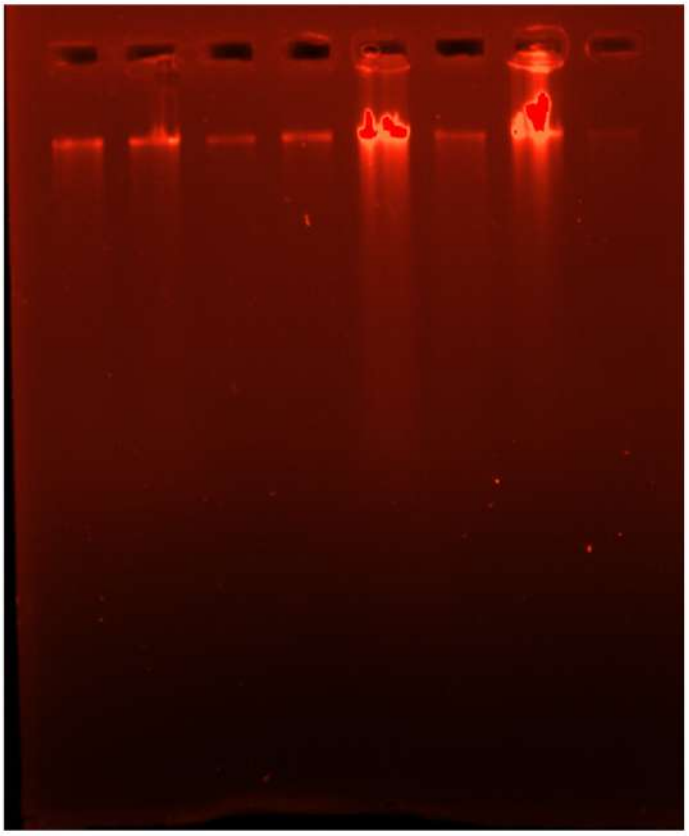
$$\% \text{ Occurrence} = \frac{\text{Number of individual colony}}{\text{Total number of colonies isolated}} \times 100$$

3.4b Molecular Identification

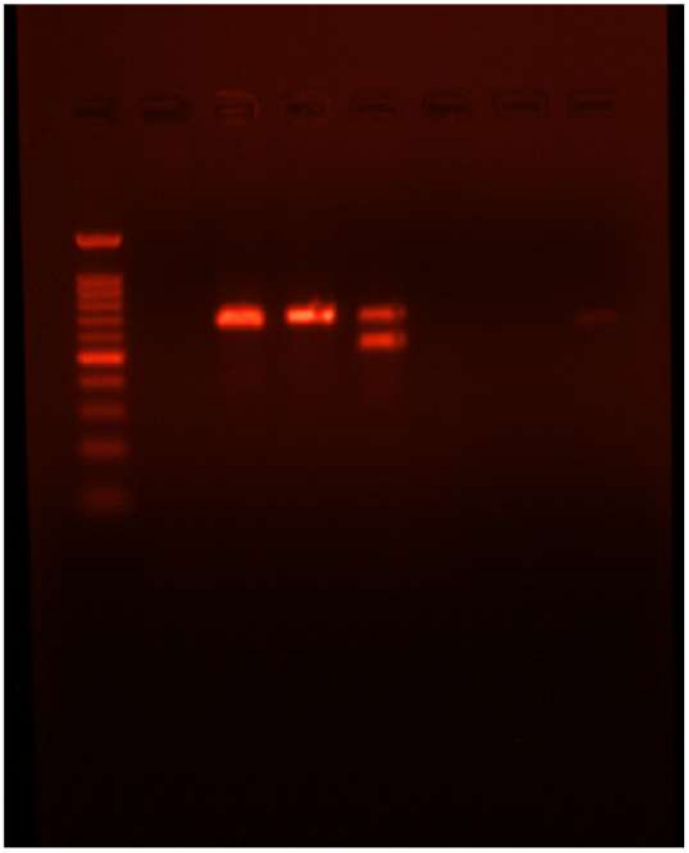
DNA extraction, PCR amplification and sequencing

Identification of some fungal pathogen was confirmed using molecular techniques. The genomic DNA was isolated from fresh fungal mycelium using CTAB DNA extraction method (Wu *et al* 2001). Seven days old freshly cultured mycelial mats (grown in potato dextrose agar at the temperature of 24±1℃) were taken for isolation of genomic DNA. The fresh fungal mycelium of culture plate was scraped out with the help of sterilized spatula. Approximately 300mg of fresh fungal mycelium was homogenized with 500 µl of 2X CTAB extraction buffer pre-warmed to 65℃ in a 1.5 ml micro centrifuge tube with the help of micro pestle, vertexing and incubated in a water bath at 65℃ for 1 hour. Then centrifugation was done at 13000 rpm for 20 min and adds 1µl of RNAse A and incubated at 37℃ for 10 min and the added PCI (Phenol: Chloroform: Isoamyl Alcohol) in 25:24:1 ratio with invert mixing. Then it is centrifuged at 10000 rpm for 10 min at room temperature and supernatant was extracted. To precipitate the DNA, add 500 µl of ice-cold isopropanol and incubated overnight at 4℃, centrifugation at 10000 rpm at 4℃ for 10 min to pellet the DNA and wash two times with 70% ethanol, dried and dissolved in 50 µl of 1X TE buffer. Then 2 µl of genomic DNA was subjected to Agarose gel electrophoresis and observed under Gel doc.

Polymerase Chain Reaction (PCR) were performed using Eppendorf Master cycler nexus GX2 in 0.2 ml PCR tubes with 50 µl reaction mixture containing, 25 µl double distilled water, 8 µl 10X PCR buffer A (HiMedia). Then take each primer of 2.5 and 0.5 µl of Taq DNA polymerase (3U/µl), 1.5 µl of dNTP's mixture and 10 µl of DNA sample. The nuclear ribosomal internal transcribed spacer (nrITS) was



Agarose Gel showing genomic DNA



Agarose Gel showing amplified ITS region

Photoplate-1

amplified using the primer pairs ITS1 – ITS4 (White *et al* 1990). The modified protocols of Kantharaja and Krishnappa (2020) were followed for PCR amplification and sequencing. The newly generated sequences were aligned and consensus sequences were generated using BioEdit v.7.2.5 (Hall 1999). The consensus sequences were used for BLASTn (Basic Local Alignment Search Tool) search on the NCBI (National Center for Biotechnology Information) GenBank nucleotide database (https:// www.ncbi.nlm.nih.gov) to know the sequence similarity and distance tree results and the identified sequences are deposited in the GenBank.

Phylogeny:

The selected sequences were retrieved from the NCBI GenBank and combined with new sequences to conduct the phylogenetic analysis. The sequences were aligned by MAFFT (Multiple Alignment using Fast Fourier Transform) and maximum likelihood (ML) analysis. The tree was analyzed and edited by using one fungus as out group species.

3.5 Pathogenicity Test

The pathogenicity test is the main criterion for the identification of pathogens suspected of being the etiological agents of a plant disease. This involves reproduction of certain symptoms following artificial infection of suitable hosts under greenhouse conditions.

3.5a Rising of Seedlings

The local seeds were collected from the local market and farmers of Chitradurga district. The collected seeds were grown in plastic trays by using

sterilized coco peat mass up to 25 days in the polyhouse. Then healthy seedlings were used for the pathogenicity test by Root Dip Method.

3.5b Preparation of spore suspension

Mycelium should be collected from one week old colonies grown on PDA with a scalpel and suspended in 10ml 0f distilled water. After that suspension should be filtered through sterilized filters. Then the concentration was adjusted to 1×10^6 spores/ ml by using Haemocytometer.

3.5c Pathogenicity test By Root Dip Method

To determine the virulence of pathogen, the analysis of the strains was carried out on a set of fifteen susceptible plants for each pathogen. A total of 34 pathogenic fungi were tested for pathogenicity. Twenty five day old healthy seedlings were inoculated by standard root dip method. Seedlings were uprooted carefully preserving the root integrity, shaken to remove the adhering particles and washed gently under tap water. The root apex (about 1 cm) was trimmed with a pair of sterile scissors and submerged in the conidial suspension for 30minutes of each pathogen separately. Seedlings dipped in sterile water served as control. The inoculated seedlings and control were transplanted to plastic pots containing sterilized soil. Five seedlings per pot of three replicates were transplanted. Plants were maintained in a greenhouse where day and night temperatures varied between 25–30°C. Seedlings were watered daily and disease symptoms were observed and recorded (Nirmaladevi *et al*-2016).

An assessment of disease incidence was calculated by using the formula (Hussein and Zubaidi-2019).

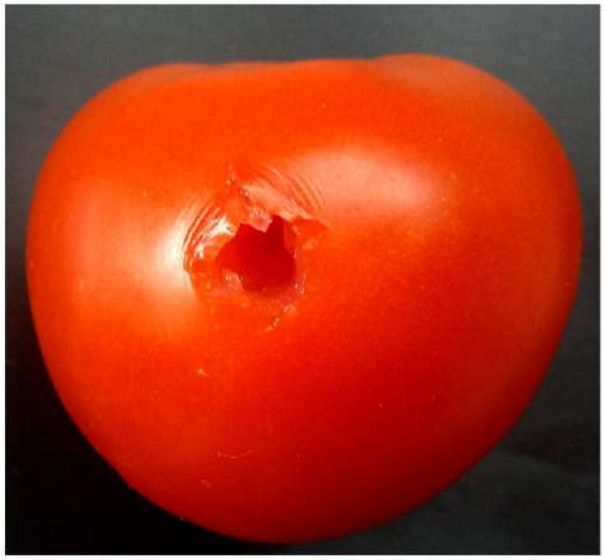
$$\text{Disease incidence (\%)} = \frac{\text{No.of infected plants}}{\text{Total number of plant inoculated}} \times 100$$

Symptoms started to be visible 15–20 days after artificial inoculation. Disease severity was assessed from 2 weeks of inoculation up to 45 days. The disease index used throughout the experiments ranged from 0 to 100% (0- healthy plant; 25- initial symptoms of leaf chlorosis; 50- severe leaf chlorosis and initial symptoms of diseases like wilting and spot; 75-severe symptoms and leaf chlorosis; 100-plant totally wilted or spotted, leaves completely necrotic or plant completely destroyed (death of plant) (Nirmaladevi *et al*-2016; Guney I G and Guldur M E-2018).

3.5d Pathogenicity test By Pricking method

Healthy matured fruits of Tomato, Chilli and Brinjal were collected and thoroughly washed under running tap water and then disinfected in 1% Sodium hypo chlorite (NaOCl) solution for one minute. Excessive Sodium hypo chlorite (NaOCl) solution was removed by placing it on two layers of sterile autoclaved filter paper. The fruits were pricked and inoculated with 5 mm actively growing mycelial block of test fungus and incubated for 7 days. In control plates 5 mm agar blocks were inoculated on fruits. The test fungus was tested to find out their pathogenic potentiality. Three replications were maintained in test fungus. All Petri plates were incubated at 25±2℃ for 7 days (Chapol *et al* -2019).

For further confirmation, the expressed disease symptomatic leaves and fruits were re-isolated in the same culture media with same morphometric and cultural characteristics. This exhibits the Koch's Postulates.



Healthy Tomato fruit pricked for inoculation

Pricked Healthy Tomato fruits in replicates

Healthy Chilli fruit pricked for inoculation

Pricked Healthy Chilli fruits in replicates

Healthy Brinjal fruit pricked for inoculation

Pricked Healthy Brinjal fruits in replicates

Plate:-2 Pathogenicity Test by Pricking method

3.6 In *vitro* control Measures by using Chemical Fungicide

Chemical control has been considered as the most effective method for management of diseases of many economically/commercially important crops against various pathogens. Carbendazim and Mancozeb are generally used for the management of fruit and foliar diseases of vegetables. Fungicide like Metalaxyl is recommended for blight disease of Tomato and Potato.

The effect of different fungicides of different concentration on the fungal pathogen was evaluated. The following fungicides were used in the treatment.

Sl. No.	Common name	Chemical name	Trade Name
1.	Mancozeb	Manganese ethylenebis-dithiocarbamate	Dithane M-45
2.	Carbendazim	Methyl-1H-benzimidazole-2-yl carbamate	Bavistin
3.	Captan	N-(trichloromethylthio)-4-cyclohexane-1,2-dicarboximide	Captan
4.	Metalaxyl	Methyl N-(Methoxyacetyl)-N-(2,6-xylyl)-DL-(alaniate)	Tagron 35
5.	Carbendazim 12%+Mancozeb 63%	Sodium salt of aryl and napthyl sulphonate	SAAF

3.6a preparation of fungicide solution

Dissolve 0.5g of all fungicides in 100ml of distilled water in a separate conical flask to make a standard solution (0.5%). Prepare a 0.05% solution to take 10 ml of

stock solution and dilute it to 100ml by adding 90ml of distilled water. Similarly, 0.1%, 0.15% and 0.2% solution were prepared by adding 20ml, 30ml and 40ml of the stock solution and make up to 100ml by adding 80ml 70ml and 60ml of distilled water respectively. All the five fungicide solution at four different concentrations was prepared.

3.6b In *vitro* inhibitory potential of fungicides against the pathogen by using Poisoned Food Technique

Different concentrations of all the fungicides were tested for its in *vitro* inhibitory activity against the pathogens using poisoned food technique (Naziya and Sharada-2018; Bashar *et al*-2015, Manju *et al*-2018 and Dahal and Shrestha-2018). Different concentration of prepared fungicide solutions was incorporated to the media and poured into petriplates separately for solidification. Next 5 mm mycelial discs of tested pathogen (seven day old) were taken and aseptically inoculated at the centre of the PDA plates. Simple PDA media plates devoid of fungicides served as control. Three replicates were used for each concentration of the fungicides. All the Plates were incubated at 25 ± 2°C for seven days and mycelial growth of the pathogen was recorded and percent inhibition of mycelial growth was calculated using the formula given by Vincent, 1947.

$$\mathbf{I = \frac{C-T}{C} \times 100}$$

Where,

I is the percent inhibition,

C is the colony diameter in control and

T is the colony diameter in treatment.

4.1 FIELD SURVEY:

Field survey was done in all the six taluks of Chitradurga districts during 2019-2021. During the survey, a total 450 isolates were collected from Chilli, Tomato and Brinjal crop fields. Out of 450 isolates, 143 were recorded in Chilli, 162 isolates recorded in Tomato and 145 isolates were in Brinjal.

Total 34 species belong to 18 genera of 12 families were isolated, identified, morphologically and microscopically characterized.

During the Kharif Season of 2019

In Chilli, total thirty four isolates were isolated from seventeen fungal species belonging to seven genera were recorded (table 4.1). All the pathogens were expressed within one week of incubation period on PDA. The major pathogenic fungi are *Fusarium oxysporum* (20.58%) and *Fusarium solani* (17.64%) were recorded in higher percentage among the isolates (Fig 4.1).

In Tomato, a total forty six isolates were recorded from twenty fungal species belonging to ten genera (Table 4.2). Among the pathogen isolated *Fusarium oxysporum* (15.21%) and *Fusarium solani* (13.04%), *Alternaria alternata* (10.86%) and *Aspergillus niger* (8.46%) were recorded in higher percentage in Kharif season (Fig 4.1)

In Brinjal, a total forty isolates were recorded from seventeen species belonging to ten genera (Table 4.3). Among the pathogen isolated *Alternaria alternata* (12.5%), Fusarium *oxysporum* (12.5%), *Cladosporium cladosporioides*

(7.5%), *Alternaria solani* (7.5%), *Fusarium solani* (7.5%) and *Aspergillus niger* (7.5%) were recorded in higher percentage in Kharif season (Fig 4.1)

In the year 2020

During Rabi season, in Chilli thirty nine isolates were recorded while seventeen fungal species were identified belongs to nine genera (Table 4.4). Among seventeen fungal pathogen *Curvularia lunata* (15.38%), *Alternaria alternata* (12.82%) exhibit the higher percentage and *Chaetomium globosum, Colletotrichum capsici, Fusarium oxysporum, Alternaria solani, Colletotrichum gloeosporioides* recorded 7.69% of occurrence among the isolates (Fig 4.2)

In Kharif, observed pathogen were *Fusarium oxysporum* (25.00%), *Fusarium solani* (21.42%), *Fusarium equiseti, Colletotrichum gloeosporioides, C. capsici, Chaetomium globosum* and *Alternaria longipes* at 7.14% having maximum percentage of occurrence (Fig 4.3) among the twenty eight isolates belonging to four genera of twelve fungal species (Table 4.7).

In Rabi season, Tomato exhibited total thirty one isolates. Among the isolates nineteen fungal pathogens were recorded belonging to ten genera (Table 4.5). In the observation *Alternaria solani* (12.90%) were recorded in maximum percentage followed by *Fusarium oxysporum* and *Fusarium solani* at 9.67% and *A. alternata, A. longipes, C. cladosporioides, L. theobromae* and *T. harzianum* of 6.45% of occurrence (Fig 4.2).

In Kharif, *Fusarium solani* (19.51%), *Fusarium oxysporum* (12.19%), *Alternaria alternata, Curvularia lunata, Aspergillus niger* showed 9.75% of

occurrence (Fig 4.3). Other fungal pathogens occur at lowest percentage among the forty one isolates belonging to eleven genera of eighteen species (Table 4.8)

During Rabi season, total thirty two isolates were recorded in Brinjal. In thirty two isolates eighteen pathogens of eleven genera were recorded (Table-4.6). *Macrophomina phaseolina* (21.87%) contribute higher percentage of occurrence followed by *C. cladosporioides* (9.37%), *A. alternata*, *F. oxysporum, F. solani, A. niger and C. lunata* contribute 6.25% among the isolates (Fig 4.2).

In Brinjal, fifteen fungal species of eleven genera were recorded out of thirty seven isolates (Table 4.9), the observed pathogenic fungi were *Alternaria alternata* (16.21%), *Alternaria solani, Curvularia lunata, Aspergillus niger* at 10.81% and *Cladosporium cladosporioides* & *Fusarium solani* of 8.10% during Kharif season (Fig 4.3).

During the Rabi Season of 2021

In Chilli total forty two isolates were isolated, among them fourteen fungal pathogens of seven genera were identified (Table 4.10). *Colletotrichum gloeosporioides* (19.04%), *Fusarium oxysporum* (16.66%), *Alternaria alternata* (11.90%), *Fusarium incarnatum* (11.90%) were found in higher percentage (Fig 4.4).

In Tomato fifteen pathogens of eleven species were identified among forty four isolates (Table 4.11). The maximum percentage of occurrence recorded in *Fusarium oxysporum* (22.72%), *Fusarium solani* (15.90%), *Curvularia lunata* (13.63%) and *Alternaria alternata* (9.09%) (Fig 4.4).

During Rabi season, Brinjal contribute thirty six fungal isolates. Among those sixteen pathogen belonging to eleven genera were recorded (Table 4.12). The maximum percentage of occurrence recorded in *Alternaria solani* (13.88%) followed by *Aspergillus niger* (11.11%), *Macrophomina phaseolina* (11.11%) and *Alternaria alternata* & *Fusarium oxysporum* of 8.33% (Fig 4.4).

The results revealed that the samples collected were heavily infected with wilt, leaf spots, blight, anthracnose and fruit rot symptoms. The major pathogens were *Fusarium oxysporum*, *Fusarium solani* and other *Fusarium* species found in Kharif season. *Alternaria solani, Alternaria alternata, Curvularia lunata, Colletotrichum gloeosporioides* and *Aspergillus niger* more in Rabi season. It may be the reason of fluctuation in environmental condition like rainfall, temperature and humidity.

During two years of survey reports revealed that the *Fusarium*, *Alternaria* and *Curvularia* species were dominant in all the regions in solanaceous vegetable crops like Tomato, Chilli and Brinjal. Among the 34 isolated fungal species *Fusarium oxysporum* contribute total 13.50% of occurrence in two years survey followed by *Fusarium solani* (11.61%), *Alternaria alternata* (9.68%), *Curvularia lunata* (7.17%), *Aspergillus niger* (6.23%), *Alternaria solani* (6.16%) and *Cladosporium cladosporioides* (4.72%). The least contribution was recorded in *Fusarium culmorum* (0.23%), *Trichoderma atroviride* (0.26%) and *Nigrospora oryzae* (0.64%) (Table 4.13).

Table: 4.1 Field survey in Chitradurga District for Chilli during Kharif-2019.

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Sirigere	Leaf spot Anthracnose	CSC01 CSC02 CSC03 CSC04	*F. solani* *F. oxysporum* *C. gloeosporioides* *A. alternata*	04
		Cheelangi	Leaf spot Wilt	CCC01 CCC02 CCC03	*F. oxysporum* *F. incarnatum* *F. solani*	03
		Kariyammanahatty	Wilt Leaf spot Anthracnose	CKC01 CKC02 CKC03 CKC04	*F. solani* *F. oxysporum* *C. cladosporioides* *A. niger*	04
2.	Holalkere	Mathigatta	Wilt Leaf spot	HMC01 HMC02 HMC03	*F. solani* *F. oxysporum* *T. harzianum*	03
		Choudagondanahalli	Wilt	HCC01 HCC02	*F. proliferatum* *F. equiseti*	02
		Gulihosahalli	Wilt Blight	HGC01 HGC02 HGC03	*F. solani* *C. akaiiensis* *A. flavus*	03
3.	Hosadurga	Nakikere	Wilt	HNC01 HNC02	*F. oxysporum* *F. solani*	02
		Kenkere	Brown spot	HKC01 HKC02	*C. lunata* *A. alternata*	02
4.	Challakere	Chikkamadure	White spot	CCC01 CCC02	*F. incarnatum* *F. oxysporum*	02
		Hirehalli	Anthracnose	CHC01 CHC02	*C. capsici* *A. niger*	02
5.	Hiriyur	M D Kote	Blight	HMC01	*A. solani*	01
		Chillahally	Spot	HCC01 HCC02	*C. fallax* *F. verticillioides*	02
6	Molakalmur	Marammanahally	Fruit Rot Leaf spot	MMC01 MMC02	*C. cladosporioides* *C. gloeosporioides*	02
		Nethranahalli	Leaf spot	MNC01 MNC02	*F. oxysporum* *A. alternata*	02
	TOTAL					34

Table: 4.2 Field survey in Chitradurga District for Tomato during Kharif-2019.

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Seegehalli	Wilt Leaf spot Blight Anthracnose	CST01 CST02 CST03 CST04 CST05	*F. solani* *F. oxysporum* *A. niger* *A. alternata* *A. solani*	05
		Kolahal	Leaf spot Wilt Fruit rot	CKT01 CKT02 CKT03 CKT04	*F. oxysporum* *F. solani* *D. halodes* *C. lunata*	04
		Hale Rangapura	Leaf spot Wilt Fruit rot	CHT01 CHT02 CHT03 CHT04	*F. equiseti* *C. cladosporioides* *A. niger* *A. flavus*	04
2.	Holalkere	Chitrahalli	Wilt	HMT01 HMT02 HMT03	*F. solani* *F. oxysporum* *T. harzianum*	03
		Choudagondanahalli	Wilt Blight	HCT01 HCT02 HCT03 HCT04	*F. proliferatum* *F. oxysporum* *F. equiseti* *A. alternata*	04
		Gulihosahalli	Leaf spot Powdery mildew	HGT01 HGT02 HGT03 HGT04	*F. solani* *C. akaiiensis* *A. flavus* *C. fallax*	04
3.	Hosadurga	Nakikere	Wilt Leaf spots	HNT01 HNT02 HNT03	*F. oxysporum* *C. cassiicola* *F. solani*	03
		Kenkere	Brown spot	HKT01 HKT02	*C. lunata* *A. alternata*	02
4.	Challakere	Chikkamadure	White spot	CCT01	*F. incarnatum*	01
		Hirehalli	Anthracnose	CHT01 CHT02 CHT03	*C. globosum* *A. niger* *C. gloeosporioides*	03
5.	Hiriyur	M D Kote	Blight	HMT01 HMT02	*A. solani* *A. alternata*	02
		Chillahally	Spot	HCT01 HCT02 HCT03 HCT04	*C. fallax* *F. verticillioides* *F. solani* *C. globosum*	04
6	Molakalmur	Marammanahally	Fruit Rot Leaf spot	MMT01 MMT02 MMT03 MMT04	*C. cladosporioides* *C. gloeosporioides* *F. oxysporum* *A. niger*	04
		Nethranahalli	Leaf spot	MNT01 MNT02 MNT03	*F. oxysporum* *A. alternata* *C. lunata*	03
TOTAL						46

Table: 4.3 Field survey in Chitradurga District for Brinjal during Kharif-2019.

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Alagavadi	Leaf spot Fruit rot	CAB01 CAB02 CAB03	*A. niger* *A. alternata* *M. phaseolina*	03
		Halavudara	Leaf spot Fruit rot	CHB01 CHB02 CHB03 CHB04	*F. moniliforme* *D. halodes* *C. cladosporioides* *A. alternata*	04
		Vijapura	Wilt	CVB01 CVB02	*F. solani* *F. oxysporum*	02
2.	Holalkere	Horakeredevarapura	Fruit rot Leaf spot	HHB01 HHB02 HHB03	*Bipolaris sps.* *L. theobromae* *C. lunata*	03
		Chitrahalli	Late blight Leaf spot	HCB01 HCB02 HCB03	*A. solani* *A. longipes* *D. halodes*	03
		Amruthapura	Wilt Leaf spot	HAB01 HAB02	*F. oxysporum* *P. vexans*	02
3.	Hosadurga	Bevinahalli	Wilt	HBB01	*F. solani*	01
		Kerehosahalli	Spots	HKB01 HKB02	*P. vexans* *A. alternata*	02
		Madadakere	Fruit rot Blight	HMB01 HMB02 HMB03 HMB04	*C. cladosporioides* *A. niger* *A. flavus* *A. solani*	04
4.	Challakere	Sanikere	Wilt Leaf spots	CSB01 CSB02 CSB03	*F. oxysporum* *A. solani* *F. verticillioides*	03
		Thaluku	Fruit rot	CTB01 CTB02 CTB03	*C. cladosporioides* *M. phaseolina* *A. niger*	03
5.	Hiriyur	Aimangala	Leaf spot	HAB01 HAB02	*C. lunata* *A. alternata*	02
		Dharmapura	Wilt Leaf spot	HDB01 HDB02 HDB03	*C. akaiiensis* *F. oxysporum* *A. solani*	03
		Harthikote	Blight	HHB01	*A. alternata*	01
6.	Molakalmur	Devasamudra	Wilt	MDB01 MDB02	*F. oxysporum* *F. solani*	02
		Surammanahalli	Wilt Spots	MSB01 MSB02	*F. solani* *A. longipes*	02
	TOTAL					40

Table: 4.4 Field survey in Chitradurga District for Chilli during Rabi-2020.

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Kariyammanahatty	Wilt Leaf spot Anthracnose	CKC01 CKC02 CKC03	*F. oxysporum* *A. alternata* *C. globosum*	03
		Kolahal	Wilt Leaf spot Anthracnose	CKC01 CKC02 CKC03 CKC04 CKC05	*C. capsici* *C. globosum* *A. longipes* *F. equiseti* *C. lunata*	05
		Vijapura	Blight Anthracnose	CVC01 CVC02 CVC03	*A. alternata* *A. solani* *C. gloeosporioides*	03
2.	Holalkere	B.Durga	Anthracnose Fruit rot	HBC01 HBC02 HBC03	*C. gloeosporioides* *C. capsici* *C. globosum*	03
		Kondapura	Leaf spot Wilt	HKC01 HKC02 HKC03 HKC04	*F. scirpi* *C. fallax* *R. stolonifer* *F. solani*	04
		T. Nulenur	Leaf spot	HTC01 HTC02	*C. cladosporioides* *C. lunata*	02
3.	Hosadurga	Kenkere	Anthracnose	HKC01 HKC02	*F. oxysporum* *C. gloeosporioides*	02
		Kerehosahalli	Wilt	HKC01	*F. solani*	01
4.	Challakere	Budnahatti	Late Blight Leaf spot	CBC01 CBC02 CBC02	*A. longipes* *A. solani* *C. lunata*	03
		Neralagunte	Anthracnose	CNC01 CNC02 CNC03	*T. harzianum* *A. niger* *C. capsici*	03
		Suranahalli	Wilt	CSC01	*F.solani*	01
5.	Hiriyur	Babbur	Wilt Leaf spot	HBC01 HBC02	*F. oxysporum* *C. lunata*	02
		Vaddikere	Blight Leaf spot	HVC01 HVC02	*A. alternata* *C. lunata*	02
		Chillahalli	Leaf spot	HCC01 HCC02	*A. alternata* *C. lunata*	02
6.	Molakalmur	Konsagara	Blight	MKC01 MKC02	*A. solani* *A. alternata*	02
		Thimmalapura	Wilt	MTC01	*F. incarnatum*	01
TOTAL						39

Table: 4.5 Field survey in Chitradurga District for Tomato during Rabi-2020.

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Seegehalli	Blight	CST01 CST02	*A. alternata* *A. longipes*	02
		Kolahal	Leaf spot Anthracnose	CKT01 CKT02 CKT03	*A. solani* *C. cassiicola* *A. niger*	03
2.	Holalkere	Kondapura	Fruit rot Leaf spot	HKT01 HKT02 HKT03	*F. oxysporum* *F. incarnatum* *N. ribis*	03
		Gulihosahalli	Leaf spot Wilt	HGT01 HGT02 HGT03 HGT04	*L. theobromae* *F. solani* *T. harzianum* *A. flavus*	04
		T nulenur	Wilt	HTT01 HTT02	*F. proliferatum* *F. scirpi*	02
3.	Hosadurga	Madadakere	Leaf spot	HMT01	*F. oxysporum*	01
		Nakikere	Wilt	HNT01	*F. solani*	01
4.	Challakere	Chikkamadure	Leaf spot Early blight	CCT01 CCT02	*F. moniliforme* *A. solani*	02
		Suranahalli	Wilt	CST01	*F. solani*	01
5.	Hiriyur	Chillahalli	Leaf spot Fruit rot	HCT01 HCT02 HCT03	*C. lunata* *A. alternata* *A. niger*	03
		M.D Kote	Late Blight	HMT01 HMT02	*A. solani* *A. longipes*	02
		Babbur	Wilt	HBT01 HBT02	*F. oxysporum* *M. phaseolina*	02
6.	Molakalmur	Marammanahalli	Early blight Leaf Spot	MMT01 MMT02	*A. solani* *L. theobromae*	02
		Nethranahalli	Wilt	MNT01	*F. equiseti*	01
		Kondlahalli	Fruit rot Anthracnose	MKT01 MKT02	*C. cladosporioides* *A. niger*	02
TOTAL						31

Table: 4.6 Field survey in Chitradurga District for Brinjal during Rabi-2020

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Sirigere	Fruit rot	CSB01 CSB02	*C. cladosporioides* *M. phaseolina*	02
		Cheelangi	Wilt	CCB01	*F. oxysporum*	01
		Alagavaadi	Leaf spot	CAB01 CAB02	*A. alternata* *A. longipes*	02
2.	Holalkere	Mathighatta	Wilt	HMB01	*F. solani*	01
		Chitrahalli	Fruit rot	HCB01 HCB02	*C. cladosporioides* *A. niger*	02
		Amruthapura	Blight	HAB01 HAB02	*A. alternata* *C. lunata*	02
3.	Hosadurga	Bevinahalli	Fruit rot	HBB01 HBB02	*C. gloeosporioides* *M. phaseolina*	02
		Kerehosahalli	Leaf spot	HKB01 HKB02 HKB03	*C. eleusinicola* *C. lunata* *M. phaseolina*	03
4.	Challakere	Chikkamadure	Leaf spot	CCB01 CCB02	*F. scirpi* *M. phaseolina*	02
		Hirehalli	Fruit rot	CHB01 CHB02 CHB03	*C. globosum* *A. niger* *T. atroviride*	03
		Thaluku	Leaf blight	CTB01 CTB02	*A. solani* *C. lunata*	02
5.	Hiriyur	Harthikote	Wilt	HHB01 HHB02	*F. solani* *F. oxysporum*	02
		Vaddikere	Leaf spot	HVB01 HVB02	*Bipolaris sps* *M. phaseolina*	02
		Mayasandra	Fruit rot	HMB01 HMB02	*M. flavus* *C. cladosporioides*	02
6.	Molakalmur	Netranahalli	Fruit rot	MNB01 MNB02	*P. vexans* *M. phaseolina*	02
		Nerlanalli	Leaf spot	MNB01 MNB02	*T. harzianum* *M. phaseolina*	02
TOTAL						32

Table: 4.7 Field survey in Chitradurga District for Chilli during Kharif-2020

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Cheelangi	Wilt Anthracnose	CCC01 CCC02 CCC03 CCC04 CCC05	*F. solani* *F. equiseti* *C. capsici* *C. gloeosporioides* *C. globosum*	05
		Kolahal	Leaf spot	CKC01 CKC02	*F. oxysporum* *F. incarnatum*	02
		Kariyammanahatty	Wilt	CKC01	*F. solani*	01
2.	Holalkere	Gulihosahalli	Wilt Leaf spot	HGC01 HGC02 HGC03	*F. oxysporum* *F.solani* *A. alternata*	03
		Choudagondanahalli	Anthracnose	HCC01	*C. capsici*	01
3.	Hosadurga	Madadakere	Wilt	HMC01	*F. solani*	01
		Koratikere	Leaf spot Early blight	HKC01 HKC02 HKC03	*F. oxysporum* *A. solani* *A. longipes*	03
		Devigere	Anthracnose	HDC01 HDC02	*C. gloeosporioides* *C. globosum*	02
4.	Challakere	Sanikere	Leaf spot	CSC01 CSC02	*F. oxysporum* *F. equiseti*	02
		Netranahalli	Wilt	CNC01	*F. oxysporum*	01
5.	Hiriyur	Vaddikere	Anthracnose	HVC01 HVC02	*F. moniliforme* *F. oxysporum*	02
		M D Kote	Leaf blight	HMC01	*A. longipes*	01
6.	Molakalmur	Konsagara	Wilt	MKC01 MKC02	*F. solani* *F. verticillioides*	02
		Kondlahalli	Leaf spot	MKC01	*F. oxysporum*	01
		Surammanahalli	Wilt	MSC01	*F. solani*	01
TOTAL						28

Table: 4.8 Field survey in Chitradurga District for Tomato during Kharif-2020

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Sirigere	Wilt Leaf spot	CST01 CST02 CST03	*F. oxysporum* *F. solani* *C. lunata*	03
		Cheelangi	Fruit rot	CCT01 CCT02 CCT03	*A. niger* *F. oxysporum* *A. flavus*	03
		Kariyammanahatty	Wilt	CKT01	*F. solani*	01
2.	Holalkere	Gulihosahalli	Fruit rot Anthracnose	HGT01 HGT02 HGT03	*A. niger* *C. globosum* *R. stolanifer*	03
		Talya	Leaf spot Wilt	HTT01 HTT02 HTT03	*F. incarnatum* *F. solani* *F. moniliforme*	03
		Bommenahalli	Wilt	HBT01 HBT02	*F. solani* *F. oxysporum*	02
3.	Hosadurga	Madadakere	Leaf spot	HMT01 HMT02 HMT03 HMT04	*C. lunata* *A. alternata* *F. solani* *Bipolaris sps.*	04
		Koratikere	Wilt	HKT01	*F. solani*	01
4.	Challakere	Sanikere	Blight	CST01 CST02	*A. alternata* *A. solani*	02
		Netranahalli	Leaf spot	CNT01 CNT02 CNT03	*F. incarnatum* *C. lunata* *D. halodes*	03
		Thalaku	Wilt	CTT01 CTT02	*F. solani* *F. equiseti*	02
5.	Hiriyur	M D Kote	Blight	HMT01 HMT02	*A. solani* *A. alternata*	02
		Vaddikere	Fruit rot	HVT01 HVT02	*A. niger* *C. gloeosporioides*	02
		Babbur	Wilt	HBT01	*F. solani*	01
6.	Molakalmur	Konsagara	Leaf spot	MKT01 MKT02 MKT03 MKT04	*A. alternata* *F. oxysporum* *C. akaiiensis* *L. theobromae*	04
		Kondlahalli	Fruit rot	MKT01 MKT02 MKT03	*A. niger* *F. oxysporum* *R. stolonifer*	03
		Surammanahalli	Leaf spot	MST01 MST02	*N. ribis* *C. lunata*	02
	TOTAL					41

Table: 4.9 Field survey in Chitradurga District for Brinjal during Kharif-2020

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Sirigere	Leaf spot Wilt	CSB01 CSB02 CSB03	*A. alternata* *F. oxysporum* *N. oryzae*	03
		Cheelangi	Leaf spot Wilt Fruit rot	CCB01 CCB02 CCB03 CCB04 CCB05	*A. alternata* *A. solani* *P. vexans* *M. phaseolina* *F. equiseti*	05
		Kariyammanahatty	Fruit rot	CKB01 CKB02	*C. cladosporioides* *A. niger*	02
2.	Holalkere	Talya	Blight	HTB01 HTB02 HTB03	*C. lunata* *A. alternata* *A. solani*	03
		Bommenahalli	Leaf spot	HBB01 HBB02	*D. halodes* *C. eleusinicola*	02
		Kondapura	Wilt Fruit rot	HKB01 HKB02 HKB03 HKB04	*F. solani* *A. niger* *M. flavus* *L. theobromae*	04
3.	Hosadurga	Kenkere	Blight	HKB01 HKB02	*A. solani* *A. alternata*	02
		Devigere	Wilt	HDB01 HDB02	*F. solani* *F. oxysporum*	02
		Madadakere	Leaf spot	HMB01 HMB02	*C. lunata* *C. eleusinicola*	02
4.	Challakere	Sanikere	Wilt	CSB01	*F. solani*	01
		Netranahalli	Fruit rot	CNB01 CNB02	*M. phaseolina* *A. niger*	02
5.	Hiriyur	Babbur	Leaf spot Blight	HBB01 HBB02	*A. alternata* *C. lunata*	02
		Chillahalli	Blight	HCB01 HCB02 HCB03	*A. alternata* *A. solani* *C. lunata*	03
6.	Molakalmur	Konsagara	Fruit rot	MKB01 MKB02	*A. niger* *C. cladosporioides*	02
		Kondlahalli	Fruit rot	MKB01 MKB02	*P. vexans* *C. cladosporioides*	02
TOTAL						37

Table: 4.10 Field survey in Chitradurga District for Chilli during Rabi-2021

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Seegehalli	Wilt Fruit rot	CSC01 CSC02	*F. oxysporum* *C. gloeosporioides*	02
		Cheelangi	Leaf spot Anthracnose	CCC01 CCC02 CCC03	*F. moniliforme* *C. gloeosporioides* *C. capsici*	03
		Haluvudara	Anthracnose	CHC01 CHC02 CHC03	*C. globosum* *F. oxysporum* *C. gloeosporioides*	03
2.	Holalkere	Nulenur	Wilt	HNC01 HNC02	*F. solani* *F. incarnatum*	02
		HD Pura	Leaf spot Blight	HHC01 HHC02 HHC03 HHC04	*F. oxysporum* *C. eleusinicola* *A. alternata* *C. lunata*	04
3.	Hosadurga	Kenkere	Leaf spot	HKC01 HKC02	*F. incarnatum* *F. oxysporum*	02
		Nakikere	Leaf spot Antracnose	HNC01 HNC02 HNC03 HNC04	*C. gloeosporioides* *C. cladosporioides* *C. capsici* *A. alternata*	04
4.	Challakere	Budnahatti	Wilt Blight	CBC01 CBC02 CBC03	*F. oxysporum* *F. incarnatum* *A. solani*	03
		Suranahallli	Wilt	CSC01	*F. solani*	01
		Madure	Leaf spot Anthracnose	CMC01 CMC02 CMC03	*F. oxysporum* *A. alternata* *C. gloeosporioides*	03
5.	Hiriyur	Harthikote	Anthracnose	HHC01 HHC02 HHC03	*C. gloeosporioides* *M. flavus* *C. capsici*	03
		Metikurke	Wilt Fruit rot	HMC01 HMC02 HMC03	*F. incarnatum* *C. gloeosporioides* *C. capsici*	03
6.	Molakalmur	Kondlahalli	Wilt Leaf spot	MKC01 MKC02 MKC03	*F. incarnatum* *C. lunata* *A. alternata*	03
		Marammanahalli	Leaf spot Wilt	MMC01 MMC02 MMC03	*F. oxysporum* *F. solani* *C. lunata*	03
		Nethranahalli	Anthracnose Blight	CNC01 CNC02 CNC03	*C. gloeosporioides* *A. alternata* *A. longipes*	03
	TOTAL					42

Table: 4.11 Field survey in Chitradurga District for Tomato during Rabi-2021

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Hale Rangapura	Wilt Leaf spot	CHT01 CHT02 CHT03 CHT04	*F. oxysporum* *F. solani* *C. cassiicola* *C. lunata*	04
		Cheelangi	Leaf spot	CCT01 CCT02	*N. ribis* *A. alternata*	02
		Kariyammanahatty	Anthracnose	CKT01 CKT02	*A. niger* *F. oxysporum*	02
2.	Holalkere	Nulenur	Fruit rot	HNT01 HNT02 HNT03	*F. solani* *C. cladosporioides* *A. niger*	03
		HD Pura	Leaf spot	HHT01 HHT02 HHT03	*C. lunata* *C. cassiicola* *A. alternata*	03
		Chitrahalli	Wilt	HCT01 HCT02	*F. oxysporum* *F. solani*	02
3.	Hosadurga	Nakikere	Leaf spot	HNT01 HNT02 HNT03	*D. halodes* *F. oxysporum* *C. lunata*	03
		Bokikere	Fruit rot Leaf spot	HBT01 HBT02 HBT03 HBT04 HBT05	*F. oxysporum* *C. lunata* *C. cladosporioides* *N. oryzae* *F. incarnatum*	05
4.	Challakere	Suranahallli	Wilt Leaf spot	CST01 CST02 CST03	*F. oxysporum* *F. solani* *C. eleusinicola*	03
		Hirehalli	Wilt	CHT01 CHT02	*F. oxysporum* *F. solani*	02
		Neralagunte	Fruit rot Leaf spot	CNT01 CNT02 CNT03 CNT04	*A. alternata* *L. theobromae* *C. lunata* *F. oxysporum*	04
5.	Hiriyur	Harthikote	Wilt	HHT01	*F. solani*	01
		Metikurke	Leaf spot	HMB01 HMB02	*F. solani* *D. halodes*	02
6.	Molakalmur	Kondlahalli	Wilt Fruit rot	MKB01 MKB02 MKB03	*A. alternata* *C. lunata* *F. oxysporum*	03
		Marammanahalli	Wilt	MMB01 MMB02	*F. incarnatum* *F. oxysporum*	02
		Nethranahalli	Anthracnose Leaf spot	MNB01 MNB02 MNB03	*R. stolonifer* *A. niger* *L. theobromae*	03
TOTAL						44

Table: 4.12 Field survey in Chitradurga District for Brinjal during Rabi-2021

Sl. No	Taluks	Village	Symptoms	Isolate	Organisms	Total isolates
1.	Chitradurga	Cheelangi	Leaf spot Early blight	CCB01 CCB02 CCB03	*A. alternata* *A. solani* *A. longipes*	03
		Kolahal	Wilt Spot	CKB01 CKB02 CKB03	*F. moniliforme* *F. culmorum* *A. solani*	03
2.	Holalkere	Nulenur	Fruit rot	HNB01 HNB02 HNB03	*M. phaseolina* *A. niger* *F. incarnatum*	03
		Chowdagondanahalli	Wilt	HCB01	*F. oxysporum*	01
		Chitrahalli	Leaf spot	HCB01 HCB02	*A. solani* *T. atroviride*	02
3.	Hosadurga	Kenkere	Leaf spot	HKB01 HKB02	*A. alternata* *L. theobromae*	02
		Nakikere	Fruit rot	HNB01 HNB02 HNB03	*M. phaseolina* *A. niger* *C. cladosporioides*	03
4.	Challakere	Suranahallli	Leaf spot	CSB01 CSB02	*C. lunata* *D. halodes*	02
		Hirehalli	Fruit rot	CHB01 CHB02	*A. niger* *C. cladosporioides*	02
		Neralagunte	Leaf spot	CNB01 CNB02 CNB03	*N. oryzae* *A. solani* *C. lunata*	03
5.	Hiriyur	Metikurke	Wilt	HMB01 HMB02	*F. oxysporum* *F. solani*	02
		Dharmapura	Blight	HDB01	*A. solani*	01
		Harthikote	Fruit rot	HHB01 HHB02	*A. niger* *M. phaseolina*	02
6.	Molakalmur	Kondlahalli	Leaf spot	HKB01 HKB02 HKB03	*M. phaseolina* *A. alternata* *N. oryzae*	03
		Marammanahalli	Wilt	HMB01 HMB02	*F. solani* *F. oxysporum*	02
		Nethranahalli	Blight Leaf spot	HNB01 HNB02	*A. longipes* *L. theobromae*	02
TOTAL						36

Table: 4.13 Percentage of Occurrence of fungus isolated on PDA medium

Sl. No	Fungal organisms	% of Occurrence			
		Chilli	Tomato	Brinjal	Total
1	*Alternaria alternata*(Fr.) Keissl	9.27	9.03	10.76	9.68
2	*Alternaria solani* Sorauer	4.14	5.52	8.82	6.16
3	*Alternaria longipes* (Ellis & Everh.)	2.38	1.61	3.41	2.46
4	*Aspergillus flavus* Link	0.73	2.49	0.62	1.28
5	*Aspergillus niger* Tiegh	2.75	7.06	8.90	6.23
6	*Bipolaris sps.* Shoemaker	-	0.60	1.40	0.66
7	*Corynespora cassiicola* (Berk. & M.A. Curtis)	-	2.48	-	0.82
8	*Curvularia lunata* (Wakker) Boedijn	6.36	8.28	6.89	7.17
9	*Curvularia akaiiensis* Sivan	0.73	1.15	0.62	0.83
10	*Curvularia eleusinicola* Ferdinandez	0.59	0.56	2.13	1.09
11	*Curvularia fallax* Boedijn	2.12	1.08	-	1.06
12	*Colletotrichum gloeosporioides* (Penz.)	9.93	1.69	0.78	4.13
13	*Colletotrichum capsici* (Syd. & P. Syd.)	6.82	-	-	2.27
14	*Chaetomium globosum* Kunze	4.30	1.69	0.78	2.25
15	*Cladosporium cladosporioides* (Fresen.)	2.70	3.83	7.63	4.72
16	*Drechslera halodes* (Drechsler)	-	2.28	2.61	1.63
17	*Fusarium oxysporum* Schltdl.	17.48	14.94	8.10	13.50
18	*Fusarium solani* (Mart.)	13.47	14.53	6.83	11.61
19	*Fusarium equiseti* (Corda)	3.16	2.49	0.67	2.10
20	*Fusarium incarnatum* (Roberge ex Desm.)	5.97	3.7	0.69	3.45
21	*Fusarium verticillioides* (Sacc.)	1.62	0.54	0.62	0.92
22	*Fusarium proliferatum* (Matsush.)	0.73	1.34	-	0.69
23	*Fusarium moniliforme* (Sacc.)	1.48	1.41	1.31	1.4
24	*Fusarium scirpi* Lambotte & Fautrey	0.64	0.80	0.78	0.74

25	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	-	-	0.69	0.23
26	*Lasiodiploidea theobromae* (Pat.)	-	3.35	3.58	2.31
27	*Macrophomina phaseolina* (Tassi)	-	0.80	8.06	2.95
28	*Mucor flavus* Bainier.	0.59	-	1.45	0.68
29	*Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.)	-	1.98	-	0.66
30	*Nigrospora oryzae* (Berk. & Broome)	-	0.56	1.36	0.64
31	*Phomopsis vexans* (Sacc. & P. Syd.)	-	-	3.38	1.12
32	*Rhizopus stolonifer* (Ehrenb.)	0.64	1.78	-	0.80
33	*Trichoderma atroviride* P. Karst.	-	-	0.78	0.26
34	*Trichoderma harzianum* Rifai,	1.37	2.15	0.78	1.43

4.2a Morphological and microscopic characters of isolated pathogen

1. *Alternaria alternata* (Fr.) Keissl., Beih. Bot. Centralbl. 29: 433 (1912)

Mycobank Number: 119834

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Alternaria*

It grows profuse mycelium on PDA. Mycelium was hyaline, grey-brownish, multicelled, septate and branched irregularly. Conidiophores are single or in cluster usually 2-6 in number and they are long or short. They were pale olivaceous to brown, straight or curved, slight swollen at the apex. Conidia are born in chains (10 or more) on conidiophores. The spores were large and appear dark in colour, varied in shape from obclavate to ellipsoidal having tapering apex with 2-10 transverse septa.

2. *Alternaria solani* Sorauer, Z. Pflanzenkrankh. Pflanzenschutz 6: 6, (1896)

Mycobank Number: 444460

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Alternaria*

It produced cottony growth, dark and grey to black with olivaceous in colour on PDA. The conidiophores are single or in groups, straight or curved, solitary, muriform and ellipsoidal tapering to a beak and pale or olivaceous brown in colour. The septation may varied from 2-12. The length of the beak was 4-10µm.

3. *Alternaria longipes* (Ellis & Everh.) E.W. Mason, Mycological Papers 2: 19 (1928)

Mycobank Number: 269712

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Alternaria*

On PDA, it forms radial colonies of greyish airy mycelia, dark green to greyish colour with clear zone. Conidiophores were brown with few septa and unbranched. Conidia were long, branched with 5-12 spores. The spores were obclavate, dark brown with 3-8 transverse and 1-2 longitudinal septa. Conidiophores and conidia were 20µm.

4. *Aspergillus flavus* Link, Mag. Ges. Naturf. Freunde Berlin 3 (1): 16 (1809)

Mycobank Number: 209842

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Eurotiomycetes, Eurotiomycetidae, Eurotiales, Aspergillaceae, *Aspergillus*

Mycelial colour of the *A. flavus* colony on PDA was white in beginning and then formed olive green conidia. The colonies were flat at border and raised in the middle. *A. flavus* were colourless, thick walled, roughed and bearing vesicles. The shape of vesicle was globose to sub-globose. The conidia were globose, thin walled, slightly roughed and 250-450µm in diameter.

5. *Aspergillus niger* Tiegh., Ann. Sci. Nat., Bot. 8: 240 (1867)

Mycobank Number: 284309

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Eurotiomycetes, Eurotiomycetidae, Eurotiales, Aspergillaceae, *Aspergillus*

The growth of *A. niger* on PDA were initially white but they changed to black after few days producing conidial spores. It having smooth, coloured conidiophores and conidia. Conidiophores are dark at apex and terminating in a globose vesicle which 30-75µm in diameter.

6. *Bipolaris sps.* Shoemaker, Canad. J. Bot. 37 (5): 882 (1959)

Mycobank Number: 7375

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Bipolaris*

On Agar plate colonies were spreading with ash grey colour to dark greenish colour. Mycelium fluffy, aerial and cottony, on reverse it is olivaceous grey to black in colour. Conidiophores are single or in small group, straight having brown colour

conidia. Conidia were brown, slightly curved, wide at middle, tapering ends and base rounded with 7 to 11 pseudosepta having 89-120µm length and 16-20µm breadth.

7. *Curvularia lunata* (Wakker) Boedijn, Bull. Jard. Bot. Buitenzorg 13 (1): 127 (1933) **Mycobank Number:** 269889

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Curvularia*

It is grown flattened greyish to brown colour colony on PDA medium and black pigmentation on reverse plate. The conidia were fusiform, curved at the second cell, septate, present in clusters on the conidiophores. The conidia measured 17-23µm in length and 6-8µm in breadth.

8. *Curvularia akaiiensis* Sivan., Mycological Papers 158: 110 (1987)

Mycobank Number: 133473

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Curvularia*

Colonies on PDA were black to olivaceous grey in colour. Hyphae were septate, branched, smooth and conidiophores were erect, branched, brown and septate. Chlamydospores were absent, conidia ellipsoidal to clavate, third cell of conidia slightly curved, brown, hila thick, slightly protuberant and darkened. Conidia measured 16-18µm length and 8-10µm in breadth.

9. *Curvularia eleusinicola* Ferdinandez, Manamgoda & Udayanga, Mycological Progress 20 (4): 438 (2021)

Mycobank Number: 835142

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Curvularia*

The colonies on PDA were flat, undulate margin, aerial mycelium and dark brown in colour. Conidiophores are brown, septate, straight and simple or branched. Conidia are dark brown, septate, middle septum was dark, smooth walled, straight, ellipsoidal and born in singly or clusters. The conidia were 19-21µm in length and 8-12µm in breadth.

10. *Curvularia fallax* Boedijn, Bull. Jard. Bot. Buitenzorg 13 (1): 129 (1933)

Mycobank Number: 264625

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Curvularia*

Colonies on PDA were dark brown to black, aerial mycelium, septate and branched. Conidiophores were brown, straight, septate and branched. Conidia were dark, septate, smooth walled and having five cells with three dark central cells and measured 30-32µm and 12-14µm in size.

11. *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc., Atti Ist. Veneto Sci. Lett. Arti Sér. 6, 2: 670 (1884)

Mycobank Number: 158410

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Glomerellales, Glomerellaceae, *Colletotrichum*

The colonies were grown fast in the PDA medium with initially white colour then turns to grey colour. In reverse creamy yellow or dull-yellow in colour. The conidia were single, one celled, cylindric, straight, few slightly curved and tapering end. The length and breadth of the conidia were 14-20µm and 4-5µm respectively.

12. *Colletotrichum capsici* (Syd. & P. Syd.) E.J. Butler & Bisby, The Fungi of India: 152 (1931)

Mycobank Number: 259713

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Glomerellales, Glomerellaceae, *Colletotrichum*

The colonies were greyish brown in colour on PDA. Mycelium was smooth, flat in growth with concentric rings. The conidia were falcate, fusiform with acute tip. The measurement ranges from 19-21µm in length and 3-3.5µm in breadth.

13. *Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei, Mycological Papers 34: 5 (1950)

Mycobank Number: 296024

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Corynesporascaceae, *Corynespora*

The colonies grown on PDA after 7days were dark grey or grey brown in colour with circular smooth margin and thinly hairy with velvety mycelial growth. Conidia were clavate or cylindrical, straight or curved, smooth, septate, brown, solitary, 53.0-230.5 x 7.3-18.5µm, with 2-14 pseudosepta.

14. *Chaetomium globosum* Kunze, Mykologische Hefte 1: 16 (1817)

Mycobank Number: 172545

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Sordariomycetidae, Sordariales, Chaetomiaceae, *Chaetomium*

Matured colonies of *Chaetomium globosum* were white to light green in colour. It produces brown colour ascospores, elliptical or lemon shaped or oval around 8-10 µm diameter with single germpore. Mycelial like appendages with tuff of hairs, ascomatal hairs are light brown in colour, ovate, ascospores are lemon shaped and measured 75.28µm.

15. *Cladosporium cladosporioides* (Fresen.) G.A. de Vries, Contribution to the knowledge of the genus Cladosporium: 57 (1952)

Mycobank Number: 294915

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Cladosporiales, Cladosporiaceae, *Cladosporium*

Colonies on PDA were grey-olivaceous, regular margin, feathery, aerial mycelium, diffuse or abundantly formed. Colony on reverse was olivaceous black and velvety. Conidia were observed in different size and shape. It may subglobose to ovoid in shape without septa but sometimes one septum was found. Sizes of the conidia were 2-13µm length and 1-4µm breadth.

16. *Drechslera halodes* (Drechsler) Subram. & B.L. Jain, Current Science 35 (14): 354 (1966)

Mycobank Number: 330196

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Drechslera*

The fungus on PDA formed brown to blackish brown colonies with black pigmentation. Conidiophores were septate, cylindrical, and brown in colour. Conidia were formed single or in groups of 2-4 with dark brown in colour. It has straight, cylindrical or ellipsoid with round ends with transversely septate with 6-8 septum with dark and thick basal septa. Conidia were 30-100µm long, 11-12µm thick and hilum distinctly protuberant.

17. *Fusarium oxysporum* Schltdl., Flora Berolinensis, Pars secunda: Cryptogamia: 139 (1824)

Mycobank Number: 218372

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

The colonies are initially white, becoming pink at maturity. Conidiophores are short, single and arranged in densely branched clusters. Macroconidia are fusiform, slightly curved, pointed at the tip, mostly 3-5 septate, basal cells pedicellate. Microconidia are abundant, never in chains, mostly non-septate, ellipsoidal to cylindrical, straight or often curved and measured 5-13µm length and 2-4µm breadth. Chlamydospores are terminal or intercalary, hyaline smooth or rough-walled.

18. *Fusarium solani* (Mart.) Sacc., Michelia 2 (7): 296 (1881)

Mycobank Number: 190352

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

On PDA growth is rapid with white colour colony, often with abundant aerial mycelium and the undersurface is generally colorless. Mycelium was branched, smooth, cylindrical and septate. Microconidia are abundant, generally single-celled and oval to kidney-shaped, 0-1 septate, 8-17µm×2-5µm. Macroconidia are abundant, stout, thick-walled and generally cylindrical and 3-4 septate. The apical cell is blunt and rounded and the basal cell is rounded or is distinctly foot-shaped or notched. Clamydospores were intercalary, single or in chains and hyaline.

19. *Fusarium equiseti* (Corda) Sacc., Syll. Fung. 4: 707 (1886)

Mycobank Number: 199819

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

The colonies were white in colour with light orange colour pigmentation. Mycelium was smooth, cylindrical, branched and septate. Conidiophores were simple, short, cylindrical and septate. Microconidia were oval, hyaline and 0-1 septate measured 12-16 µm and 3-5 µm in size. Macroconidia were curved with tapered and elongated apical cell, 2-5 septate and measured 24-40 µm and 4-6 µm in size. Clamydospores were produced intercalary, single, spherical and hyaline.

20. *Fusarium incarnatum* (Roberge ex Desm.) Sacc., Syll. Fung. 4: 712 (1886)

Mycobank Number: 231142

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

The colonies were white with light brown pigmentation and having aerial mycelia. Conidiophores were simple, short, cylindrical and septate. Microconidia were fusoid or slightly curved and 1-3 septate. Macroconidia were slender with curved surface, 3-5 septate and curved apical cell. Clamydospores were intercalary, globose and single or in chains.

21. *Fusarium verticillioides* (Sacc.) Nirenberg, Mitt. Biol. Bundesanst. Land- Forstw. 169: 26 (1976)

Mycobank Number: 314223

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

The colour of the colony was white with light orange pigmentation. The mycelium was aerial and compact. The Microconidia were oval to club shaped with flattened base, aseptate and arranged in long chains. The size of Microconidia measured 4-33 µm and 2-4 µm. Macroconidia were curved, tapering at end, 3-5 septate and measured 37-55 µm and 3-4 µm. Chlamydospores were usually absent.

22. *Fusarium proliferatum* (Matsush.) Nirenberg, Mitt. Biol. Bundesanst. Land-Forstw. 169: 38 (1976)

Mycobank Number: 362256

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

On PDA, the white aerial colour mycelium were grows rapidly. The undersurface was colorless. Microconidia are abundant, single-celled or clubshaped with a flattened base. Microconidia are borne in chains of varying length and in false heads. Macroconidia are abundant, slightly sickle-shaped to almost straight. The walls are thin and delicate and the basal cell is foot-shaped. Chlamydospores were absent.

23. *Fusarium moniliforme* J. Sheld., Annual Report of the Nebraska Agricultural Experimental Station 17: 23 (1904)

Mycobank Number: 142842

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

On PDA, the white aerial mycelium grows rapidly and is sometimes tinged with purple. The undersurface was colorless. Conidiophores were branched and Microconidia are abundant, oval, and usually single-celled, but may be 1-3 septate. Microconidia are produced only in false heads. Macroconidia are abundant, only slightly sickle-shaped to almost straight with thin, delicate walls. The basal cell is foot-shaped. Chlamydospores usually absent.

24. *Fusarium scirpi* Lambotte & Fautrey, Rev. Mycol. (Toulouse) 16: 111 (1894)

Mycobank Number: 177235

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

On PDA the mycelium was aerial and white in colour. The undersurface is generally colorless. Microconidia were scarce and almost absent, fusoid, 3 septate. Macroconidia were spindle-shaped, straight to slightly curved, 3-5 septate, apical cell tapered and pointed and foot shaped basal cell.

25. *Fusarium culmorum* (Wm.G. Sm.) Sacc., Syll. Fung. 11: 651 (1895)

Mycobank Number: 196997

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Nectriaceae, *Fusarium*

The growth is rapid on PDA with dense aerial mycelium, generally white but it turns into yellow to tan toward the. Orange to red-brown sporodochia were appears as the culture ages. The undersurface is carmine red in colour. Conidiophores were Unbranched and branched monophialides, Microconidia are absent and Macroconidia were stout, distinctly septate, thick-walled, and have curved ventral and dorsal surfaces. The basal cell varies from distinctly foot-shaped to slightly notched.

26. *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl., Bull. Soc. Mycol. France 25: 57 (1909)

Mycobank Number: 188476

Classification: Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Botryosphaeriales, Botryosphaeriaceae, *Lasiodiplodia*

Colonies were initially grey to black in colour, later it turns into black colour. On reverse it is black in colour. Pycnidia were formed with septate paraphyses between conidiogenous cells. The conidia were hyaline, dark brown with single septa, ellipsoidal to oval in shape, thin wall and measured 20-24 µm length and 10-13 µm width.

27. *Macrophomina phaseolina* (Tassi) Goid., Annali della Sperimentazione Agaria 1 (3): 457 (1947)

Mycobank Number: 300023

Classification: Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Botryosphaeriales, Botryosphaeriaceae, *Macrophomina*

The colonies were dark brown-grey in colour on PDA. The mycelium was semi appressed microsclerotia imbedded within the hyphae. The Pycnidia were black, globose and ostiolate apically. The conidiophores and conidia were hyaline, simple, cylindrical and apical. The hyphae were hyaline and thin walled and the aggregation of hyphae formed black coloured microsclerotia measured 100-120 µm in size. Microsclerotia were smooth, irregular to round or oblong in shape.

28. *Mucor flavus* Bainier, Bull. Soc. Mycol. France 19: 157 (1903)

Mycobank Number: 179990

Classification: Fungi, Mucoromyceta, Mucoromycota, Mucoromycotina, Mucoromycetes, Mucorales, Mucoraceae, *Mucor*

On PDA it forms cream or light yellow coloured mycelium. The mature sporangium has prominent columella, bulbous vesicle and sporangiophores. Sporangiospores were simple or branched, apical and globular sporangia. Hyphae were well developed and non-septate. The spores are arranged in single row and the shape of the spore was round to oval.

29. *Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.) Crous, Slippers & A.J.L. Phillips, Stud. Mycol. 55: 249 (2006)

Mycobank Number: 500881

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Dothideomycetes, Botryosphaeriales, Botryosphaeriaceae, *Neofusicoccum*

The colonies on PDA were brown to black in colour. White colour fluffy mycelium present at the margins. Conidia were hyaline, aseptate, light brown and later it 1-2 septa formed. The conidia were ellipsoidal with round apices and having truncate base and measured 16-24µm and 3.5-6.5µm in size.

30. *Nigrospora oryzae* (Berk. & Broome) Petch, J. Indian Bot. Soc. 4: 24 (1924)

Mycobank Number: 253729

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Xylariomycetidae, Xylariales, Apiosporaceae, *Nigrospora*

On PDA, the isolates were initially developed white floccose colonies and later it turns into greyish colour. The mycelium was aerial and dark brown to black in colour. The hyphae were smooth, septate, branched and hyaline. The conidiophores were in sporodochia and hyaline in nature. Conidia were single celled, subglobose, black and measured 12-14µm and 8-14µm in size.

31. ***Phomopsis vexans*** (Sacc. & P. Syd.) Harter, Journal of Agricultural Research 2 (5): 338 (1914)

Mycobank Number: 121648

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Diaporthomycetidae, Diaporthales, Diaporthaceae, *Phomopsis*

The fungal pathogen produced white mycelium with dark coloured pycnidia. The pycnidia were dark, immersed and globose. The conidiophores were simple, hyaline, one celled, ovoid to fusoid shape of conidia and measured 20 µm in size.

32. *Rhizopus stolonifer* (Ehrenb.) Vuill., Rev. Mycol. (Toulouse) 24: 54 (1902)

Mycobank Number: 119545

Classification: Fungi, Mucoromyceta, Mucoromycota, Mucoromycotina, Mucoromycetes, Mucorales, Mucoraceae, *Rhizopus*

On PDA it is initially white and cottony and turns to grey colour after three to four days with black globule structure. Mycelium was aerial and on reverse black in colour. Sporangiophores are large saclike and connected with septate hyphae.

33. *Trichoderma atroviride* P. Karst., Bidrag Kännedom Finlands Natur Folk 51: 363 (1892)

Mycobank Number: 451289

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Hypocreaceae, *Trichoderma*

Colonies of the *Trichoderma atroviridae* were green in colour at the maturity but white in initial stage. Mycelia were simple, septate and branched. Conidiophores were hyaline, septate, upright, well branched and measured 2-3 µm × 2-4 µm. Conidia were hyaline, single celled and subspherical to ovoid in shape.

34. *Trichoderma harzianum* Rifai, Mycol. Pap. 116: 38 (1969)

Mycobank Number: 340299

Classification: Fungi, Dikarya, Ascomycota, Pezizomycotina, Sordariomycetes, Hypocreomycetidae, Hypocreales, Hypocreaceae, *Trichoderma*

Colonies are green in colour. Conidiophores were hyaline, upright, branched, single or in group. Conidia hyaline, single celled, ovoid, born on the terminal clusters. It is easily identified by its rapid growth and green colour patches and number conidia.

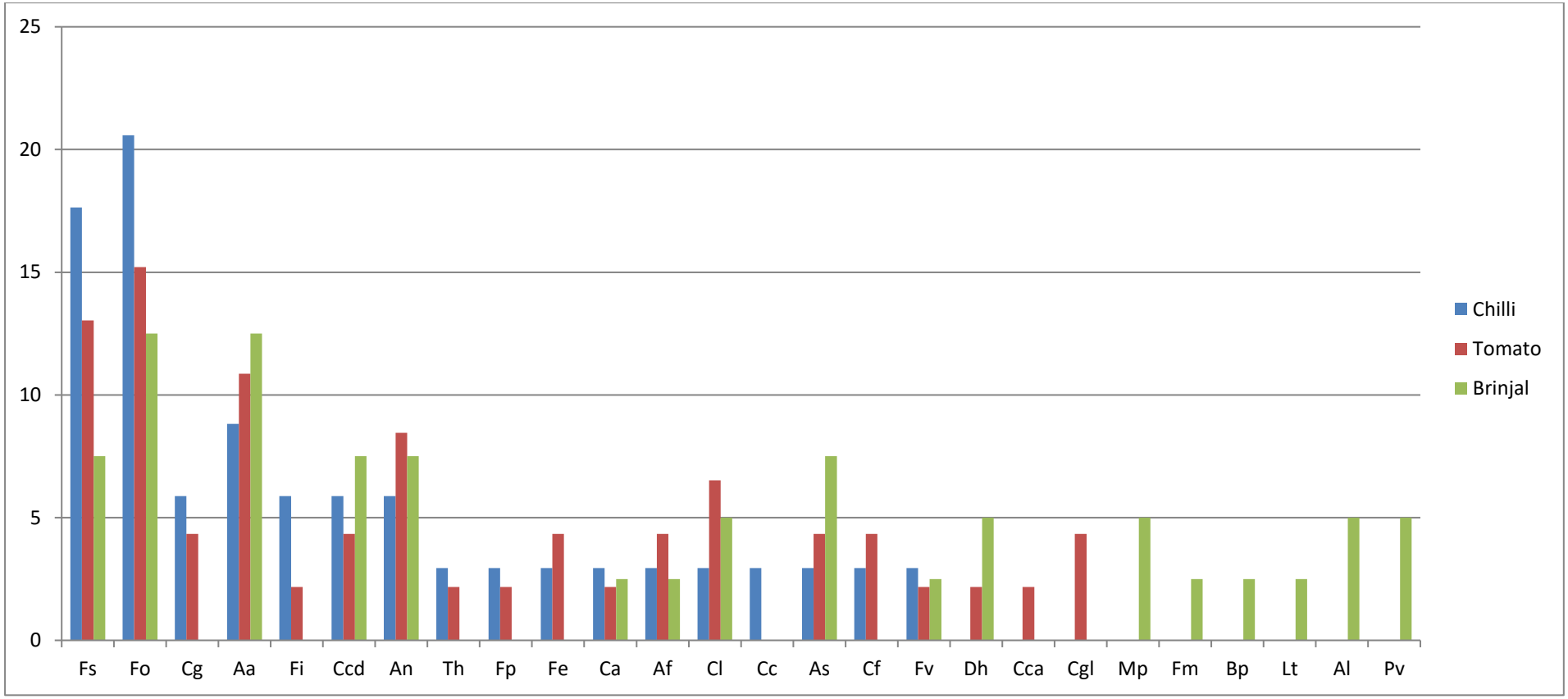


Fig 4.1: Percentage of occurrence of fungal pathogen in Kharif - 2019

Fs- Fusarium solani, Fo-Fusarium oxysporum, Cg-Colletotrichum gloeosporioides, Aa-Alternaria alternata, Fi-Fusarium incarnatum, Ccd-Cladosporium cladosporioides, An-Aspergillus niger, Th-Trichoderma harzianum, Fp-Fusarium proliferatum, Fe-Fusarium equiseti, Ca-Curvularia akaiiensis, Af-Aspergillus flavus, Cl-Curvularia lunata, Ccp-Colletotrichum capsici, As-Alternaria solani, Cf-Curvularia fallax, Fv-Fusarium verticillioides, Dh-Drechslera halodes, Cca-Corynespora cassiicola, Cgl-Chaetomium globosum, Mp-Macrophomina phaseolina, Fm-Fusarium moniliforme, Bp-Bipolaris sps, Lt-Lasiodiploidea theobromae, Al-Alternaria longipes, Pv-Phomopsis vexans

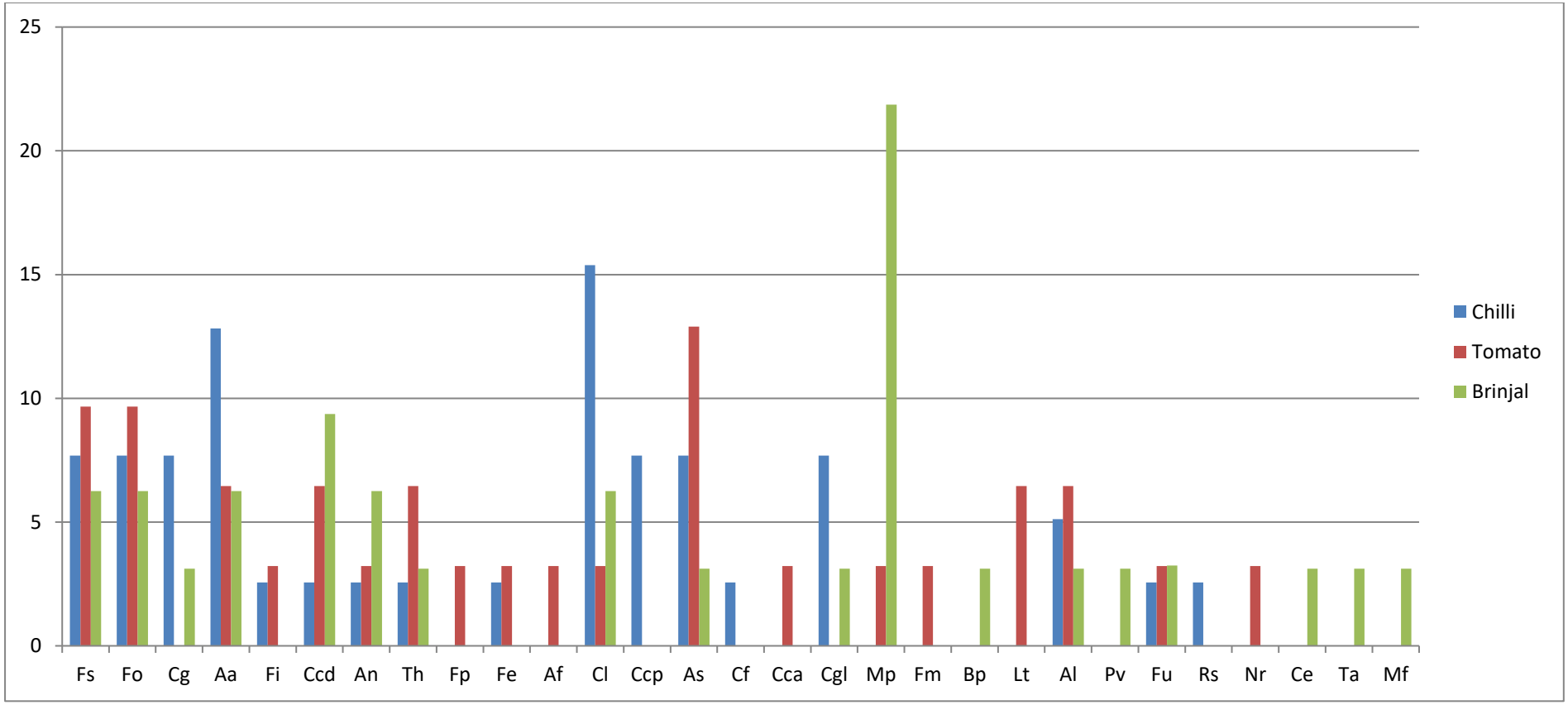


Fig 4.2: Percentage of occurrence of fungal pathogen in Rabi - 2020

Fs- Fusarium solani, Fo-Fusarium oxysporum, Cg-Colletotrichum gloeosporioides, Aa-Alternaria alternata, Fi-Fusarium incarnatum, Ccd-Cladosporium cladosporioides, An-Aspergillus niger, Th-Trichoderma harzianum, Fp-Fusarium proliferatum, Fe-Fusarium equiseti, Af-Aspergillus flavus,Cl-Curvularia lunata, Ccp-Colletotrichum capsici, As-Alternaria solani, Cf-Curvularia fallax, Cca-Corynespora cassiicola, Cgl-Chaetomium globosum, Mp-Macrophomina phaseolina, Fm-Fusarium moniliforme, Bp-Bipolaris sps, Lt-Lasiodiploidea theobromae, Al-Alternaria longipes, Pv-Phomopsis vexans, Fu-Fusarium scirpi, Rs-Rhizopus stolanifer, Nr-Neofusicoccum ribis, Ce-Curvularia eleusinicola, Ta-Trichoderma atroviride and *Mf-Mucor flavus.*

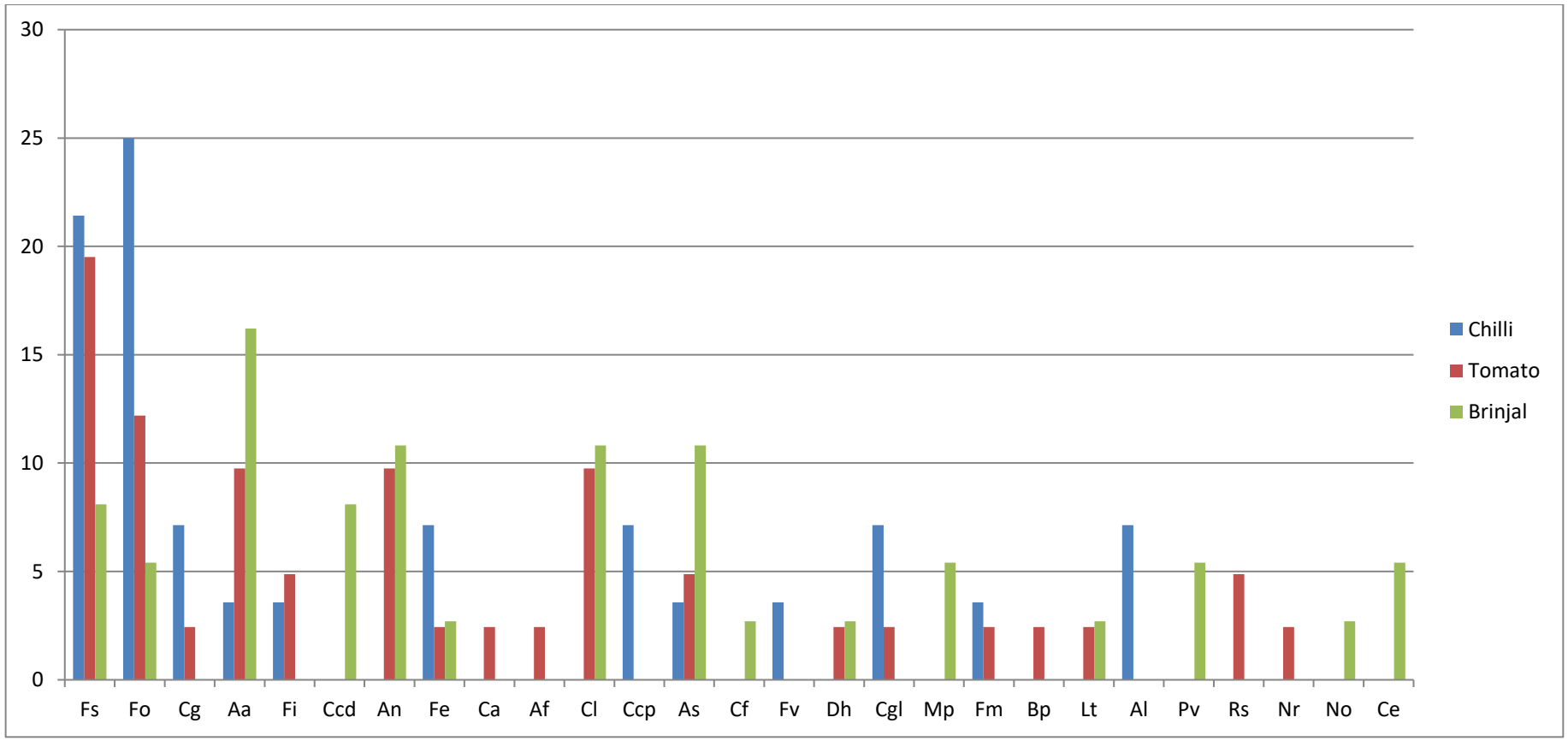


Fig 4.3: Percentage of occurrence of fungal pathogen in Kharif - 2020

Fs- Fusarium solani, Fo-Fusarium oxysporum, Cg-Colletotrichum gloeosporioides, Aa-Alternaria alternata, Fi-Fusarium incarnatum, Ccd-Cladosporium cladosporioides, An-Aspergillus niger, Fe-Fusarium equiseti, Ca-Curvularia akaiiensis, Af-Aspergillus flavus,Cl-Curvularia lunata, Ccp-Colletotrichum capsici, As-Alternaria solani, Cf-Curvularia fallax, Fv-Fusarium verticillioides, Dh-Drechslera halodes, Cgl-Chaetomium globosum, Mp-Macrophomina phaseolina, Fm-Fusarium moniliforme, Bp-Bipolaris sps, Lt-Lasiodiploidea theobromae, Al-Alternaria longipes, Pv-Phomopsis vexans, Rs-Rhizopus stolanifer, Nr-Neofusicoccum ribis, No-Nigrospora oryzae, Ce-Curvularia eleusinicola.

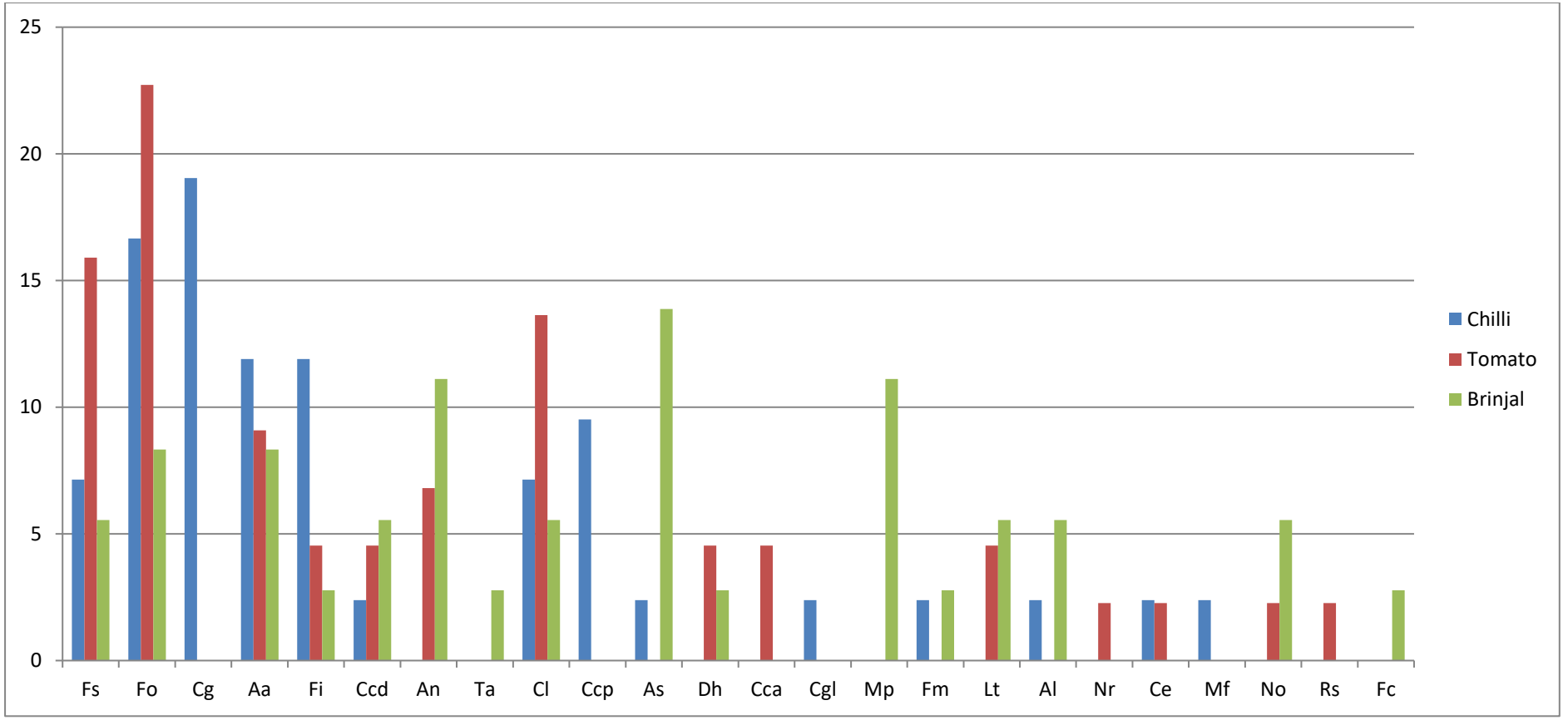


Fig 4.4: Percentage of occurrence of fungal pathogen in Rabi - 2021

Fs- Fusarium solani, Fo-Fusarium oxysporum, Cg-Colletotrichum gloeosporioides, Aa-Alternaria alternata, Fi-Fusarium incarnatum, Ccd-Cladosporium cladosporioides, An-Aspergillus niger, Ta-Trichoderma atroviride, Cl-Curvularia lunata, Ccp-Colletotrichum capsici, As-Alternaria solani, Dh-Drechslera halodes, Cca-Corynespora cassiicola, Cgl-Chaetomium globosum, Mp-Macrophomina phaseolina, Fm-Fusarium moniliforme, Lt-Lasiodiploidea theobromae, Al-Alternaria longipes, Nr-Neofusicoccum ribis, Ce-Curvularia eleusinicola, Mf-Mucor flavus, No-Nigrospora oryzae, Rs-Rhizopus stolanifer, Fc-Fusarium culmorum.

4.2b Molecular identification/Characterization:

The isolated pathogenic fungi were treated for molecular phylogenetic analysis and 14 of them yielded DNA for sequencing. The molecular characterization of nrITS nuclear gene sequences and newly generated 14 sequences are comprised with their GenBank accession number (Table 4.14).

Table 4.14: GenBank accession numbers of newly generated sequences of nrITS region during current study.

Sl. No	Species name	Specimen voucher	Accession No
1.	*Alternaria alternata* (Fr.) Keissl	NRSGH-S3	OM004050
2.	*Cladosporium cladosporioides* (Fresen.)	NRSGH-S11	OP090573
3.	*Corynespora cassiicola* (Berk. & M.A. Curtis)	NRSGH-S2	OM004059
4.	*Curvularia akaiiensis* Sivan	NRSGH-S1	OL979168
5.	*Curvularia fallax* Boedijn	NRSGH-S10	OP850601
6.	*Fusarium equiseti* (Corda)	NRSGH-S7	OM004294
7.	*Fusarium incarnatum* (Roberge ex Desm.)	NRSGH-13	OP809599
8.	*Fusarium oxysporum* Schltdl.	NRSGH-S8	OM190396
9.	*Fusarium proliferatum* (Matsush.)	NRSGH-S5	OM004067
10.	*Fusarium solani* (Mart.)	NRSGH-14	OP809604
11.	*Fusarium verticillioides* (Sacc.)	NRSGH-S4	OM004065
12.	*Lasiodiploidea theobromae* (Pat.)	NRSGH-S9	OM190399
13.	*Macrophomina phaseolina* (Tassi)	NRSGH-S6	OM004289
14.	*Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.)	NRSGH-12	OP090588

The phylogenetic relationship inferred from the Maximum Likelihood (ML) analysis of the nrITS sequence (Table 3.1) dataset consisted the alignment file with 506 distinct alignment patterns with 54.96% gaps and undetermined characters. The

phylogenetic tree (Fig 4.5) obtained by ML analysis with GTR+G+I (General Time Reversible with GAMMA model heterogeneity and Invariance) nucleotide substitution model as suggested by jModelTest v.2.1.10. The best tree of ML search was obtained after 0.303 hours with ML optimization score of -5601.545323.

In the phylogenetic tree (Fig 4.5), fourteen species from the current study and other members included in the ML analysis depicted different clades respective to their families. The newly generated sequences were recovered in the respective clusters with maximum bootstrap support. Within these clusters, monophyletic groups are recognized based on the bootstrap support values and these groups are broadly labeled based on the family which the specimens belonging to; Botryosphaeriaceae, Cladosporiaceae, Corynesporaceae, Nectriaceae and Pleosporaceae.

In the phylogenetic tree of nrITS sequence dataset, the first cluster included one newly generated sequence of specimen NRSGH-S2, which was identified as *Corynespora cassiicola* based on the formation of clade with specimen from Brazil (Cc317), Coasta Rica (INBio:627A) with 100% bootstrap support. The second clade included three newly generated specimen sequences viz., NRSGH-S1, NRSGH-S10 and NRSGH-S3, they were identified as *Curvularia akaiiensis, Curvularia fallax* and *Alternaria alternata* based on the formation of clades with specimens from Netherlands (CBS:127726, CBS:164.60, CBS:155.34), India (MLS043, MLS042), China (HNHY001), South Africa (STE-U4242) and Turkey (B74) (Table 4.15).

The third clade includes a monophyletic cluster of *Cladosporium cladosporioides* (NRSGH-S11) with 100% bootstrap support. They were identified based on the specimen from India (DJP03), China (BJ1-10, C23N) and Mexico (MTCc) (Table 4.15).

The family Nectriaceae consists of 6 species formed well supported clades with respective specimen sequences. The Fusarium clade was resolved as monophyletic with highest bootstrap support. The clade consists of six collections from the current study i.e., NRSGH-14, NRSGH-S4, NRSGH-S7, NRSGH-13, NRSGH-S5 and NRSGH-S8. *Fusarium solani* (NRSGH-14) was identified based on its cluster with species from Egypt (AUMC 9299), India (G5 and LDCMYE20) and China (G1). *F. verticillioides* (NRSGH-S4) clustered with two specimens from China (82N and PAT –M18). *F. equiseti* (NRSGH-S7) was identified based on the cluster of species from Bangladesh (feBD2) and Thailand (CL06, CL05 and CCR-02). *F. incarnatum* (NRSGH-13) clustered with species from china (JL3-3, JL5-2, CBS-2 and JL3-4-1). The collection of *F. proliferatum* (NRSGH-S5) was well recovered in a clade with 97% bootstrap support including specimens from China (254N). *F. oxysporum* (NRSGH-S8) forms grouping with specimens from Poland (S255), Morocco (BMT2) and Kenya (R24 and R36) (Table 4.15).

Botryosphaeriaceae is the second largest family found in the current study, comprising 3 collections of 3 taxa in the molecular phylogenetic analysis. The phylogenetic analysis revealed three major clades of genera Lasiodiploidea, Neofusicoccum and Macrophomina. The first clade *Lasiodiploidea theobromae* (NRSGH-S9) identified based on their clustering with the specimens from Brazil (CMM4499, CMM4513 and CMM4508) and China (ZW 50-1 and ZW 49-1). The second clade *Neofusicoccum ribis* (NRSGH-12) was based on their clustering with specimens from Malaysia (ASCM278, MPWL91 and DPWL41) and China (ZJTH1). *Macrophomina phaseolina* (NRSGH-S6) was identified based on its cluster with a specimen from India (soybean, TEF1) and China (B1) with 100% bootstrap support.

The present phylogenetic tree deliberated here consisted 14 collected pathogenic fungi from the current study and all of the reference sequences were aligned in very stable clusters with maximum (>95%) statistical support. Phylogeny was reconstructed using most similar sequences found by analyzing the NCBI BLAST search on GenBank database with *Puccinia graminis* (Basidiomycetes) as an outgroup. Based on the relative grouping of specimens in different clusters, the collections are identified and the specimen sequences were deposited in the GenBank database under specific accession numbers.

Table 4.15: List of species, their voucher number and the Genbank accession numbers of their DNA sequences used in the molecular phylogenetic analysis. The sequences generated in the current study are indicated in bold characters.

Sl. No	Species name	Voucher no.	Country of origin	Genbank accession no
	Botryosphaeriaceae			
1.	***Neofusicoccum ribis***	**NRSGH-12**	**India**	**OP090588**
2.	*Neofusicoccum ribis*	ASCM278	Malaysia	MK557959
3.	*Neofusicoccum ribis*	MPWL91	Malaysia	MK557956
4.	*Neofusicoccum ribis*	DPWL41	Malaysia	MK557955
5.	*Neofusicoccum ribis*	ZJTH1	China	MW435023
6.	*Neofusicoccum andinum*	DMW1034	USA	KU593533
7.	*Neofusicoccum andinum*	DMW1037	USA	KU593522
8.	***Lasiodiplodia theobromae***	**NRSGH-S9**	**India**	**OM190399**
9.	*Lasiodiplodia theobromae*	CMM4499	Brazil	KT325578
10.	*Lasiodiplodia theobromae*	CMM4513	Brazil	KT325577
11.	*Lasiodiplodia theobromae*	CMM4508	Brazil	KT325576
12.	*Lasiodiplodia theobromae*	ZW 50-1	China	MT644474
13.	*Lasiodiplodia theobromae*	ZW 49-1	China	MT644473
14.	*Lasiodiplodia brasiliensis*	A2A	USA	MT784902
15.	*Lasiodiplodia brasiliensis*	A2	USA	MT784901
16.	*Lasiodiplodia brasiliensis*	CFMS1342	Brazil	MF952733
17.	*Lasiodiplodia brasiliensis*	CERC 2284	China	KX278010
18.	***Macrophomina phaseolina***	**NRSGH-S6**	**India**	**OM004289**
19.	*Macrophomina phaseolina*	B1	China	OP185242
20.	*Macrophomina phaseolina*	soybean	India	OP164542
21.	*Macrophomina phaseolina*	TEF1	India	OP038266
22.	*Macrophomina phaseolina*	FCQ61	Paraguay	ON951967
	Nectriaceae			
23.	***Fusarium solani***	**NRSGH-14**	**India**	**OP809604**
24.	*Fusarium solani*	AUMC 9299	Egypt	MG734215
25.	*Fusarium solani*	G5	India	OM283616
26.	*Fusarium solani*	G1	China	MK439612
27.	*Fusarium solani*	LDCMYE20	India	MG980302
28.	*Fusarium incarnatum*	**NRSGH-13**	**India**	**OP809599**
29.	*Fusarium incarnatum*	JL5-2	China	MT563420
30.	*Fusarium incarnatum*	JL3-4-1	China	MT563419
31.	*Fusarium incarnatum*	CBB-2	China	MT563418
32.	*Fusarium incarnatum*	JL3-3	China	MT563417
33.	***Fusarium oxysporum***	**NRSGH-S8**	**India**	**OM190396**
34.	*Fusarium oxysporum*	S255	Poland	MH681159
35.	*Fusarium oxysporum*	BMT2	Morocco	OM876879
36.	*Fusarium oxysporum*	R24	Kenya	MT420651
37.	*Fusarium oxysporum*	R36	Kenya	MT420633
38.	***Fusarium equiseti***	**NRSGH-S7**	**India**	**OM004294**
39.	*Fusarium equiseti*	feBD2	Bangladesh	OP482159
40.	*Fusarium equiseti*	CL06	Thailand	OP247734

41.	*Fusarium equiseti*	CL05	Thailand	OP247732
42.	*Fusarium equiseti*	CCR-02	Thailand	OP247660
43.	***Fusarium proliferatum***	**NRSGH-S5**	**India**	**OM004067**
44.	*Fusarium proliferatum*	254N	China	OP237228
45.	***Fusarium verticillioides***	**NRSGH-S4**	**India**	**OM004065**
46.	*Fusarium verticillioides*	82N	China	OP237229
47.	*Fusarium verticillioides*	PAT-M18	China	ON008184
48.	*Gibberella moniliformis*	RKSDPK-01	India	GU055307
49.	*Gibberella moniliformis*	FKCB-006	China	EU314979
50.	*Gibberella moniliformis*	bxq33108	China	EF534189
	Corynesporaceae			
51.	***Corynespora cassiicola***	**NRSGH-S2**	**India**	**OM004059**
52.	*Corynespora cassiicola*	Cc317	Brazil	MK212951
53.	*Corynespora cassiicola*	INBio:627A	Costa Rica	KU204615
54.	*Corynespora cassiicola*	CICR-NCS	India	MN945374
55.	*Corynespora pseudocassiicola*	CPC:31708	Netherlands	MH327794
	Pleosporaceae			
56.	***Alternaria alternata***	**NRSGH-S3**	**India**	**OM004050**
57.	*Alternaria alternata*	MLS043	India	OL587526
58.	*Alternaria alternata*	MLS042	India	OL587522
59.	*Alternaria alternata*	STE-U4242	South Africa	AF397231
60.	*Alternaria alternata*	B74	Turkey	KX090314
61.	***Curvularia akaiiensis***	**NRSGH-S1**	**India**	**OL979168**
62.	*Curvularia akaiiensis*	CBS:127726	Netherlands	MH864700
63.	*Curvularia akaiiensis*	Rhizosphere Soil	India	ON209553
64.	*Curvularia lunata*	WHKKM1	India	MW494395
65.	*Curvularia lunata*	A112	Brazil	MT683262
66.	*Curvularia lunata*	B-5	Iraq	MZ314908
67.	***Curvularia fallax***	**NRSGH-10**	**India**	**OP850601**
68.	*Curvularia fallax*	HNHY001	China	JQ360963
69.	*Curvularia fallax*	CBS:164.60	Netherlands	MH857943
70.	*Drechslera avenae*	DA16	Brazil	AF260328
71.	*Drechslera avenae*	ASA-13	China	MN560117
72.	*Drechslera avenae*	ASA-12	China	MN560116
	Cladosporiaceae			
73.	***Cladosporium cladosporioides***	**NRSGH-S11**	**India**	**OP090573**
74.	*Cladosporium cladosporioides*	DJP03	India	KU707926
75.	*Cladosporium cladosporioides*	BJ1-10	China	KX527874
76.	*Cladosporium cladosporioides*	MTCc	Mexico	KP788715
77.	*Cladosporium cladosporioides*	C23N	China	OP237398
	Outgroup			
78.	*Puccinia graminis*	HSZ0928	USA	DQ417390
79.	*Puccinia graminis*	Aecia_19SPA0156	USA	OM265457
80.	*Puccinia graminis*	HSZ0802	USA	DQ417384

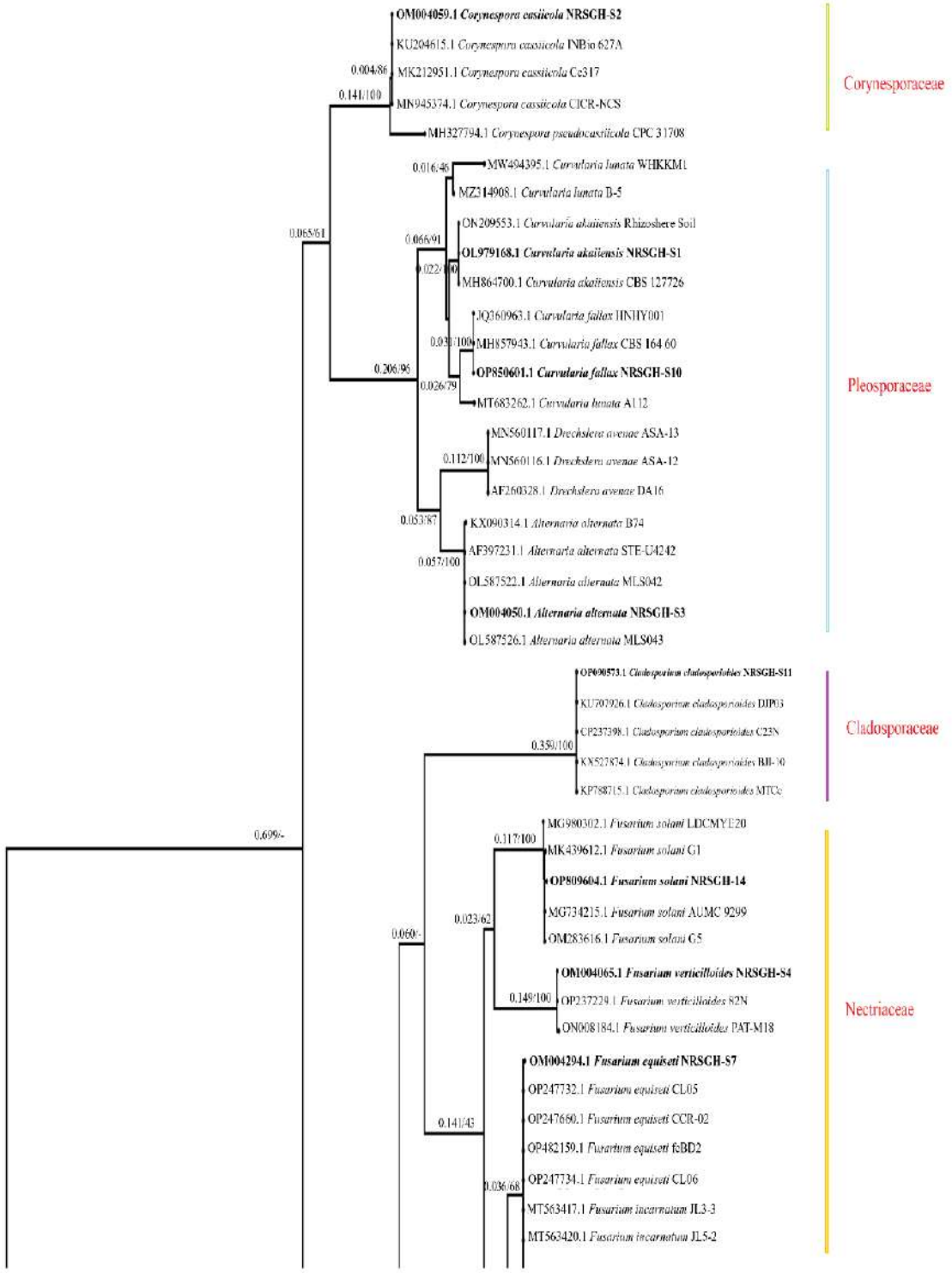
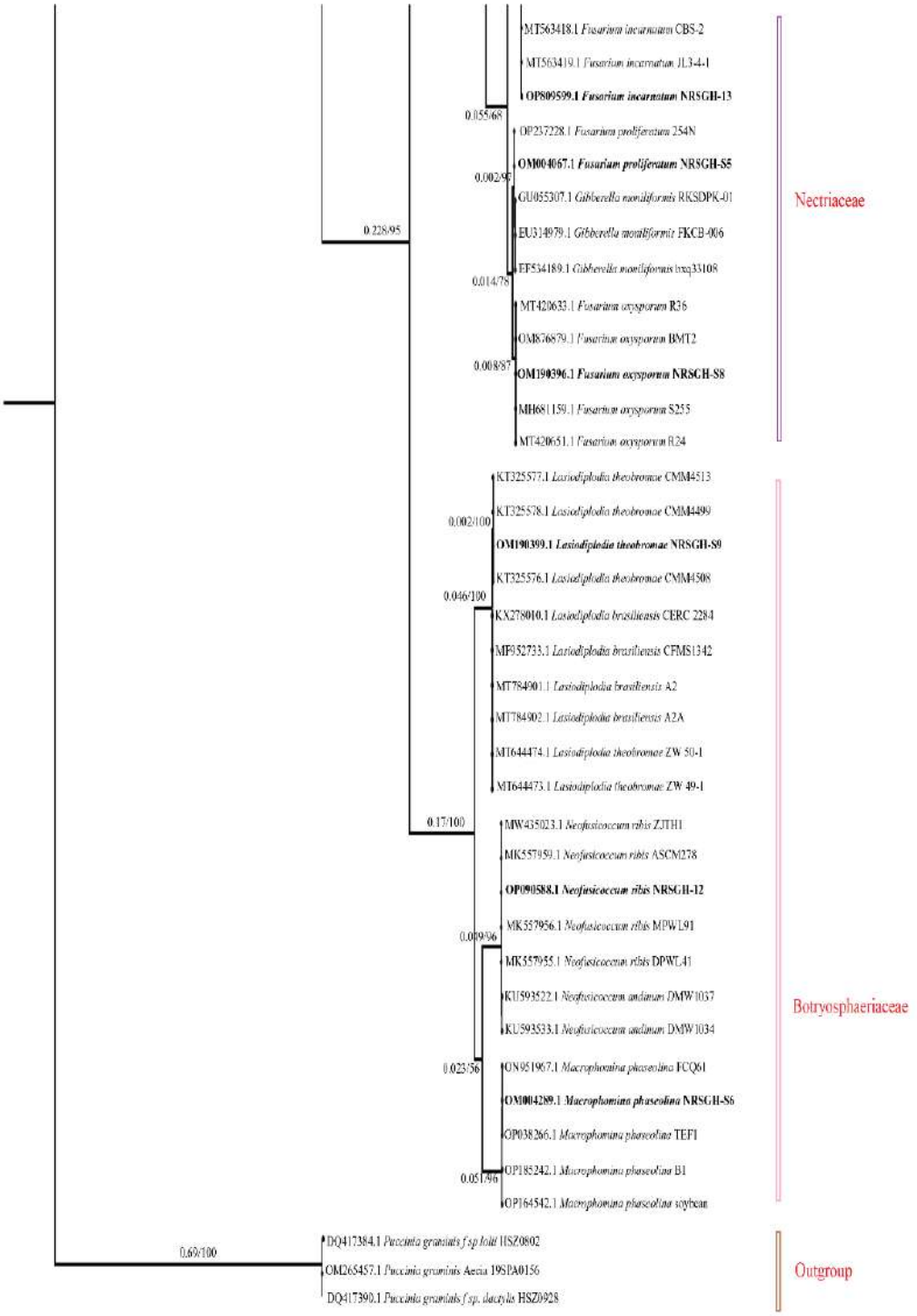


Fig 4.5: RAxML tree of Pathogenic fungi based on Maximum Likelihood analysis of nrITS sequences by GTR+G+I model with *Puccinia graminis* as outgroup showing Branch Length (BL), and Bootstrap Support values (BS>40%) as (BL/ BS).


MT563418.1 Fusarium incarnatum CBS-2
MT563419.1 Fusarium incarnatum JL3-4-1
OP809599.1 Fusarium incarnatum NRSGH-13
0.055/68
OP237228.1 Fusarium proliferatum 254N
OM004067.1 Fusarium proliferatum NRSGH-S5
0.002/95
GU055307.1 Gibberella noniliformis RKSDPK-01
0.228/95
EU314979.1 Gibberella moniliformis FKCB-006
EF534189.1 Gibberella moniliformis treq33108
0.014/78
MT420633.1 Fusarium oxysporum R36
OM876879.1 Fusarium oxysporum BMT2
0.008/87
OM190396.1 Fusarium oxysporum NRSGH-S8
MH681159.1 Fusarium oxysporum S255
MT420651.1 Fusarium oxysporum R24
Nectriaceae
KT325577.1 Lasiodiplodia theobromae CMM4513
KT325578.1 Lasiodiplodia theobromae CMM4499
0.002/100
OM190399.1 Lasiodiplodia theobromae NRSGH-S9
KT325576.1 Lasiodiplodia theobromae CMM4508
0.046/100
KX278040.1 Lasiodiplodia brasiliensis CERC 2284
MF952733.1 Lasiodiplodia brasiliensis CFMS1342
MT784901.1 Lasiodiplodia brasiliensis A2
MT784902.1 Lasiodiplodia brasiliensis A2A
MT644474.1 Lasiodiplodia theobromae ZW 50-1
MT644473.1 Lasiodiplodia theobromae ZW 49-1
0.17/100
MW435023.1 Neofusicoccum ribis ZJTH1
MK557959.1 Neofusicoccum ribis ASCM278
OP090588.1 Neofusicoccum ribis NRSGH-12
MK557956.1 Neofusicoccum ribis MPWL91
0.009/96
MK557955.1 Neofusicoccum ribis DPWL41
KU593522.1 Neofusicoccum andinum DMW1057
KU593533.1 Neofusicoccum andinum DMW1034
Botryosphaeriaceae
0.023/56
ON951967.1 Macrophomina phaseolina FCQ61
OM004289.1 Macrophomina phaseolina NRSGH-S6
OP038266.1 Macrophomina phaseolina TEF1
OP185242.1 Macrophomina phaseolina B1
0.057/96
OP164542.1 Macrophomina phaseolina soybean
0.69/100
DQ417384.1 Puccinia graminis f sp lolii HSZ0802
OM265457.1 Puccinia graminis Aecia 19SPA0156
DQ417390.1 Puccinia graminis f sp. dactylis HSZ0928
Outgroup

Contd...

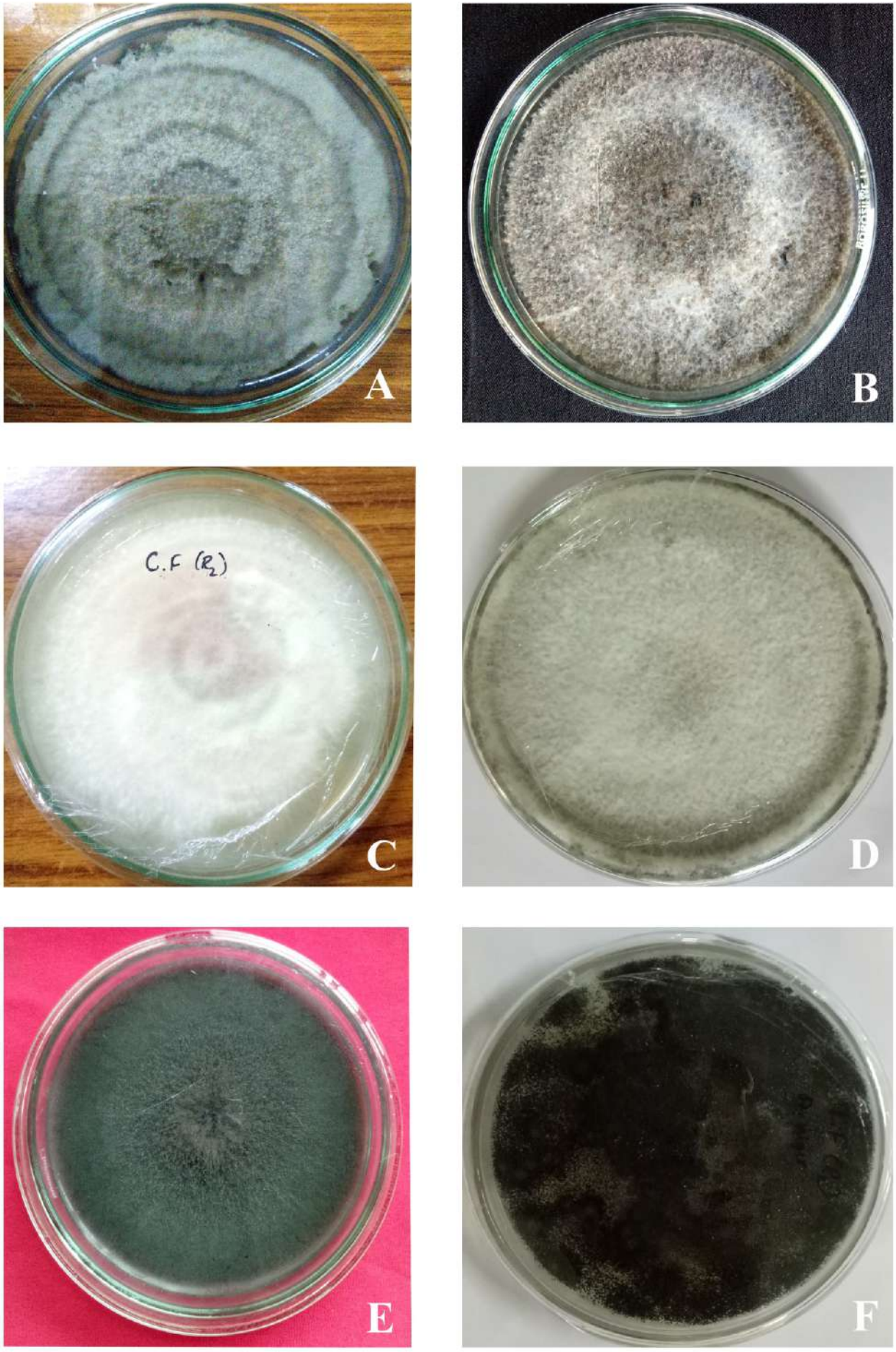


Plate-3: Pure culture of, A - *Corynespora cassiicola*, B - *Alternaria solani*, C - *Fusarium oxysporum*, D - *Colletotrichum gloeosporioides*, E - *Curvularia lunata* and F - *Aspergillus niger*

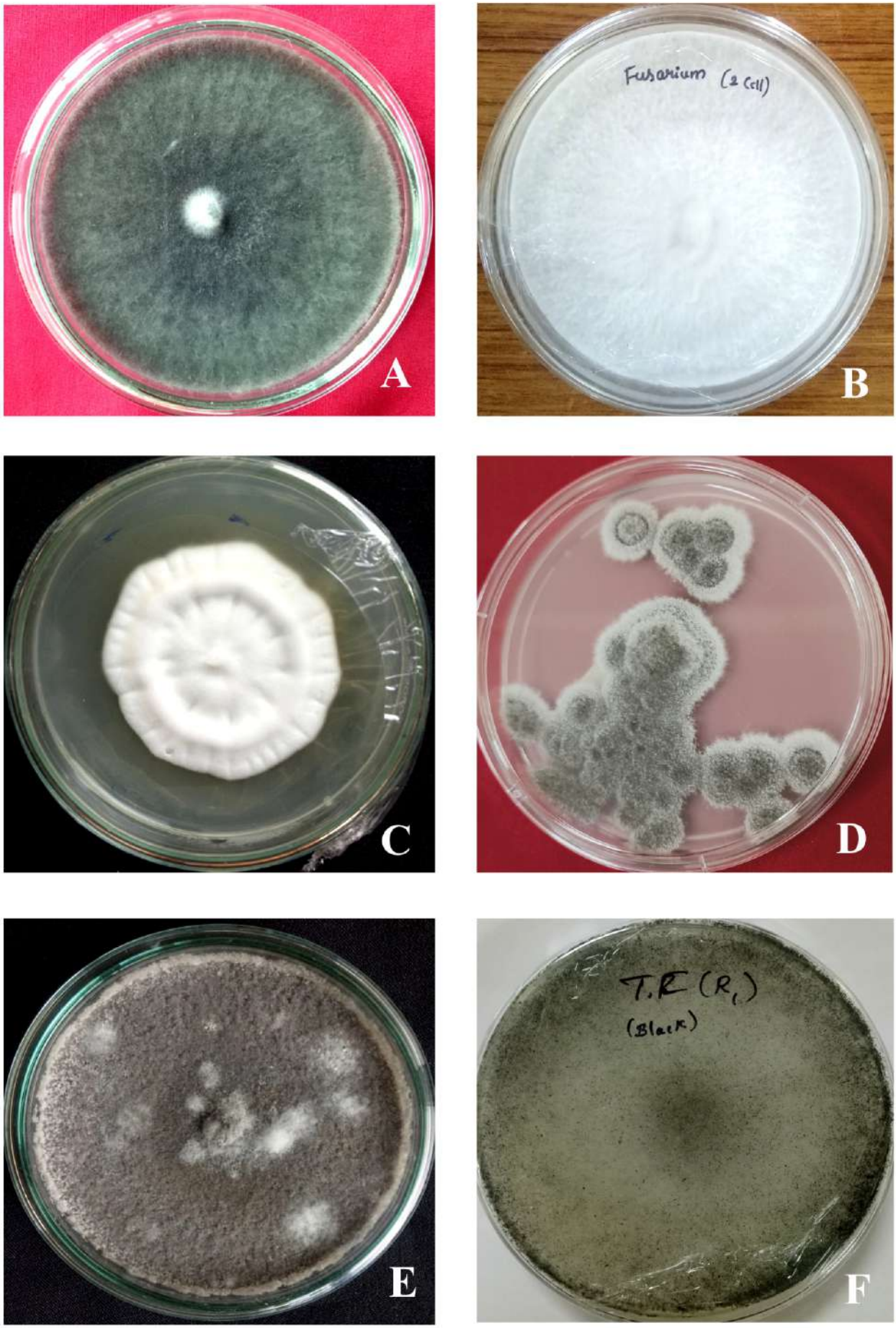


Plate-4: Pure culture of, A - *Macrophomina phaseolina*, B - *Fusarium solani*, C - *Fusarium proliferatum*, D - *Cladosporium cladosporioides*, E - *Nigrospora oryzae* and F - *Rhizopus stolonifer*

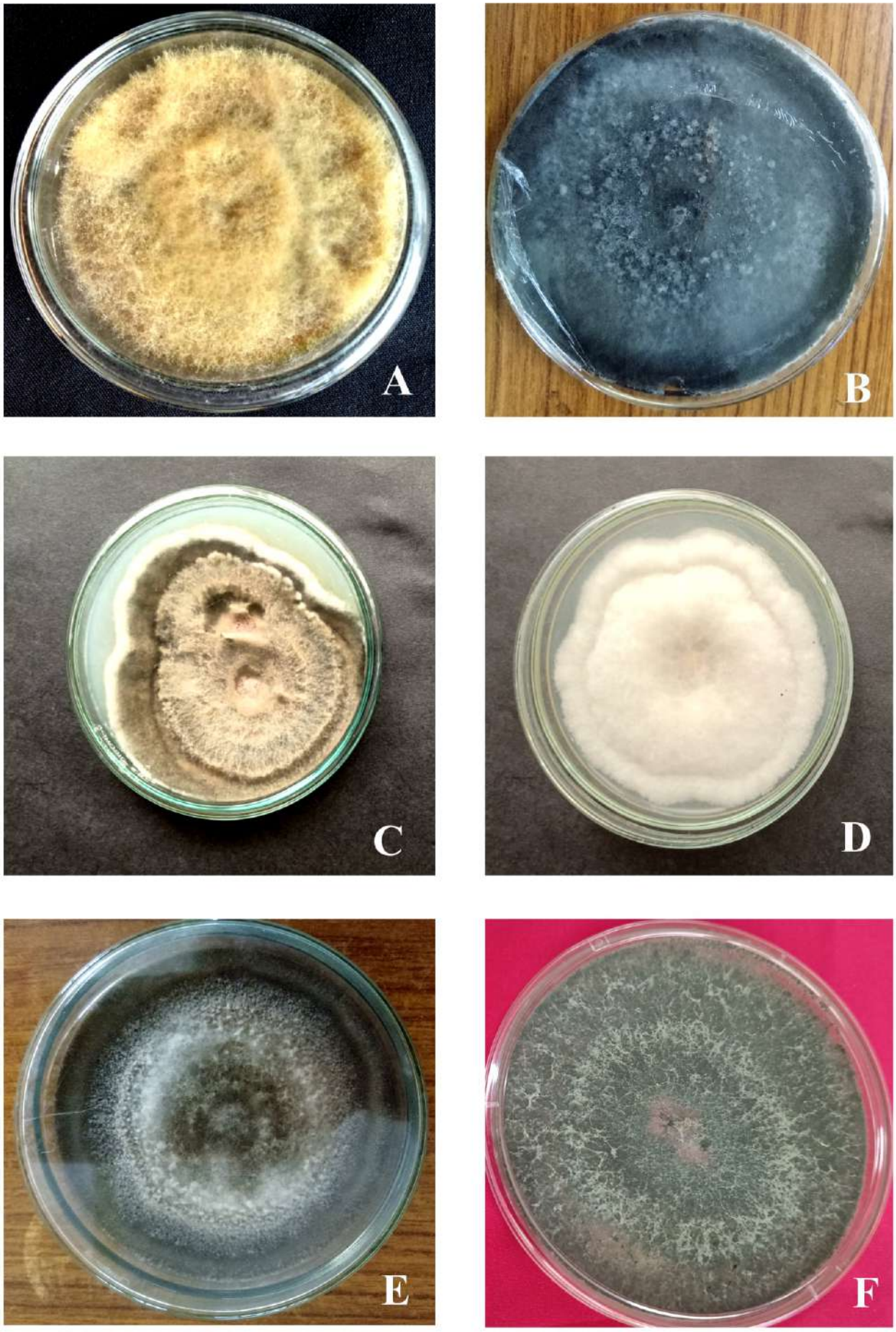


Plate-5: Pure culture of, A - *Fusarium culmorum*, B - *Lasiodiploidea theobromae*, C - *Curvularia akaiiensis*, D - *Fusarium incarnatum*, E - *Alternaria alternata* and F - *Trichoderma harzianum*

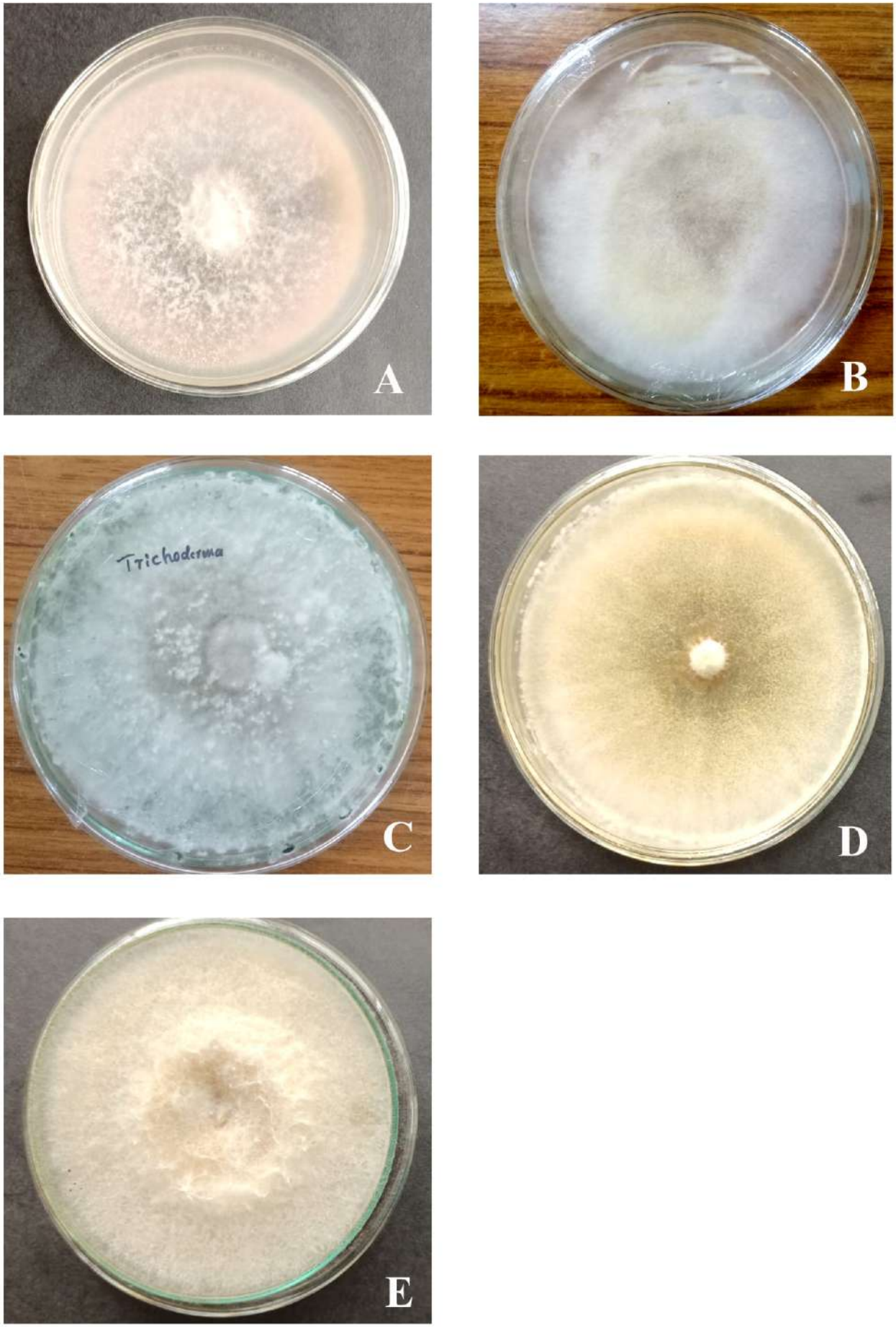


Plate-6: Pure culture of, A - *Fusarium verticillioides*, B - *Mucor flavus*, C - *Trichoderma atroviride*, D - *Fusarium moniliforme* and E - *Fusarium equiseti*

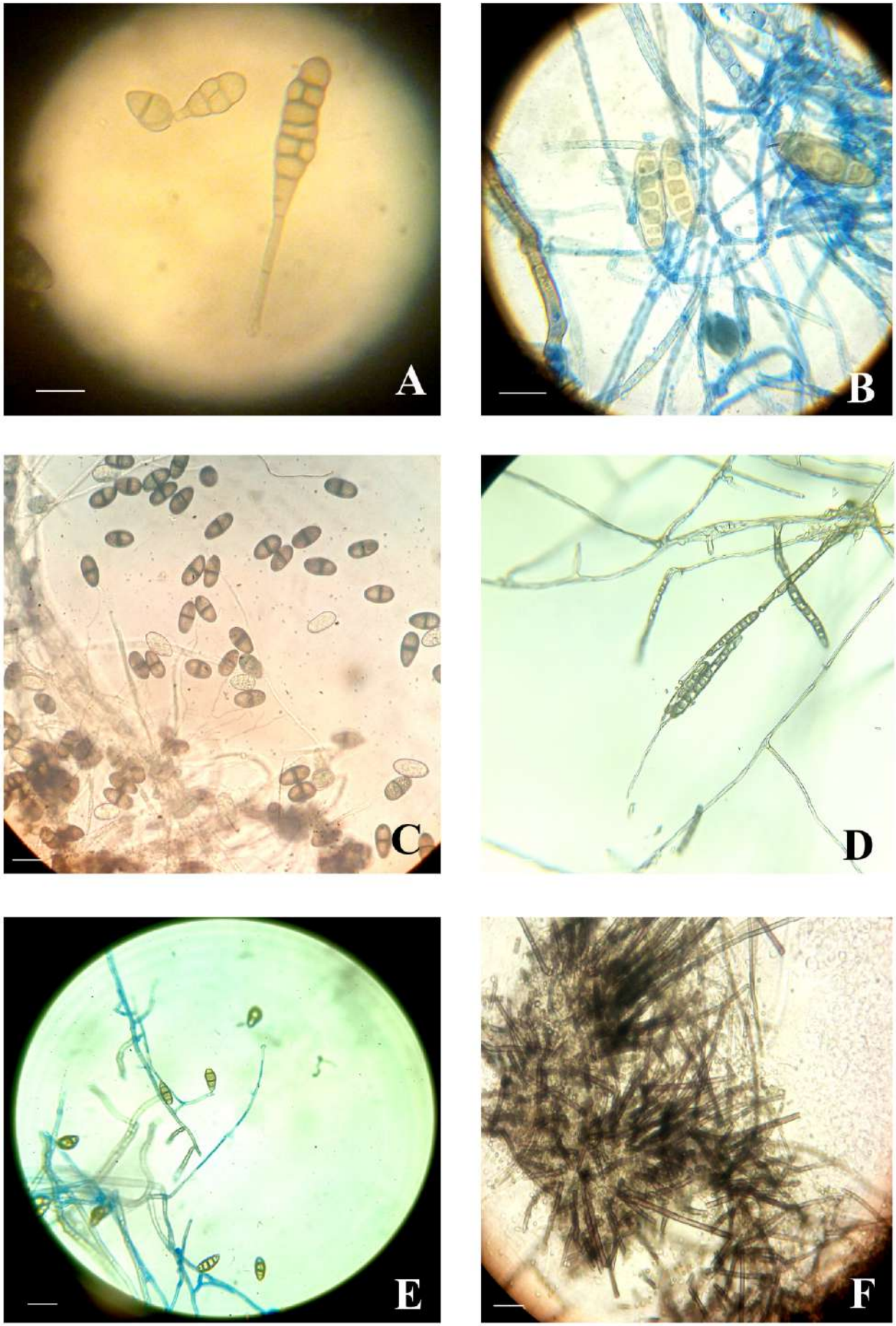


Plate-7: Microscopic photos of, A - *Alternaria longipes*, B - *Drechslera halodes*, C - *Lasiodiploidea theobromae*, D - *Corynespora cassiicola*, E - *Curvularia akaiiensis* and F - *Colletotrichum globosum*

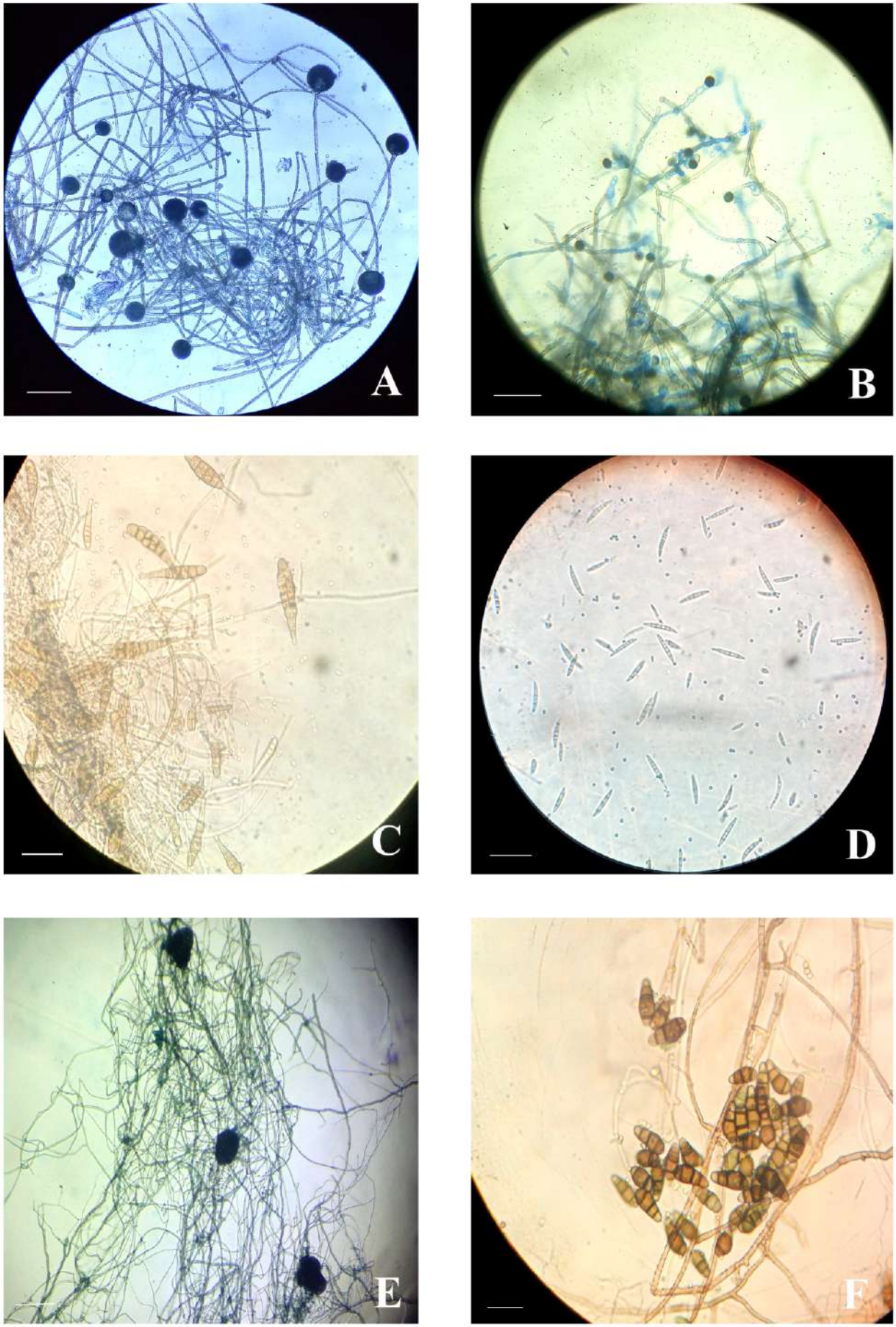


Plate-8: Microscopic photos of, A - *Rhizopus stolonifer,* B - *Nigrospora oryzae,* C - *Alternaria solani,* D - *Fusarium oxysporum,* E - *Macrophomina phaseolina* and F - *Curvularia fallax*

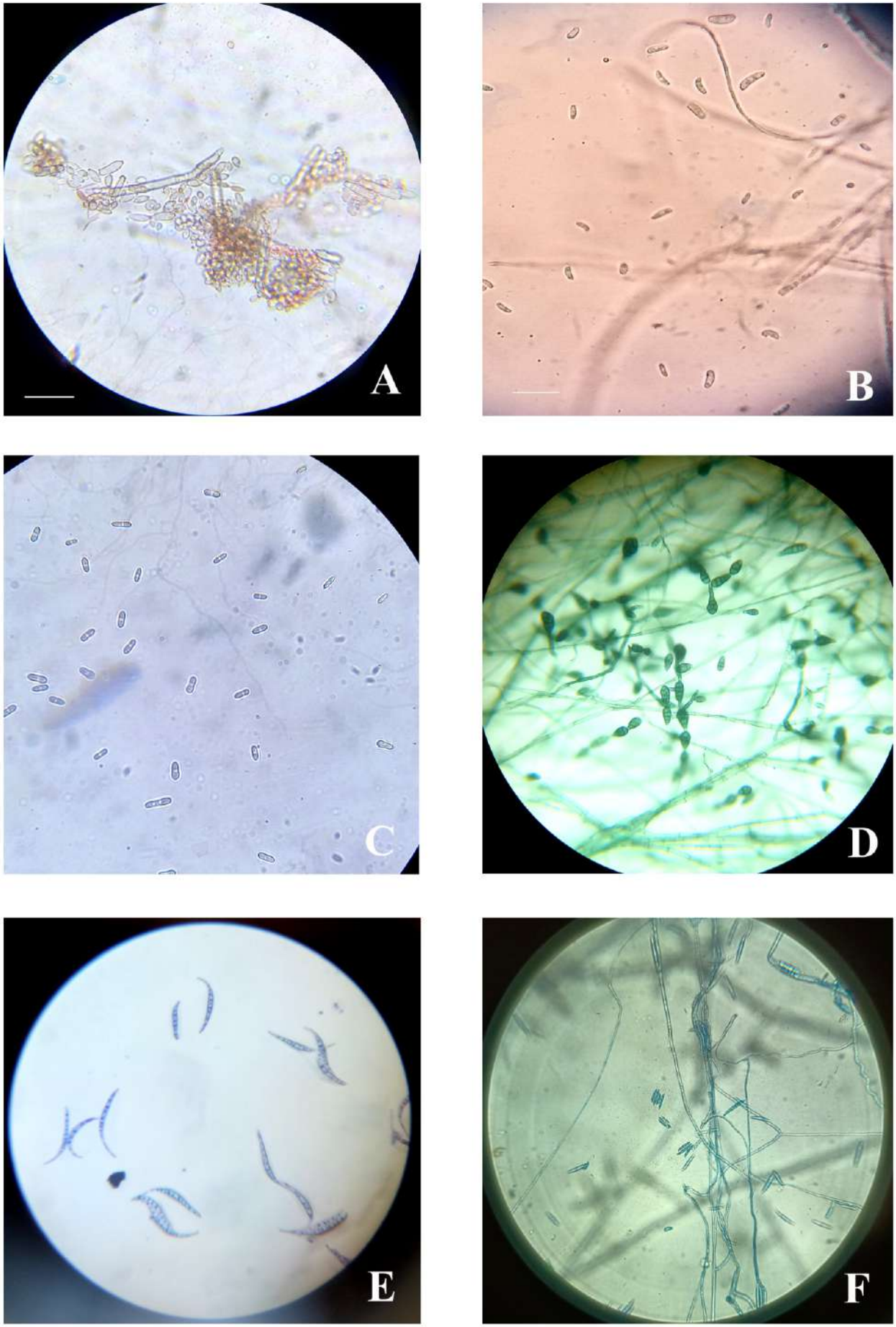


Plate-9: Microscopic photos of, A - *Cladosporium cladosporioides,* B - *Fusarium solani,* C - *Colletotrichum gloeosporioides,* D - *Alternaria alternata,* E - *Fusarium scirpi* and F - *Fusarium verticillioides*

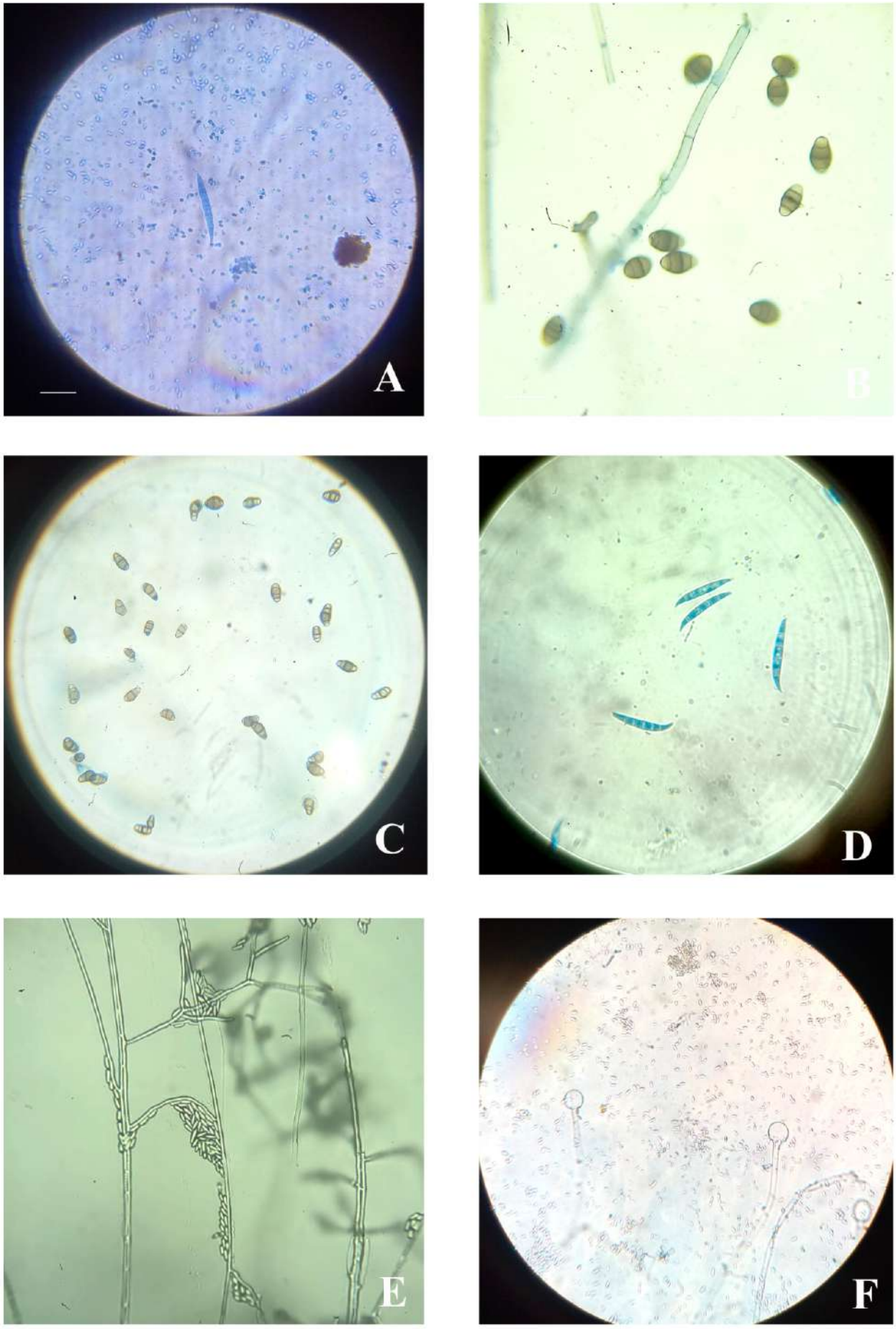


Plate-10: Microscopic photos of, A - *Fusarium incarnatum*, B - *Curvularia eleusinicola*, C - *Curvularia lunata*, D - *Fusarium equiseti*, E - *Fusarium proliferatum* and F - *Mucor flavus*

4.3 Pathogenicity:

The results of this experiment carried out to know the effect of different pathogens on the seedlings of Chilli, Tomato and Brinjal. Pathogenicity test was done for all the 34 isolated pathogens for 25 days old seedlings grown in polyhouse. Daily plants were observed and expressed symptoms were recorded separately. The symptoms were recorded up to forty five days after inoculation.

The visible symptoms were noticed from 8th day onwards after inoculation of the pathogens. The inoculated seedlings were found to be infected with typical lesions, small dark brown circular spots, black spots, wilting of leaves, chlorosis and necrosis (Photoplate- 11, 12 and 13). Defoliation of leaves also observed in most of the inoculated plants and death of the plant also occurs in some highly virulent pathogen.

The morphological characteristics of the re-isolates were identical with the original isolates. And this proved the Koch's postulates to confirm the causal agent of the diseases.

4.3a Pathogenicity test By Root Dip Method

In Chilli, Tomato and Brinjal seedlings, the inoculated pathogens like *Alternaria*, *Curvularia*, *Colletotrichum*, *Corynespora*, *Drechslera*, *Macrophomina* and *Neofusicoccum* species exhibit small, oval, round, regular or irregular, black and brown spots on the leaves of the seedlings after the artificial inoculation. But the percentage of disease incidence was varied from one species to another (0 to 100%). The symptoms were gradually increased with increasing the days of inoculation and some of the pathogen shows death of the plants also in shorter duration.

The variation in symptoms on aerial part of infected plants (Chilli, Tomato and Brinjal) inoculated with *Fusarium* species were observed. In this observation at early stage, symptoms appeared as yellowing of the lower leaves and later drooping of the leaves was observed in the plants. The tip of the younger leaves was curled and incase of severe infection lower leaves were dried and ultimately aerial parts showed turgidity and finally showed wilting. The first sign of wilting and spots were appeared around 8th days after inoculation and gradually increased. In the early stages vascular discoloration also observed and later it extended throughout the plant.

The percentages of disease incidence were calculated on 15th, 30th and 45th days after inoculation in Chilli, Tomato and Brinjal seedlings. The mean of the result of PDI was recorded in Table 4.14, 4.15 and 4.16 respectively.

The most virulent pathogen against tomato plants were *F. oxysporum, F. solani, A. alternata, C. cassiicola, C. lunata.* In Chilli, *Fusarium oxysporum, Corynespora cassiicola, Fusarium solani, Alternaria alternata* and *Lasiodiploidea theobromae* are the most virulent and in case of Brinjal *Fusarium solani, Fusarium oxysporum, Curvularia lunata, Lasiodiploidea theobromae* and *Corynespora cassiicola* are the most virulent pathogens. *Trichoderma* species does not showed any disease symptoms on seedlings of Chilli, Tomato and Brinjal.

In Chilli, the maximum percentage of disease incidence was recorded in *Fusarium* species followed by *Corynespora cassiicola* and *Alternaria* species (Photoplate-11). *Fusarium oxysporum* found 97.77% of disease incidence followed by *Corynespora cassiicola* (95.55%), *Fusarium solani* (88.88%), *Alternaria alternata* (88.33%) and *Lasiodiploidea theobromae* (86.66%). Lowest incidences were recorded in *Aspergillus flavus* and *Phomopsis vexans* (8.88%), *Chaetomium globosum*

(13.33%), *Fusarium scirpi* (17.77%) and *Fusarium culmorum* (22.22%). *Mucor flavus, Rhizopus stolonifer, Trichoderma atroviride* and *Trichoderma harzianum* have does not showing any disease symptoms in the plants. In control, the plants showed good growth and healthy in condition without any symptoms of diseases.

In Tomato, the maximum percentage of disease incidence was recorded in *Corynespora cassiicola* followed by *Curvularia lunata, Fusarium oxysporum* and *Neofusicoccum ribis* (Photoplate-12). *Corynespora cassiicola* found 100% of disease incidence followed by *Fusarium oxysporum* (95.55%), *Curvularia lunata* (91.10%), *Fusarium solani* (88.88%), *Alternaria alternata, Neofusicoccum ribis* (86.66%) and *Macrophomina phaseolina* (77.77%). Lowest incidences were recorded in *Aspergillus niger* and *Aspergillus flavus* (13.33%), *Mucor flavus* (17.77%) and *Rhizopus stolonifer* (26.66%). *Phomopsis vexans, Trichoderma atroviride* and *Trichoderma harzianum* have does not showing any disease symptoms in the plants. In control, the plants showed good growth and healthy plants without any symptoms of diseases.

In Brinjal, the maximum percentage of disease incidence was recorded in *Fusarium solani, Fusarium oxysporum, Curvularia lunata, Lasiodiploidea theobromae* and *Corynespora cassiicola* (Photoplate-13). *Fusarium solani* found 95.55% of disease incidence followed by *Fusarium oxysporum* (91.10%), *Curvularia lunata* (88.88%), *Lasiodiploidea theobromae* and *Corynespora cassiicola* (84.44%) and *Alternaria solani* (77.77%). Lowest incidences were recorded in *Colletotrichum capsici* (8.88%) and *Colletotrichum gloeosporioides* (22.22%), *Chaetomium globosum* (24.44%) and *Aspergillus flavus* (26.66%). *Aspergillus niger, Mucor flavus, Rhizopus stolonifer, Trichoderma atroviride* and *Trichoderma harzianum* have

does not showing any disease symptoms in the plants. In control, the plants showed good growth and developments without any symptoms of diseases.

Trichoderma species like *Trichoderma harzianum* and *T. atroviride* were does not exhibiting the any disease symptoms in the pathogenicity test. It concludes that these are not harmful to the plants and cause any symptomatic diseases.

4.3b Pathogenicity test By Pricking method

The inoculated fruits are showing symptoms like rotting, water lesions, shrinking and drying after 3 days of inoculation. After the inoculation, infected area of fruits was increased from 3 day to 7days later the fungal pathogen completely colonizing within the fruits.

At first, infected fruits show small, slightly sunken, water soaked spots. The spots were enlarged and become darker in colour, sunken and have concentric rings until the entire fruit is consumed by the rot (Photoplate-14, 15 and 16).

Aspergillus niger, *Aspergillus flavus*, *Rhizopus stolonifer Fusarium sps* and *Mucor flavus* were came in the first position with high incidence. In the second position *Alternaria*, *Curvularia*, *Colletotrichum* and *Cladosporium* were represented and remaining pathogens were representing the last position in causing the infection.

In Chilli, artificially inoculated chilli fruits were showed soaked lesions at earlier stage then showed rotting in case of *Fusarium* species. In *Aspergillus* and *Rhizopus* species showed complete colonizing of mycelium and leads to complete rotting of fruits within 3-4 days. *Colletotrichum* species showed the symptoms of

anthracnose in the inoculated area and enlarged its size as on the day's increases and at the end the fruit completely collapses (Photoplate-14).

In tomato, artificially inoculated fruits were showed water soaked lesions first then shrunken, inoculated area were goes on rotten and pathogen completely colonizing their mycelium within the fruits and finally the fruits were completely destroyed within a week (Photoplate-15).

In Brinjal, the inoculated fruits showed the symptoms of shrinking first, then as the days increases it undergoes colour change and inoculated area rotten first and extends through the fruit. The pathogenic fungal mycelium completely colonizing within the fruits and destroy the fruits within 7-8 days after inoculation (Photoplate-16).

Table 4.16: Percentage of disease incidence on Chilli seedlings by Root Dip method

Sl. No	Pathogen	% of disease incidence			
		Days after inoculation (DAI)			
		15	30	45	Mean
1	*Alternaria alternata* (Fr.) Keissl	73.33	93.33	100	88.33
2	*Alternaria solani* Sorauer	53.33	86.66	86.66	75.55
3	*Alternaria longipes* (Ellis & Everh.)	33.33	53.33	73.33	53.33
4	*Aspergillus flavus* Link	00	13.33	13.33	8.88
5	*Aspergillus niger* Tiegh	26.66	33.33	53.33	37.77
6	*Bipolaris sps.* Shoemaker	46.66	60	60	55.55
7	*Corynespora cassiicola* (Berk. & M.A. Curtis)	86.66	100	100	95.55
8	*Curvularia lunata* (Wakker) Boedijn	40	73.33	80	64.44
9	*Curvularia akaiiensis* Sivan	53.33	66.66	86.66	68.88
10	*Curvularia eleusinicola* Ferdinandez	33.33	53.33	86.66	57.77
11	*Curvularia fallax* Boedijn	00	40	66.66	35.55
12	*Colletotrichum gloeosporioides* (Penz.)	60	86.66	93.33	79.99
13	*Colletotrichum capsici* (Syd. & P. Syd.)	53.33	73.33	93.33	73.33
14	*Chaetomium globosum* Kunze	00	13.33	26.66	13.33
15	*Cladosporium cladosporioides* (Fresen.)	33.33	46.66	53.33	44.44
16	*Drechslera halodes* (Drechsler)	53.33	73.33	73.33	66.66
17	*Fusarium oxysporum* Schltdl.	93.33	100	100	97.77
18	*Fusarium solani* (Mart.)	86.66	86.66	93.33	88.88
19	*Fusarium equiseti* (Corda)	53.33	53.33	53.33	53.33
20	*Fusarium incarnatum* (Roberge ex Desm.)	33.33	40	40	37.77
21	*Fusarium verticillioides* (Sacc.)	00	40	53.33	31.11
22	*Fusarium proliferatum* (Matsush.)	26.66	26.66	33.33	28.88
23	*Fusarium moniliforme* (Sacc.)	33.33	33.33	60	42.22
24	*Fusarium scirpi* Lambotte & Fautrey	00	26.66	26.66	17.77
25	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	00	26.66	40	22.22

26	*Lasiodiploidea theobromae* (Pat.)	86.66	86.66	86.66	86.66
27	*Macrophomina phaseolina* (Tassi)	53.33	60	73.33	62.22
28	*Mucor flavus* Bainier.	00	00	00	00
29	*Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.)	53.33	53.33	73.33	59.99
30	*Nigrospora oryzae* (Berk. & Broome)	40	40	73.33	51.11
31	*Phomopsis vexans* (Sacc. & P. Syd.)	00	00	26.66	8.88
32	*Rhizopus stolonifer* (Ehrenb.)	00	00	00	00
33	*Trichoderma atroviride* P. Karst.	00	00	00	00
34	*Trichoderma harzianum* Rifai,	00	00	00	00
35	Control	00	00	00	00

Table 4.17: Percentage of disease incidence on Tomato seedlings by Root Dip method

Sl. No	Pathogen	% of disease incidence			
		Days after inoculation (DAI)			
		15	30	45	Mean
1	*Alternaria alternata* (Fr.) Keissl	86.66	86.66	86.66	86.66
2	*Alternaria solani* Sorauer	60	73.33	73.33	68.88
3	*Alternaria longipes* (Ellis & Everh.)	40	40	53.33	44.44
4	*Aspergillus flavus* Link	00	13.33	26.66	13.33
5	*Aspergillus niger* Tiegh	00	6.66	33.33	13.33
6	*Bipolaris sps.* Shoemaker	66.66	66.66	66.66	66.66
7	*Corynespora cassiicola* (Berk. & M.A. Curtis)	100	100	100	100
8	*Curvularia lunata* (Wakker) Boedijn	86.66	86.66	100	91.10
9	*Curvularia akaiiensis* Sivan	53.33	53.33	73.33	59.99
10	*Curvularia eleusinicola* Ferdinandez	53.33	53.33	53.33	53.33
11	*Curvularia fallax* Boedijn	40	40	40	40
12	*Colletotrichum gloeosporioides* (Penz.)	33.33	53.33	53.33	46.66
13	*Colletotrichum capsici* (Syd. & P. Syd.)	26.66	26.66	40	30.8
14	*Chaetomium globosum* Kunze	33.33	33.33	33.33	33.33
15	*Cladosporium cladosporioides* (Fresen.)	33.33	46.66	53.33	44.44
16	*Drechslera halodes* (Drechsler)	73.33	73.33	73.33	73.33
17	*Fusarium oxysporum* Schltdl.	93.33	93.33	100	95.55
18	*Fusarium solani* (Mart.)	86.66	86.66	93.33	88.88
19	*Fusarium equiseti* (Corda)	53.33	53.33	53.33	53.33
20	*Fusarium incarnatum* (Roberge ex Desm.)	40	40	40	40
21	*Fusarium verticillioides* (Sacc.)	26.66	26.66	33.33	28.88
22	*Fusarium proliferatum* (Matsush.)	40	53.33	53.33	48.88
23	*Fusarium moniliforme* (Sacc.)	40	60	60	53.33
24	*Fusarium scirpi* Lambotte & Fautrey	33.33	33.33	33.33	33.33
25	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	53.33	53.33	53.33	53.33

26	*Lasiodiploidea theobromae* (Pat.)	73.33	73.33	80	75.55
27	*Macrophomina phaseolina* (Tassi)	73.33	80	80	77.77
28	*Mucor flavus* Bainier.	00	26.66	26.66	17.77
29	*Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.)	86.66	86.66	86.66	86.66
30	*Nigrospora oryzae* (Berk. & Broome)	60	60	60	60
31	*Phomopsis vexans* (Sacc. & P. Syd.)	00	00	00	00
32	*Rhizopus stolonifer* (Ehrenb.)	26.66	26.66	26.66	26.66
33	*Trichoderma atroviride* P. Karst.	00	00	00	00
34	*Trichoderma harzianum* Rifai,	00	00	00	00
35	Control	00	00	00	00

Table 4.18: Percentage of disease incidence on Brinjal seedlings by Root Dip method

Sl. No	Pathogen	% of disease incidence			
		Days after inoculation (DAI)			
		15	20	45	Mean
1	*Alternaria alternata* (Fr.) Keissl	66.66	73.33	73.33	71.10
2	*Alternaria solani* Sorauer	73.33	80	80	77.77
3	*Alternaria longipes* (Ellis & Everh.)	46.66	53.33	53.33	51.10
4	*Aspergillus flavus* Link	26.66	26.66	26.66	26.66
5	*Aspergillus niger* Tiegh	00	00	00	00
6	*Bipolaris sps.* Shoemaker	53.33	66.66	66.66	62.21
7	*Corynespora cassiicola* (Berk. & M.A. Curtis)	80	86.66	86.66	84.44
8	*Curvularia lunata* (Wakker) Boedijn	86.66	86.66	93.33	88.88
9	*Curvularia akaiiensis* Sivan	73.33	73.33	73.33	73.33
10	*Curvularia eleusinicola* Ferdinandez	66.66	66.66	73.33	68.88
11	*Curvularia fallax* Boedijn	46.66	46.66	66.66	53.32
12	*Colletotrichum gloeosporioides* (Penz.)	00	33.33	33.33	22.22
13	*Colletotrichum capsici* (Syd. & P. Syd.)	00	00	26.66	8.88
14	*Chaetomium globosum* Kunze	13.33	13.33	46.66	24.44
15	*Cladosporium cladosporioides* (Fresen.)	53.33	53.33	66.66	57.77
16	*Drechslera halodes* (Drechsler)	73.33	73.33	73.33	73.33
17	*Fusarium oxysporum* Schltdl.	86.66	93.33	93.33	91.10
18	*Fusarium solani* (Mart.)	86.66	100	100	95.55
19	*Fusarium equiseti* (Corda)	46.66	46.66	46.66	46.66
20	*Fusarium incarnatum* (Roberge ex Desm.)	53.33	60	60	57.77
21	*Fusarium verticillioides* (Sacc.)	33.33	33.33	40	35.55
22	*Fusarium proliferatum* (Matsush.)	40	46.66	46.66	44.44
23	*Fusarium moniliforme* (Sacc.)	60	60	60	60
24	*Fusarium scirpi* Lambotte & Fautrey	40	46.66	46.66	44.44
25	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	53.33	53.33	60	55.55

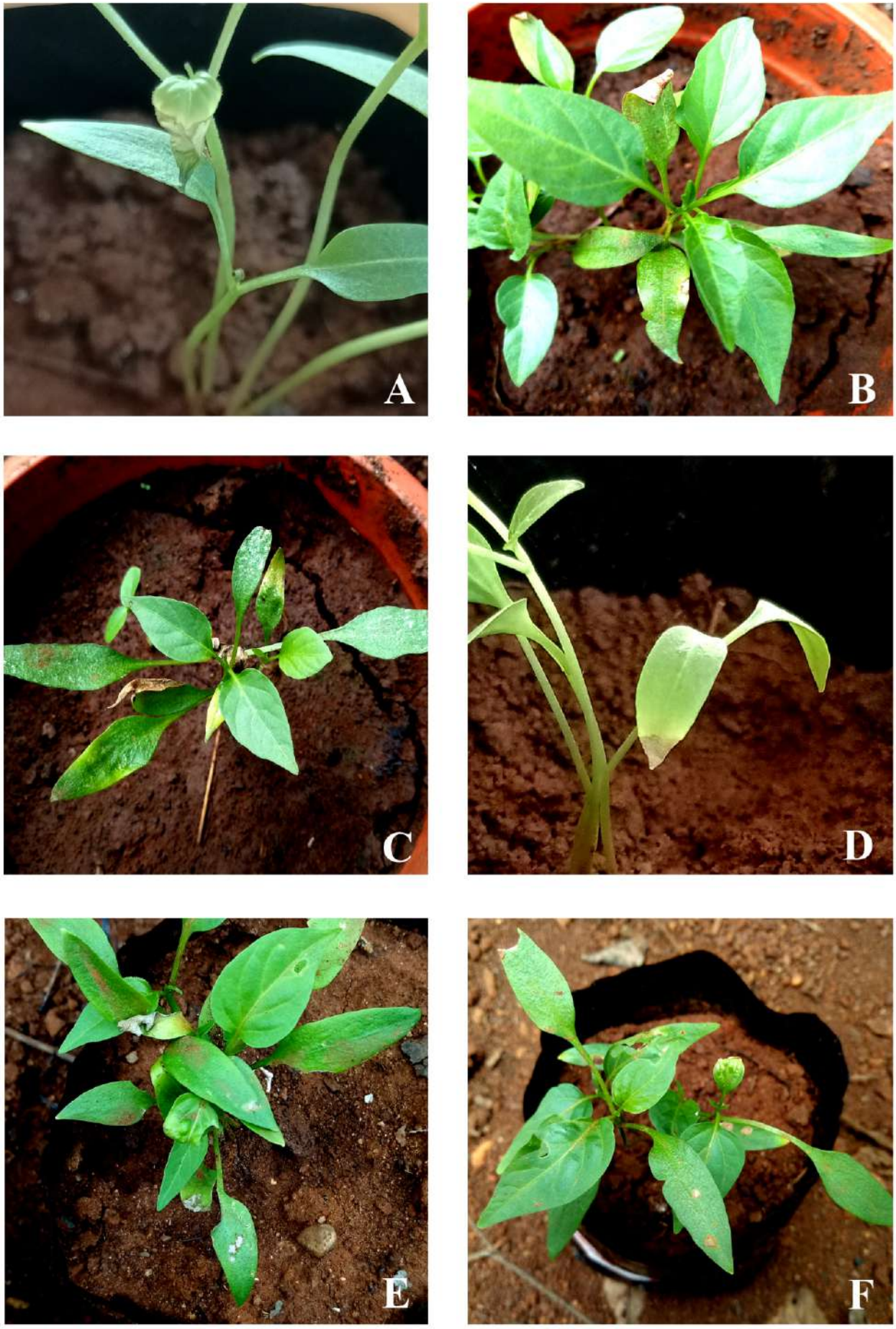


Plate-11: Pathogenicity test by Root Dip method, A-Leaf tip showed infection with *A. alternata*, B- *C. lunata* on Chilli,C- Chlorosis of younger leaves due to inoculation of *L. theobromae*, D-Younger leaf showing spots due to inoculation of *C. eleusinicola*, E-Leaf infected with *N. oryzae* and F-*A. solani* causes Leaf spot.

Plate-12: Pathogenicity test by Root Dip method, A-Leaf spot of *C. cassiicola*, B-Initial yellowing symptoms appeared due to *F. incarnatum*, C- *F. oxysporum* showed Wilt symptoms, D- *F. solani* showed death of seedlings in younger stages, E- Concentric rings of *C. lunata* spots on Tomato leaf and F-Leaf showed disease symptoms due to inoculation of *N. oryzae*

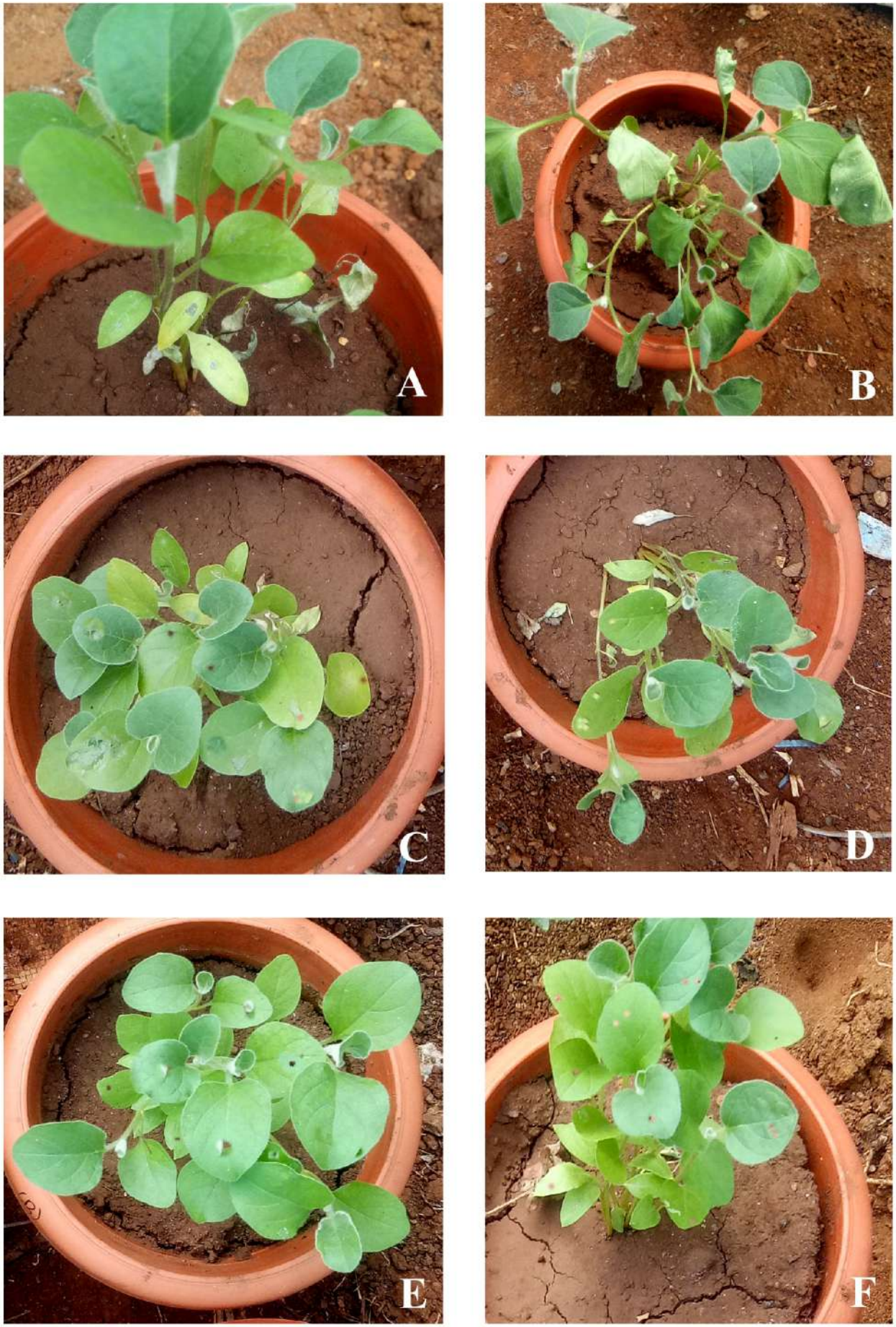


Plate-13: Pathogenicity test by Root Dip method, A- Leaf spot caused by *C. cassiicola*, B- *F. solani* showed wilting of leaves, C- *C. lunata* showed spot on leaf, D-Initial yellowing symptoms appeared due to inoculation of *M. phaseolina*, E- Spot symptoms due to *D. halodes* and F- leaf spot caused by *A. alternata*

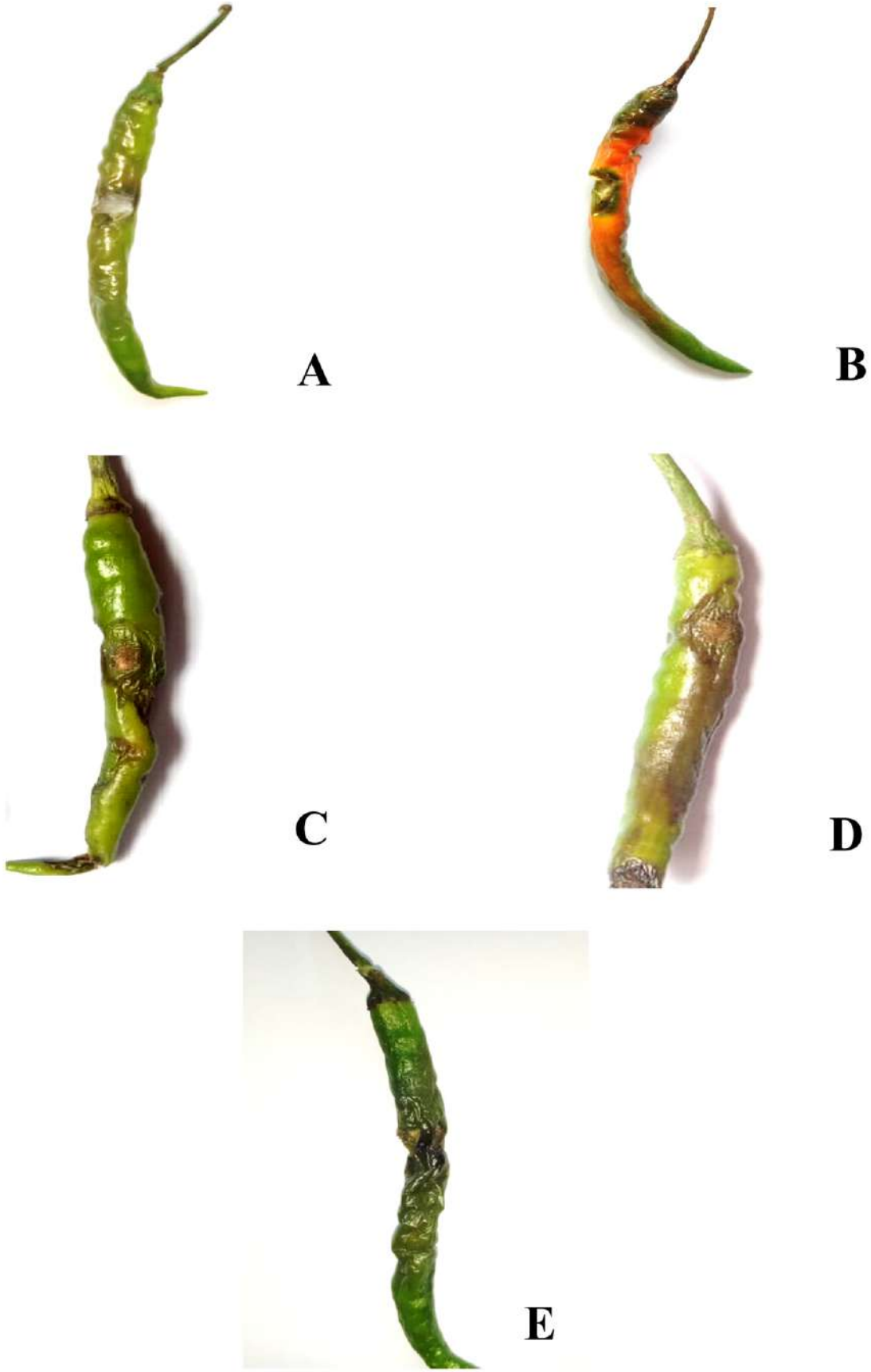


Plate-14: Pathogenicity test by Pricking method, A-Chilli inoculated with *F. oxysporum* showed colonizing their mycelium within fruit,B-Chilli inoculated with *A. alternata,* C-Rotting of Chilli due to inoculation of *C. cladosporioides*, D- Anthracnose symptoms due to *C. gloeosporioides* and E-Chilli showing rots symptoms due to inoculation with *A. niger*

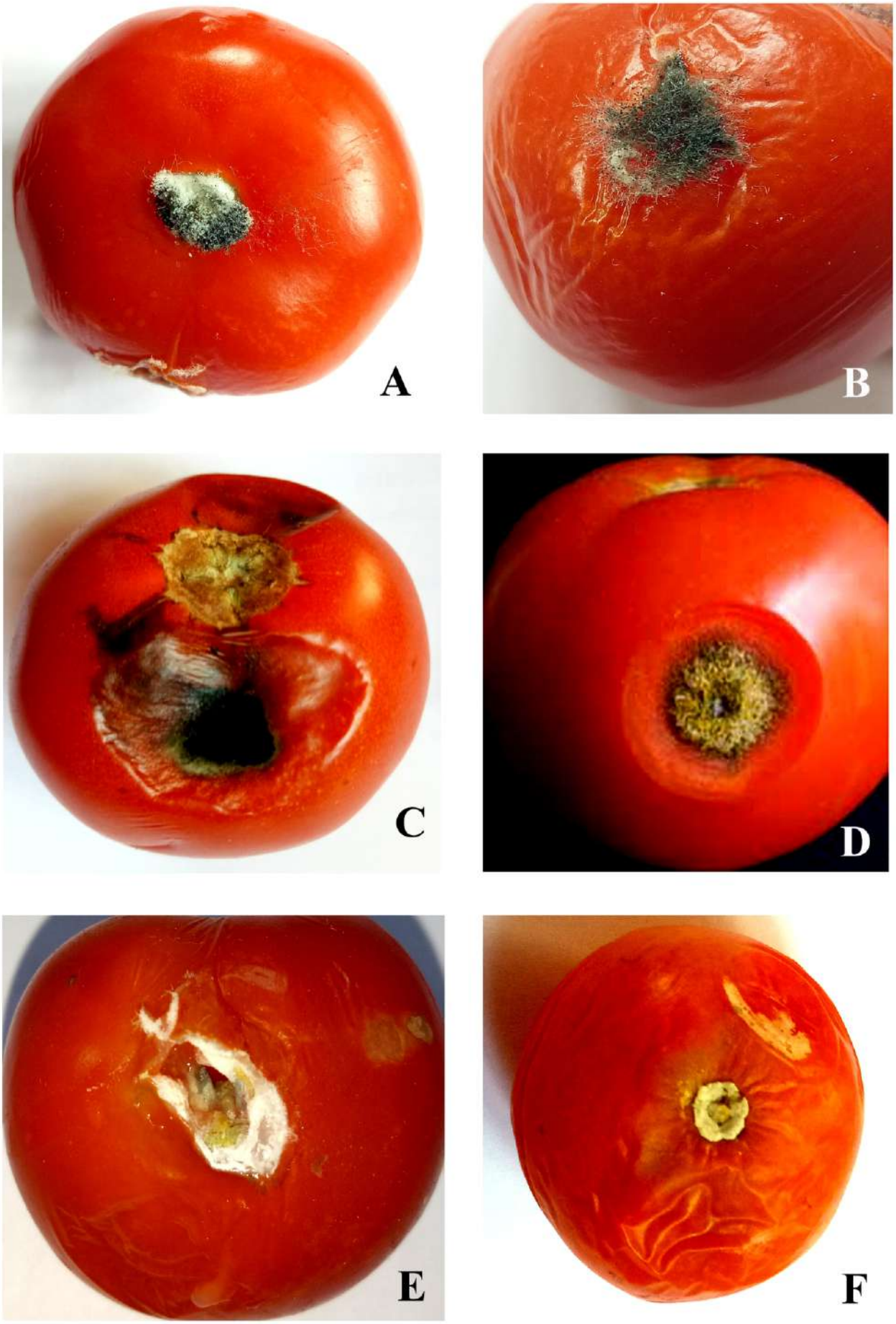


Plate-15: Pathogenicity test by Pricking method, A-inoculated Tomato infected with *R. stolonifer*, B-*C. cladosporioides* showed rotting symptoms, C-*A. niger* showed rotting symptoms, D-Tomato fruit infected with the *A. flavus*, E-*F. oxysporum* showed colonizing their mycelium within the fruit and F- Tomato fruit showed shrinking symptoms due to inoculation of *F. scirpi*

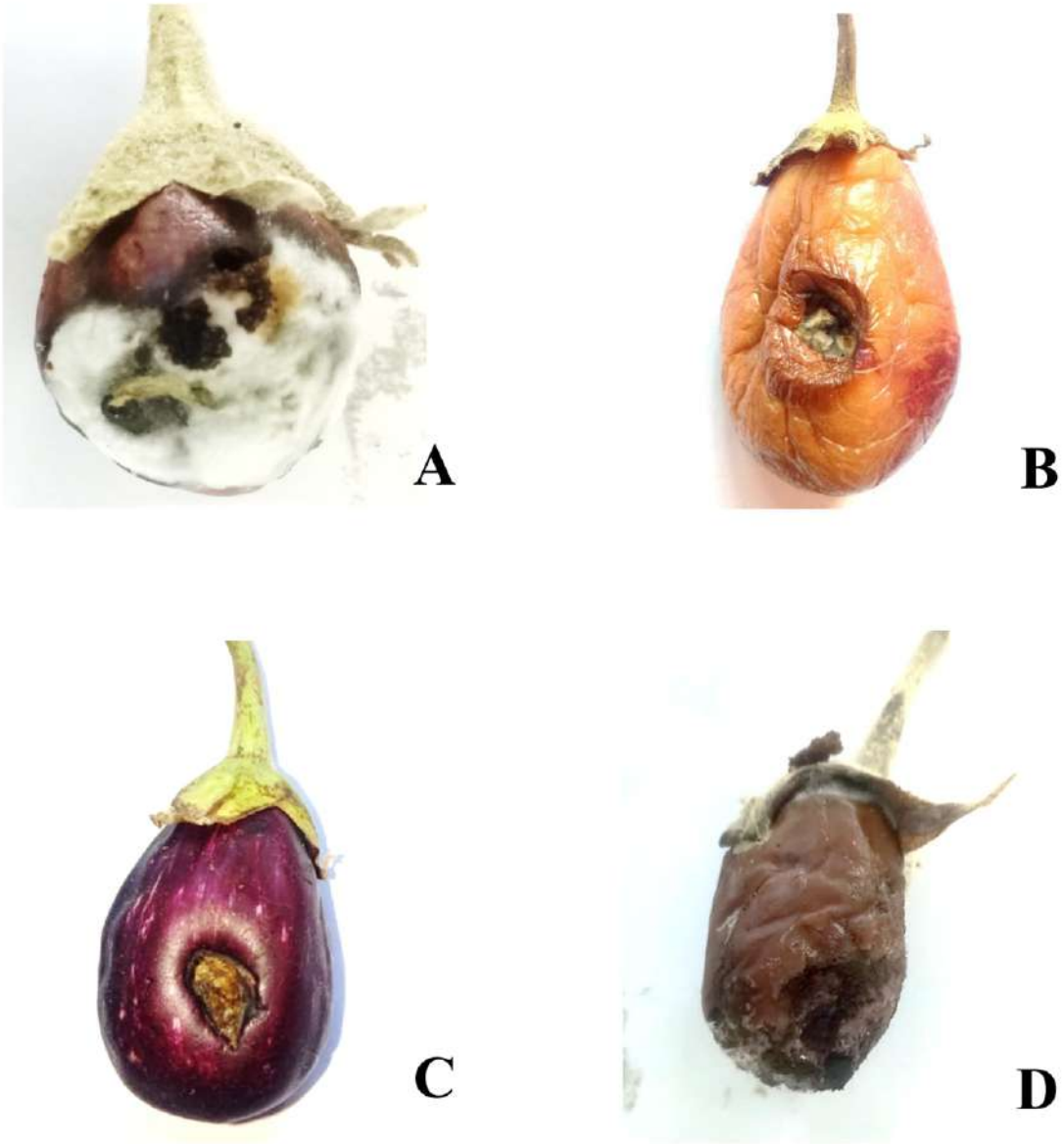


Plate-16: Pathogenicity test by Pricking method, A-Brinjal inoculated with *F. solani* showing rotting symptoms, B-Brinjal inoculated with *M. phaseolina* showed rot symptoms, C-Brinjal Fruit inoculated with *A. niger* and D-Brinjal inoculated with *C. cladosporioides*

26	*Lasiodiploidea theobromae* (Pat.)	80	86.66	86.66	84.44
27	*Macrophomina phaseolina* (Tassi)	73.33	73.33	80	75.55
28	*Mucor flavus* Bainier.	00	00	00	00
29	*Neofusicoccum ribis* (Slippers, Crous & M.J. Wingf.)	00	53.33	53.33	35.55
30	*Nigrospora oryzae* (Berk. & Broome)	66.66	66.66	66.66	66.66
31	*Phomopsis vexans* (Sacc. & P. Syd.)	53.33	73.33	73.33	66.66
32	*Rhizopus stolonifer* (Ehrenb.)	00	00	00	00
33	*Trichoderma atroviride* P. Karst.	00	00	00	00
34	*Trichoderma harzianum* Rifai,	00	00	00	00
35	Control	00	00	00	00

4.4 Effect of mycelial growth inhibition of pathogens by using different fungicides in Poison Food Technique at 8th days after inoculation.

Five fungicides namely Mancozeb, Bavistin, Captan, Metalaxyl and SAAF were used at four different concentrations (0.05%, 0.1%, 0.15% and 0.2%). All the fungicides showed good inhibition of fungal growth. Some fungicides showed complete inhibition in all the tested concentration for some pathogenic fungi and some are showed increased percent inhibition with increase in the concentration.

All the fungicides significantly inhibited mycelial growth of *Corynespora cassiicola* compared to the control. Among the fungicides, Mancozeb showed 100% growth inhibition in 0.15% and 0.2% concentration. While inhibitory effect of Bavistin, Captan, Metalaxyl and SAAF increased with increase in the concentrations (Table 4.19; Fig 4.6). In the 8th day of experimentation, highest inhibition i.e., 100% was shown in the concentration (0.15 & 0.2%) of Mancozeb followed by 0.2% of Captan, Bavistin, SAAF and Metalaxyl which showed 97.64%, 94.11%, 94.11% and 80% respectively. Lowest inhibition was observed in Metalaxyl (54.11%) of 0.05% concentration

In *Fusarium solani*, Bavistin showed 100% of inhibition in all the tested concentration. Mancozeb and SAAF at 0.15% and 0.2% concentration, Captan and Metalaxyl at 0.2% concentration also showed 100% of inhibition. All the fungicides showed good inhibition effect compared to control. Minimum inhibition (44.59%) was recorded in Mancozeb at 0.05% concentration (Table 4.19; Fig 4.7).

In case of *Curvularia akaiiensis*, all the fungicides showed good inhibition with increase in the concentration. While 100% of inhibition was recorded in Mancozeb and SAAF at 0.15% and 0.2% concentration, Captan also showed 100% inhibition at 0.2% concentration. Bavistin and Metalaxyl showed maximum inhibition of 75% and 92.18% at 0.2% concentration respectively and Minimum inhibition (70.31%) was recorded at 0.05% concentration (Table 4.19; Fig 4.8).

In *Fusarium incarnatum* all the concentration of SAAF and Mancozeb except at 0.05% and Captan at 0.15% and 0.2% concentration showed 100% inhibition of mycelial growth. Metalaxyl at 0.2% concentration also showed 100% inhibition. In Bavistin, Maximum inhibition (81.92%) was recorded at 0.2% concentration. Among all the fungicide used Minimum inhibition (75.90%) was showed in 0.05% concentration of Bavistin. SAAF and Mancozeb were best to control the *Fusarium incarnatum* in *vitro* (Table 4.20; Fig 4.9).

In *Lasiodiploidea theobromae*, all the fungicide inhibits the mycelial growth in all the concentration. Mancozeb, Bavistin, Captan and SAAF showed 100% inhibition in all the used concentration. Fungicide Metalaxyl showed maximum (76.66) and minimum (50) inhibition at 0.2% and 0.05% concentration respectively (Table 4.20; Fig 4.10).

Fusarium oxysporum showed 100% inhibition of mycelial growth in all the concentration of Bavistin and SAAF. Mancozeb and Captan recorded complete (100%) inhibition at 0.2% concentration. Fungicide Mancozeb and Captan showed increased in the percentage of inhibition with increase in the concentration but in Metalaxyl at 0.15% showed maximum inhibition and then reduces the percentage of inhibition in 0.2% concentration. Minimum inhibition (44.44%) was found in Mancozeb of 0.05% concentration (Table 4.20; Fig 4.11).

Fusarium proliferatum also showed complete inhibition (100%) in Bavistin and SAAF in all the four concentration we used. Here also 100% inhibition seen in 0.15% and 0.2% concentration of Mancozeb and 0.2% concentration of Captan. Fungicide Metalaxyl showed increased inhibition with increase in the concentration up to 0.1% but again it reduces at remaining concentration (Table 4.21; Fig 4.12). Mancozeb and Captan showed ascending order of inhibition with respect to concentration used.

Neofusicoccum ribis showed 100% inhibition in all the four concentrations of Mancozeb, Bavistin and SAAF. Captan found ascending order of inhibition with concentration of fungicide. Maximum inhibition (80%) of Metalaxyl recorded at 0.15% concentration and then it reduces its inhibition at 0.2% concentration. Lowest inhibition (50.58%) found at 0.05% concentration of Fungicide Captan (Table 4.21; Fig 4.13).

In case of *Alternaria alternata*, Bavistin showed 100% inhibition in all the concentration and SAAF showed complete inhibition in three concentrations out of four concentrations used. Mancozeb and Captan increased inhibition with increase in concentration and Mancozeb also showed 100% in 0.15% and 0.2% concentration.

Metalaxyl showed interesting result, it showed 100% inhibition at 0.1% Conc. but decrease the inhibition in higher concentration i.e., 0.15% and 0.2% (Table 4.21; Fig 4.14).

In *Fusarium verticillioides,* found 100% inhibition in all concentration of Fungicide Bavistin. SAAF showed complete inhibition in two concentrations (0.15% and 02%). Mancozeb, Captan and Metalaxyl showed increased inhibition with increase in the concentration. Minimum inhibition (40.69) was found at 0.05% concentration of Metalaxyl (table 4.22; Fig 4.15).

Bavistin and SAAF showed complete inhibition in all the concentration in case of *Alternaria solani.* In case of Mancozeb and Metalaxyl maximum inhibition found at 0.1% conc again it reduces inhibition in 0.15% and 0.2% conc. Captan reveals that inhibition percentage increases with increase in the concentration. Minimum inhibition (38.88) was found in Mancozeb at 0.05%. (Table 4.22; Fig 4.16).

In case of *Drechslera halodes* fungicide SAAF completely inhibit the fungal growth in all the concentration. Metalaxyl showed 100% inhibition at 0.1% and 0.2% concentration and remaining three fungicides namely Mancozeb, Bavistin and Captan showed ascending order of inhibition with respect to concentration. Minimum inhibition was found at 0.05% of Captan (Table 4.22; Fig 4.17).

Alternaria longipes showed 100% inhibition in all concentrations of Bavistin and SAAF. In case of Mancozeb, Captan and Metalaxyl all are showing same result like as on increase the concentration similarly percentage of inhibition also increases. In these three fungicides maximum inhibition (92.22) and minimum inhibition (24.44)

was seen in 0.2% of Captan and 0.05% of Metalaxyl respectively (Table 4.23; Fig 4.18).

Curvularia lunata completely inhibited in all the four concentrations in Captan and 100% inhibition also found in three concentrations (0.1%, 0.15% and 0.2%) of Mancozeb, two concentrations (0.15% and 0.2%) of SAAF and 0.2% of Metalaxyl. Bavistin showed various inhibitions in different concentration and the maximum inhibition was recorded at 0.2% concentration (Table 4.23; Fig 4.19). But in case of *Curvularia eleusinicola* complete inhibition was recorded in 0.15% and 0.2% of SAAF and 0.2% of Mancozeb and Captan. Least inhibition (46.66) was found at 0.05% of Bavistin (Table 4.23; Fig 4.20).

Colletotrichum gloeosporioides and *Colletotrichum capsici* showed highest percent of inhibition in Bavistin and SAAF. Lowest inhibition was found in 0.05% concentration of Metalaxyl and Mancozeb in *Colletotrichum gloeosporioides* and *Colletotrichum capsici* respectively. Captan was moderately effective in both the organism. In *Colletotrichum gloeosporioides* 100% was found in Mancozeb also at two concentrations (0.15% and 0.2%). In case of *Colletotrichum capsici* Metalaxyl also showed 100% at 0.2% concentration (Table 4.24; Fig 4.21 and Fig 4.22).

Out of four Concentrations, three concentrations of Bavistin, two concentration of SAAF and 0.2% concentration of Mancozeb were showed highest percent of inhibition in *Macrophomina phaseolina.* Captan and Metalaxyl also showed good inhibition in all the concentration used. Lowest inhibition was recorded in 0.05% of Mancozeb and Captan (Table 4.24; Fig 4.23).

Curvularia fallax showed highest (100%) percentage of inhibition in three concentrations of Bavistin and two concentrations (0.15% and 0.2%) of Mancozeb and SAAF. Captan and Metalaxyl also recorded good inhibition with increase in the concentration. Minimum inhibition was found in 0.1% Concentration Metalaxyl (Table 4.25; Fig 4.24).

Bavistin and SAAF completely inhibited the fungal growth of *Cladosporium cladosporioides* in all the tested concentration. Mancozeb at 0.2% conc also showed 100% inhibition. Captan recorded increases the inhibition percentage with increase in the concentration. Metalaxyl showed lesser inhibition in 0.1% and 0.2% concentration compared to 0.05% but higher inhibition was recorded at 0.2% concentration (Table 4.25; Fig 4.25).

Like other Fusarium species, *Fusarium equiseti* also controlled in fungicide Bavistin and SAAF at lower concentration. All the five fungicide showed significant inhibition in all the tested concentration. Among all the fungicide lowest inhibition (63.33) was recorded in Mancozeb at 0.05% concentration (Table 4.25; Fig 4.26).

Bipolaris showed complete inhibition in all the tested concentration in SAAF and three concentrations of Bavistin. Mancozeb at 0.2% also showed 100% inhibition while other three fungicides recorded increased inhibition with increase in the concentration. Lowest inhibition (36.36) was found at 0.05% concentration of Metalaxyl (Table 4.26; Fig 4.27).

All the fungicides at all the tested concentration significantly inhibited the fungal growth compared to the control. *Fusarium culmorum* showed 100% inhibition in 0.15% and 0.2% concentration of Bavistin and SAAF. In Mancozeb, Captan and

Metalaxyl percent inhibition increases with the increased concentration. Metalaxyl and Captan at 0.05% concentration was least effective in reducing the fungal growth (32.22) (Table 4.26; Fig 4.28).

But in case of *Fusarium moniliforme* 100% inhibition was found at all the tested concentration of Bavistin and SAAF like other Fusarium species and again Captan showing least inhibition among five fungicides. Mancozeb and Metalaxyl showed increased inhibition with increase in the concentration and also showed 100% inhibition at 0.15% & 0.2% concentration and 0.2% concentration respectively (Table 4.26; Fig 4.29).

In control of *Phomopsis vexans,* Bavistin played a major role which inhibits the fungal growth in all the concentration. SAAF also showed 100% inhibition in two higher concentration and Mancozeb at 0.2% concentration. Captan and Metalaxyl showed increased inhibition with increase in concentration, it shows from 32.22% to 76.66%. Among five fungicides, Bavistin was more effective to control the *Phomopsis vexans* in *vitro* (Table 4.27; Fig 4.30).

Bavistin found to be good fungicide to control *Chaetomium globosum* in *vitro* condition because it inhibits complete fungal growth in three concentrations among four tested concentrations followed by SAAF which also showed complete inhibition in two concentrations (0.15% and 0.2%). Mancozeb, Captan and Metalaxyl exhibits gradual increasing in the concentration it shows increase the inhibition percentage. At 0.2% of Mancozeb also showed complete inhibition. Hence Bavistin was more effective followed by SAAF and Mancozeb (Table 4.27; Fig 4.31).

Fusarium scirpi also showed complete inhibition in Bavistin and SAAF like other Fusarium species. Mancozeb also showed 100% inhibition in 0.2% concentration. All the fungicide reveals good inhibition with increased concentration. Captan, Metalaxyl showed minimum inhibition of 40% to maximum inhibition of 86.66% (Table 4.27; Fig 4.32).

Aspergillus flavus, *Aspergillus niger* and *Nigrospora oryzae* also showed good inhibition in Bavistin, SAAF and Mancozeb. In *Aspergillus flavus* complete inhibition was found in all concentration of Bavistin, three concentrations of Mancozeb and SAAF (Table 4.28; Fig 4.33). In case of *Aspergillus niger* SAAF showed complete inhibition in all the tested concentration and Metalaxyl also showed in 0.15% and 0.2% concentrations and 0.2% of Captan. Least inhibition was found in 0.05% of Metalaxyl (Table 4.28; Fig 4.34). In *Nigrospora oryzae* 100% inhibition found in Bavistin and SAAF. Mancozeb, Captan and Metalaxyl also showed good inhibition to control the fungal growth in *vitro* and recorded least inhibition from 25.88% to highest inhibition of 100% (Table 4.28; Fig 4.35).

Mucor flavus and *Rhizopus stolonifer* also showed good inhibition in Bavistin, SAAF and Mancozeb. In *Mucor flavus* complete inhibition was found in all concentration of Bavistin, three concentrations of SAAF. The least inhibition (24.44%) was seen in 0.05% of Metalaxyl (Table 4.29; Fig 4.36). In case of *Rhizopus stolonifer* SAAF showed complete inhibition in all the tested concentration and Bavistin in three concentrations and two concentrations of Mancozeb. Least inhibition was found in 0.05% of Metalaxyl (Table 4.29; Fig 4.37).

Table: 4.19 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration (cm)				Mean	SD	SE
			0.05	0.1	0.15	0.2			
1.	*Corynespora cassiicola*	Mancozeb	3.7 (56.47)	1.6 (81.17)	00 (100)	00 (100)	1.32	1.75	±0.876
		Bavistin	3.5 (58.82)	2.1 (75.29)	1.1 (87.05)	0.5 (94.11)	1.8	1.31	±0.655
		Captan	2.9 (65.88)	1.7 (80)	1.9 (77.64)	0.2 (97.64)	1.67	1.1	±0.557
		Metalaxyl	3.9 (54.11)	2.7 (68.23)	1.9 (77.64)	1.7 (80)	2.55	0.99	±0.499
		SAAF	3.2 (62.35)	1.5 (82.35)	1.2 (85.88)	0.5 (94.11)	1.6	1.14	±0.573
		Control	8.5	-	-	-			-
2.	*Fusarium solani*	Mancozeb	4.1 (44.59)	2.0 (72.97)	00 (100)	00 (100)	1.525	1.95	±0.979
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	2.3 (68.91)	2.1 (71.62)	1.8 (75.67)	00 (100)	1.55	1.05	±0.526
		Metalaxyl	1.9 (74.32)	1.7 (77.02)	1.4 (81.08)	00 (100)	1.25	0.85	±0.429
		SAAF	0.9 (87.83)	0.5 (93.24)	00 (100)	00 (100)	0.35	0.43	±0.217
		Control	7.4	-	-	-			-
3.	*Curvularia akaiiensis*	Mancozeb	1.8 (71.87)	1.4 (78.12)	00 (100)	00 (100)	0.8	0.93	±0.469
		Bavistin	1.9 (70.31)	1.9 (70.31)	1.8 (71.87)	1.6 (75)	1.8	0.14	±0.070
		Captan	1.6 (75)	1.1 (82.81)	0.8 (87.5)	00 (100)	0.875	0.67	±0.335
		Metalaxyl	1.2 (81.25)	1.3 (79.68)	0.8 (87.5)	0.5 (92.18)	0.95	0.36	±0.184
		SAAF	1.0 (84.37)	0.3 (95.31)	00 (100)	00 (100)	0.325	0.47	±0.235
		Control	6.4	-	-	-			-

Table: 4.20 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
4.	*Fusarium incarnatum*	Mancozeb	1.2 (85.54)	00 (100)	00 (100)	00 (100)	0.3	0.6	±0.3
		Bavistin	2.0 (75.90)	1.0 (87.95)	1.2 (85.54)	1.5 (81.92)	1.425	0.43	±0.21
		Captan	1.7 (79.51)	1.3 (84.33)	00 (100)	00 (100)	0.75	0.88	±0.44
		Metalaxyl	1.8 (78.31)	1.6 (80.72)	1.5 (81.92)	00 (100)	1.225	0.82	±0.41
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.3	-	-	-			-
5.	*Lasiodiplodia theobromae*	Mancozeb	00 (100)	00 (100)	00 (100)	00 (100)	00	00	00±
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	00±
		Captan	00 (100)	00 (100)	00 (100)	00 (100)	00	00	00±
		Metalaxyl	4.5 (50)	3.6 (60)	2.3 (74.44)	2.1 (76.66)	3.125	1.13	±0.56
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	00±
		Control	9.0	-	-	-			-
6.	*Fusarium oxysporum*	Mancozeb	5.0 (44.44)	4.6 (48.88)	2.0 (77.77)	00 (100)	2.9	2.34	±1.17
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	3.5 (61.11)	2.9 (67.77)	2.1 (76.66)	00 (100)	2.125	1.52	±0.76
		Metalaxyl	2.3 (74.44)	2.1 (76.66)	1.6 (82.22)	2.5 (72.22)	2.125	0.38	±0.19
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-

Table: 4.21 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
7.	*Fusarium proliferatum*	Mancozeb	3.1 (50)	2.7 (56.45)	00 (100)	00 (100)	1.45	1.68	±0.84
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	3.7 (40.32)	2.0 (67.41)	1.5 (75.80)	00 (100)	1.8	1.52	±0.76
		Metalaxyl	2.0 (67.41)	1.9 (69.35)	3.0 (51.61)	2.8 (54.83)	2.425	0.55	±0.27
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	6.2	-	-	-			-
8.	*Neofusicoccum ribis*	Mancozeb	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	4.2 (50.58)	3.7 (56.47)	3.4 (60)	2.8 (67.05)	3.525	0.58	±0.29
		Metalaxyl	2.5 (70.58)	2.1 (75.29)	1.7 (80)	1.9 (77.64)	2.05	0.34	±0.17
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.5	-	-	-			-
9.	*Alternaria alternata*	Mancozeb	3.4 (58.53)	2.1 (74.39)	00 (100)	00 (100)	1.375	1.67	±0.83
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	3.8 (53.65)	3.1 (62.19)	2.9 (64.63)	2.1 (74.39)	2.975	0.69	±0.34
		Metalaxyl	1.7 (79.26)	00 (100)	1.1 (86.58)	1.6 (80.48)	1.1	0.77	±0.38
		SAAF	2.2 (73.17)	00 (100)	00 (100)	00 (100)	0.55	1.1	±0.55
		Control	8.2	-	-	-			-

Table: 4.22 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
10.	*Fusarium verticillioides*	Mancozeb	3.8 (55.81)	3.4 (60.46)	2.7 (68.60)	1.5 (82.55)	2.85	1.00	±0.50
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	4.5 (47.67)	3.9 (54.65)	2.8 (67.44)	1.9 (77.90)	3.275	1.15	±0.57
		Metalaxyl	5.1 (40.69)	4.9 (43.02)	3.7 (56.97)	2.5 (70.93)	4.05	1.20	±0.60
		SAAF	3.3 (61.62)	2.6 (69.76)	00 (100)	00 (100)	1.475	1.72	±0.86
		Control	8.6	-	-	-			-
11.	*Alternaria solani*	Mancozeb	5.5 (38.88)	2.4 (73.33)	6.7 (25.55)	4.2 (53.33)	4.7	1.84	±0.92
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	5.4 (40)	3.0 (66.66)	2.7 (70)	2.1 (76.66)	3.3	1.44	±0.724
		Metalaxyl	3.5 (61.11)	2.5 (72.22)	5.0 (44.44)	5.0 (44.44)	4	1.22	±0.61
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-
12.	*Drechslera halodes*	Mancozeb	3.8 (55.29)	3.3 (61.17)	3.3 (61.17)	2.6 (69.41)	3.25	0.49	±0.24
		Bavistin	3.2 (62.35)	3.0 (64.70)	3.0 (64.70)	2.9 (65.88)	3.025	0.12	±0.06
		Captan	4.3 (49.41)	3.4 (60)	3.1 (63.52)	2.7 (68.23)	3.375	0.68	±0.34
		Metalaxyl	2.4 (71.76)	00 (100)	3.2 (62.35)	00 (100)	1.4	1.64	±0.82
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.5	-	-	-			-

Table: 4.23 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
13.	*Alternaria longipes*	Mancozeb	1.8 (80)	1.6 (82.22)	1.0 (88.88)	0.8 (91.11)	1.3	0.47	±0.23
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	1.4 (84.44)	1.3 (85.55)	1.0 (88.88)	0.7 (92.22)	1.1	0.31	±0.15
		Metalaxyl	6.8 (24.44)	5.2 (42.22)	4.0 (55.55)	2.0 (77.77)	4.5	2.02	±1.01
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-
14.	*Curvularia lunata*	Mancozeb	0.6 (93.33)	00 (100)	00 (100)	00 (100)	0.15	0.3	±0.15
		Bavistin	5.1 (43.33)	4.5 (50)	5.3 (41.11)	4.0 (55.55)	4.725	0.59	±0.29
		Captan	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Metalaxyl	2.3 (74.44)	2.6 (71.11)	1.3 (85.55)	00 (100)	1.55	1.17	±0.58
		SAAF	1.4 (84.44)	1.3 (85.55)	00 (100)	00 (100)	0.675	0.78	±0.39
		Control	9.0	-	-	-			-
15.	*Curvularia eleusinicola*	Mancozeb	1.5 (83.33)	1.2 (86.66)	0.6 (93.33)	00 (100)	0.825	0.66	±0.33
		Bavistin	4.8 (46.66)	4.5 (50)	4.4 (51.11)	3.8 (57.77)	4.375	0.41	±0.20
		Captan	2.8 (68.88)	1.8 (80)	1.2 (86.66)	00 (100)	1.45	1.17	±0.58
		Metalaxyl	2.5 (72.22)	1.9 (78.88)	1.3 (85.55)	1.2 (86.66)	1.725	0.60	±0.30
		SAAF	3.2 (64.44)	2.8 (68.88)	00 (100)	00 (100)	1.5	1.73	±0.86
		Control	9.0	-	-	-			-

Table: 4.24 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
16.	*Colletotrichum gloeosporioides*	Mancozeb	3.4 (62.22)	2.6 (71.11)	00 (100)	00 (100)	1.5	1.76	±0.88
		Bavistin	1.6 (82.22)	00 (100)	00 (100)	00 (100)	0.4	0.8	±0.4
		Captan	4.8 (46.66)	4.3 (52.22)	3.5 (61.11)	3.2 (64.44)	3.95	0.73	±0.36
		Metalaxyl	5.2 (42.22)	4.4 (51.11)	4.1 (54.44)	3.8 (57.77)	4.375	0.60	±0.30
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-
17.	*Colletotrichum capsici*	Mancozeb	5.3 (37.64)	5.1 (40)	3.9 (54.11)	2.2 (74.11)	4.125	1.42	±0.71
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	3.9 (54.11)	3.8 (55.29)	2.7 (68.23)	1.9 (77.64)	3.075	0.95	±0.47
		Metalaxyl	4.4 (48.23)	3.7 (56.47)	1.8 (78.82)	00 (100)	2.475	1.98	±0.99
		SAAF	1.2 (85.88)	1.2 (85.88)	00 (100)	00 (100)	0.6	0.69	±0.34
		Control	8.5	-	-	-			-
18.	*Macrophomina phaseolina*	Mancozeb	3.4 (60.46)	3.2 (62.79)	2.2 (74.41)	00 (100)	2.2	1.55	±0.77
		Bavistin	1.4 (83.72)	00 (100)	00 (100)	00 (100)	0.35	0.7	±0.35
		Captan	3.4 (60.46)	3.4 (60.46)	4.2 (51.16)	3.7 (56.97)	3.675	0.37	±0.18
		Metalaxyl	2.5 (70.93)	2.1 (75.58)	1.7 (80.23)	1.9 (77.90)	2.05	0.34	±0.17
		SAAF	3.3 (61.62)	2.6 (69.76)	00 (100)	00 (100)	1.475	1.72	±0.86
		Control	8.6	-	-	-			-

Table: 4.25 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
19.	*Curvularia fallax*	Mancozeb	1.5 (81.48)	1.2 (85.18)	00 (100)	00 (100)	0.675	0.78	±0.39
		Bavistin	1.7 (79.01)	00 (100)	00 (100)	00 (100)	0.425	0.85	±0.42
		Captan	2.6 (67.90)	1.3 (83.95)	1.3 (83.95)	1.2 (85.18)	1.6	0.66	±0.33
		Metalaxyl	3.3 (59.25)	3.5 (56.79)	2.8 (65.43)	2.3 (71.60)	2.975	0.53	±0.26
		SAAF	1.6 (80.24)	1.4 (82.71)	00 (100)	00 (100)	0.75	0.86	±0.43
		Control	8.1	-	-	-			-
20.	*Cladosporium cladosporioides*	Mancozeb	3.3 (62.50)	3.5 (60.22)	2.8 (68.18)	00 (100)	2.4	1.62	±0.81
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	4.8 (45.45)	4.3 (51.13)	4.5 (48.86)	3.5 (60.22)	4.275	0.55	±0.27
		Metalaxyl	3.5 (60.22)	3.9 (55.68)	3.6 (59.09)	2.1 (76.13)	3.275	0.80	±0.40
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.8	-	-	-			-
21.	*Fusarium equiseti*	Mancozeb	3.3 (63.33)	2.7 (70.00)	1.9 (78.88)	00 (100)	1.975	1.43	±0.71
		Bavistin	1.9 (78.88)	1.8 (80.00)	00 (100)	00 (100)	0.925	1.06	±0.53
		Captan	1.7 (81.11)	1.3 (85.55)	00 (100)	00 (100)	0.75	0.88	±0.44
		Metalaxyl	2.6 (71.11)	1.8 (80.00)	1.4 (84.44)	1.5 (83.33)	1.825	0.54	±0.27
		SAAF	2.1 (76.66)	00 (100)	00 (100)	00 (100)	0.525	1.05	±0.52
		Control	9.0	-	-	-			-

Table: 4.26 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
22.	*Bipolaris sps.*	Mancozeb	3.8 (56.81)	3.2 (63.63)	1.9 (78.40)	00 (100)	2.225	1.68	±0.84
		Bavistin	1.3 (85.22)	00 (100)	00 (100)	00 (100)	0.325	0.65	±0.32
		Captan	4.4 (50)	4.1 (53.40)	3.6 (59.09)	2.2 (75)	3.575	0.97	±0.48
		Metalaxyl	5.6 (36.36)	4.2 (52.27)	3.5 (60.22)	2.8 (68.18)	4.025	1.19	±0.59
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.8	-	-	-			-
23.	*Fusarium culmorum*	Mancozeb	5.7 (36.66)	5.1 (43.33)	5.1 (43.33)	3.3 (63.33)	4.8	1.03	±0.51
		Bavistin	2.8 (68.88)	1.5 (83.33)	00 (100)	00 (100)	1.075	1.35	±0.67
		Captan	6.1 (32.22)	5.2 (42.22)	4.4 (51.11)	4.2 (53.33)	4.975	0.86	±0.43
		Metalaxyl	6.1 (32.22)	4.2 (53.33)	4.8 (46.66)	3.9 (56.66)	4.75	0.97	±0.48
		SAAF	3.7 (58.88)	2.7 (70)	00 (100)	00 (100)	1.6	1.89	±0.94
		Control	9.0	-	-	-			-
24.	*Fusarium moniliforme*	Mancozeb	2.4 (72.09)	1.1 (87.20)	00 (100)	00 (100)	0.875	1.14	±0.57
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	4.2 (51.16)	4.2 (51.16)	3.8 (55.81)	3.5 (59.30)	3.925	0.34	±0.17
		Metalaxyl	2.7 (68.60)	2.6 (69.76)	2.1 (75.58)	00 (100)	1.85	1.26	±0.63
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.6	-	-	-			-

Table: 4.27 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
25.	*Phomopsis vexans*	Mancozeb	3.5 (61.11)	3.1 (65.55)	1.7 (81.11)	00 (100)	2.075	1.58	±0.79
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	5.5 (38.88)	5.4 (40)	4.2 (53.33)	4.0 (55.55)	4.775	0.78	±0.39
		Metalaxyl	6.1 (32.22)	5.5 (38.88)	3.3 (63.33)	2.1 (76.66)	4.25	1.87	±0.93
		SAAF	2.3 (74.44)	2.2 (75.55)	00 (100)	00 (100)	1.125	1.29	±0.64
		Control	9.0	-	-	-			-
26.	*Chaetomium globosum*	Mancozeb	2.2 (72.83)	2.1 (74.07)	1.8 (77.77)	00 (100)	1.525	1.03	±0.51
		Bavistin	1.1 (86.41)	00 (100)	00 (100)	00 (100)	0.275	0.55	±0.27
		Captan	1.5 (81.48)	1.3 (83.95)	1.0 (87.65)	0.8 (90.12)	1.15	0.31	±0.15
		Metalaxyl	5.8 (28.39)	5.3 (34.56)	4.2 (48.14)	2.0 (75.30)	4.325	1.68	±0.84
		SAAF	2.2 (72.83)	1.6 (80.24)	00 (100)	00 (100)	0.95	1.12	±0.56
		Control	8.1	-	-	-			-
27.	*Fusarium scirpi.*	Mancozeb	4.8 (46.66)	3.4 (62.22)	1.2 (86.66)	00 (100)	2.35	2.15	±1.07
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	5.4 (40)	3.9 (56.66)	3.1 (65.55)	1.9 (78.88)	3.575	1.46	±0.73
		Metalaxyl	5.1 (43.33)	3.8 (57.77)	1.9 (78.88)	1.2 (86.66)	3	1.77	±0.88
		SAAF	2.6 (71.11)	2.5 (72.22)	00 (100)	00 (100)	1.275	1.47	±0.73
		Control	9.0	-	-	-			-

Table: 4.28 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
28.	*Aspergillus flavus*	Mancozeb	2.1 (75.58)	00 (100)	00 (100)	00 (100)	0.525	1.05	±0.52
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	3.4 (60.46)	2.2 (74.41)	2.3 (73.25)	1.8 (79.06)	2.425	0.68	±0.34
		Metalaxyl	6.8 (20.93)	6.4 (25.58)	6.3 (25.58)	5.2 (39.53)	6.175	0.68	±0.34
		SAAF	2.1 (75.58)	00 (100)	00 (100)	00 (100)	0.525	1.05	±0.52
		Control	8.6	-	-	-			-
29.	*Aspergillus niger*	Mancozeb	3.5 (61.11)	2.3 (74.44)	00 (100)	00 (100)	1.45	1.74	±0.87
		Bavistin	1.2 (86.66)	00 (100)	00 (100)	00 (100)	0.3	0.6	±0.3
		Captan	2.4 (73.33)	2.3 (74.44)	1.3 (85.55)	00 (100)	1.5	1.11	±0.55
		Metalaxyl	3.7 (58.88)	2.6 (71.11)	00 (100)	00 (100)	1.575	1.87	±0.93
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-
30.	*Nigrospora oryzae*	Mancozeb	2.7 (68.23)	2.3 (72.94)	1.2 (85.88)	00 (100)	1.55	1.21	±0.60
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	6.3 (25.88)	5.7 (32.94)	3.9 (54.11)	2.4 (71.76)	4.575	1.77	±0.88
		Metalaxyl	4.8 (43.52)	3.6 (57.64)	1.4 (83.52)	00 (100)	2.45	2.15	±1.07
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	8.5	-	-	-			-

Table: 4.29 Effect of mycelial growth inhibition of pathogens by different fungicides in Poison Food Technique at 8 days after inoculation.

Sl. No	Pathogen	Fungicide	Mycelial growth at different Concentration.				Mean	SD	SE
			0.05	0.1	0.15	0.2			
31.	*Mucor flavus*	Mancozeb	4.5 (50)	4.1 (54.44)	2.1 (76.66)	00 (100)	2.675	2.06	±1.03
		Bavistin	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Captan	4.3 (52.22)	2.9 (67.77)	2.3 (74.44)	1.5 (83.33)	2.75	1.18	±0.59
		Metalaxyl	6.8 (24.44)	6.4 (28.88)	5.9 (34.44)	4.9 (45.55)	6	0.82	±0.41
		SAAF	1.9 (78.88)	00 (100)	00 (100)	00 (100)	0.475	0.95	±0.47
		Control	9.0	-	-	-			-
32.	*Rhizopus stolonifer*	Mancozeb	3.9 (56.66)	2.8 (68.88)	00 (100)	00 (100)	1.675	1.98	±0.99
		Bavistin	1.2 (86.66)	00 (100)	00 (100)	00 (100)	0.3	0.6	±0.3
		Captan	3.9 (56.66)	2.7 (70)	1.6 (82.22)	1.9 (78.88)	2.525	1.02	±0.51
		Metalaxyl	4.2 (53.33)	2.6 (71.11)	1.7 (81.11)	00 (100)	2.125	1.75	±0.87
		SAAF	00 (100)	00 (100)	00 (100)	00 (100)	00	00	±00
		Control	9.0	-	-	-			-

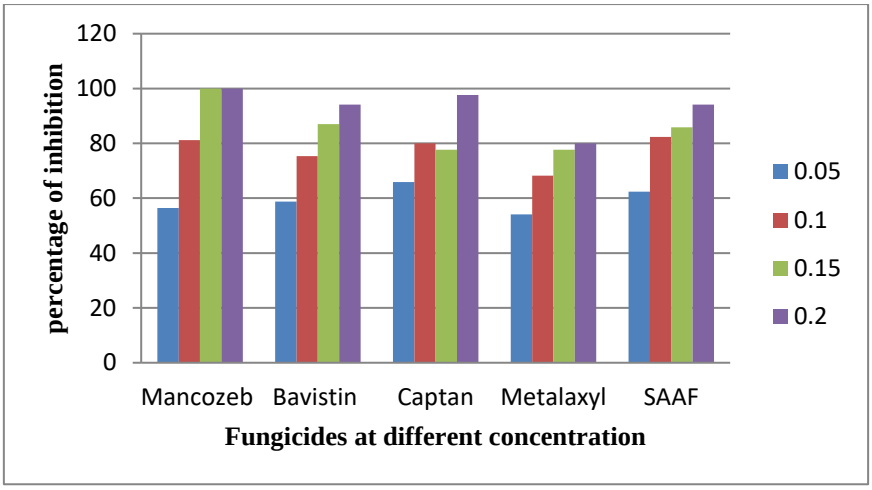


Fig:4.6 *In vitro* evaluation of *Corynespora cassiicola* using different fungicides

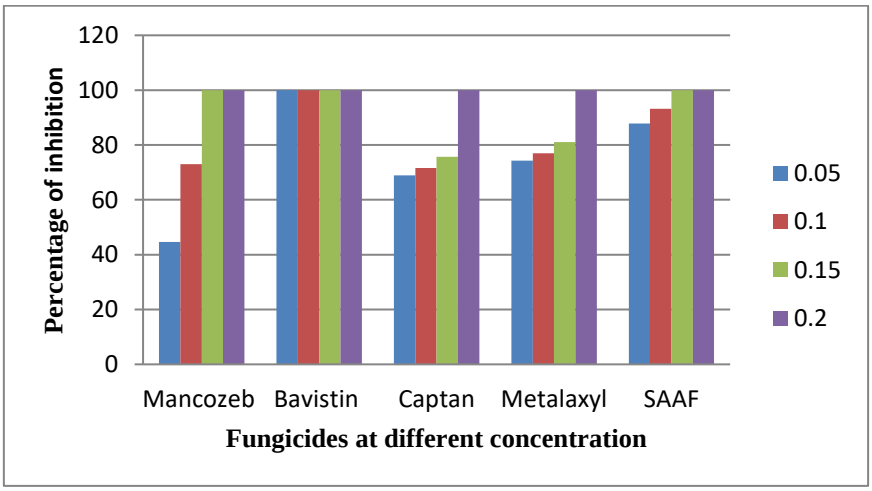


Fig:4.7 *In vitro* evaluation of *Fusarium solani* using different fungicides

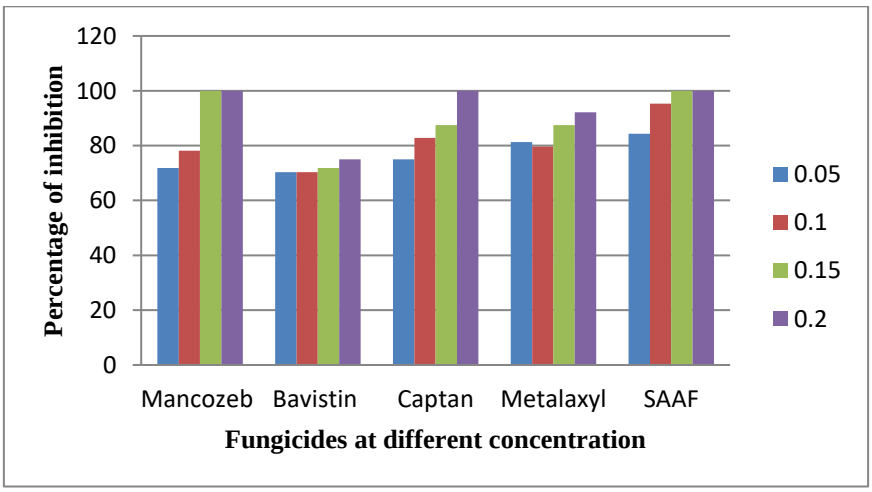


Fig:4.8 *In vitro* evaluation of *Curvularia akaiiensis* using different fungicides

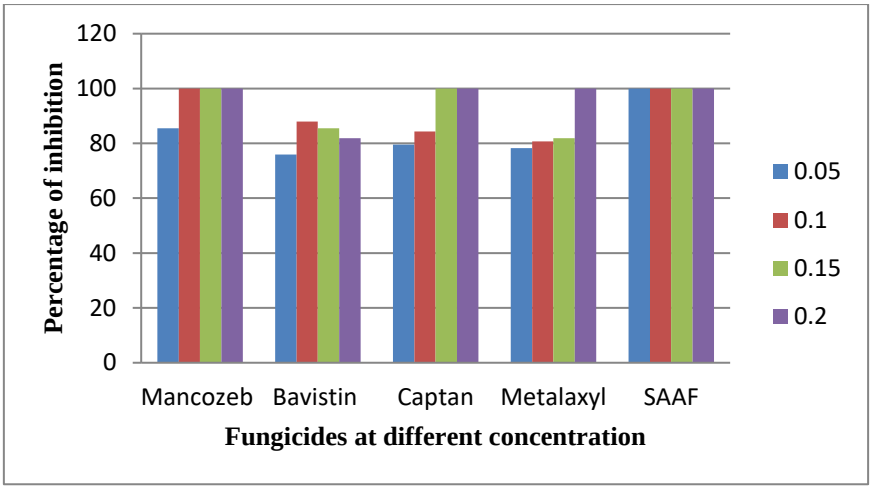


Fig:4.9 *In vitro* evaluation of *Fusarium incarnatum* using different fungicides

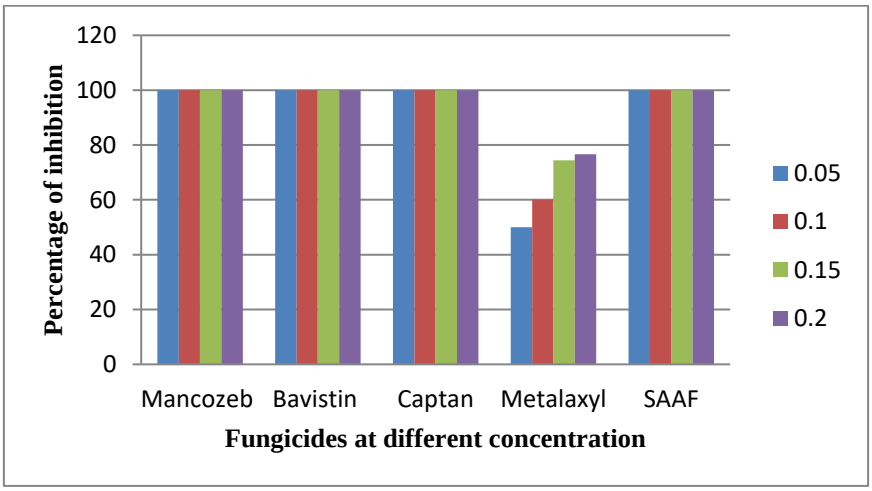


Fig:4.10 *In vitro* evaluation of *Lasiodiplodia theobromae* using different fungicides

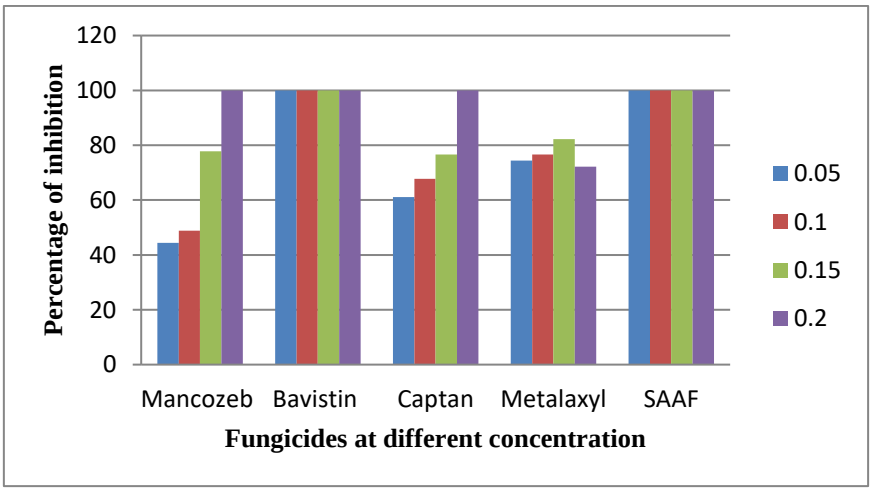


Fig:4.11 *In vitro* evaluation of *Fusarium oxysporum* using different fungicides

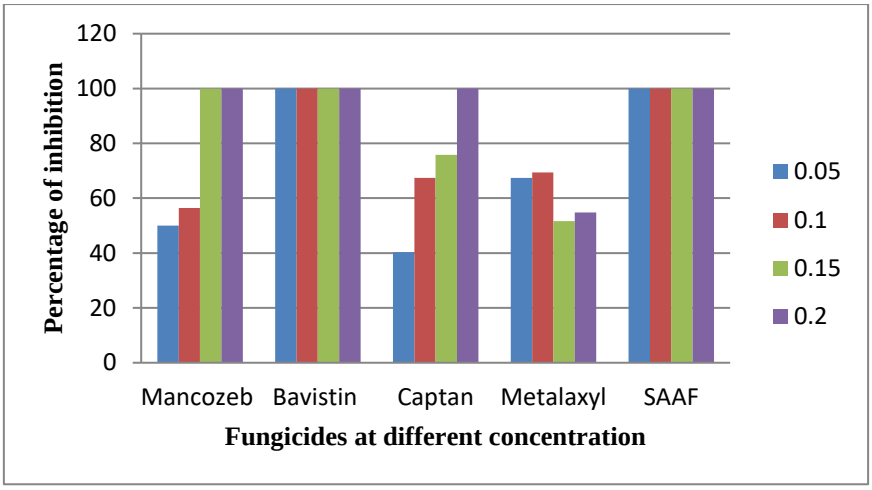


Fig:4.12 *In vitro* evaluation of *Fusarium proliferatum* using different fungicides

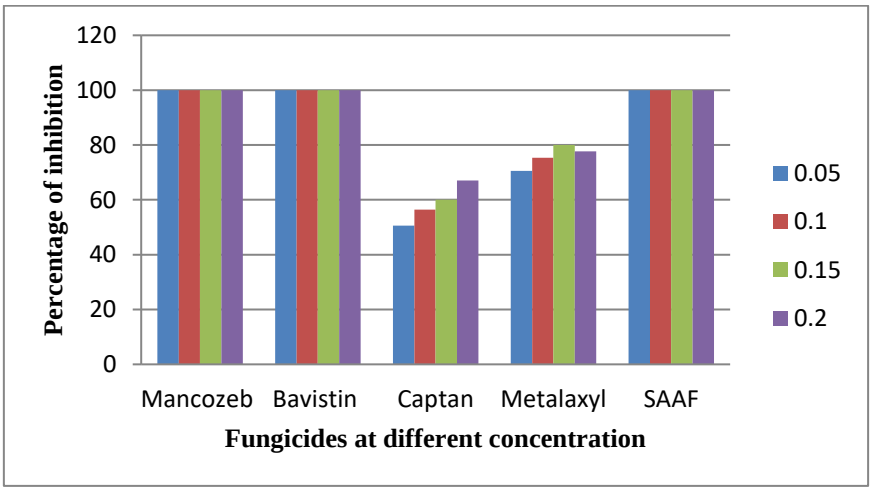


Fig:4.13 *In vitro* evaluation of *Neofusicoccum ribis* using different fungicides

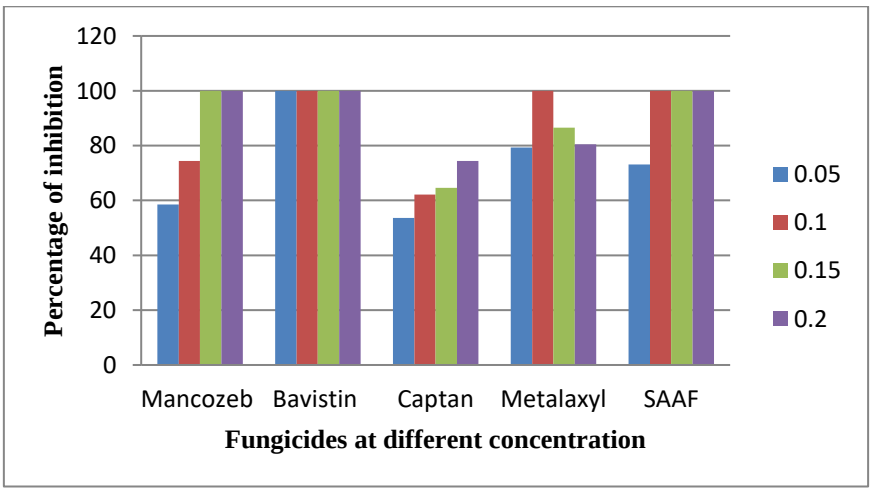


Fig:4.14 *In vitro* evaluation of *Alternaria alternata* using different fungicides

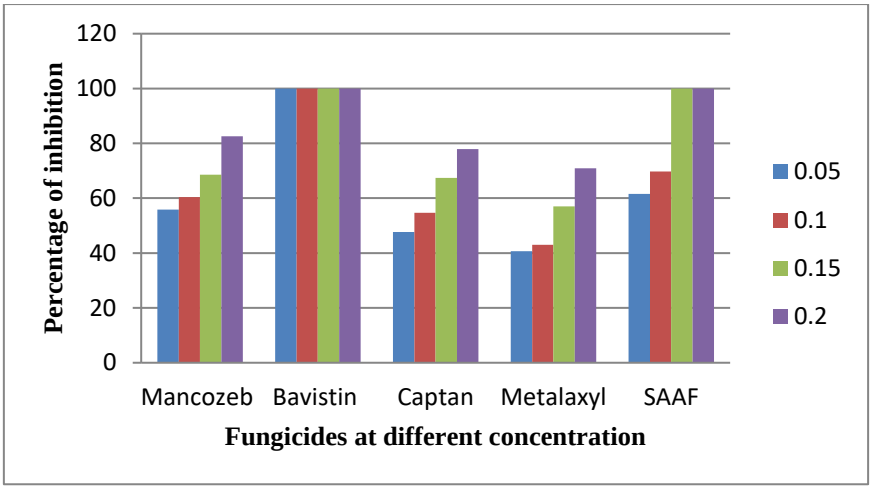


Fig:4.15 *In vitro* evaluation of *Fusarium verticillioides* using different fungicides

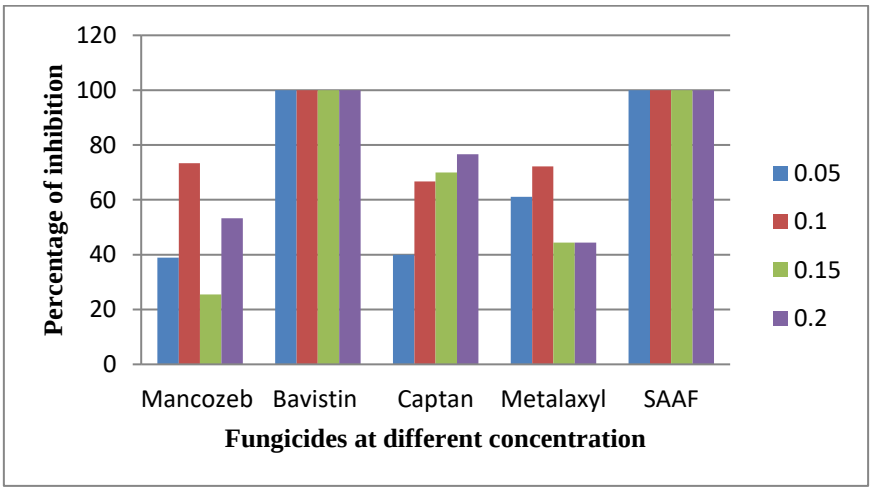


Fig:4.16 *In vitro* evaluation of *Alternaria solani* using different fungicides

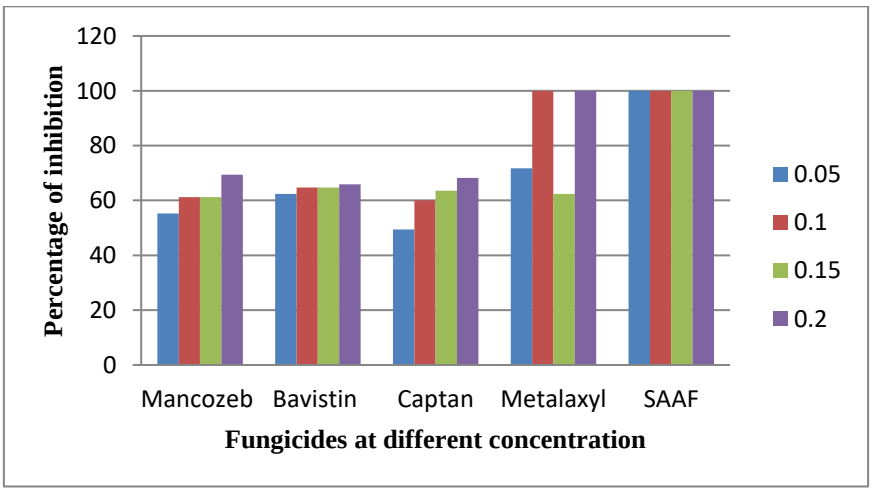


Fig:4.17 *In vitro* evaluation of *Drechslera halodes* using different fungicides

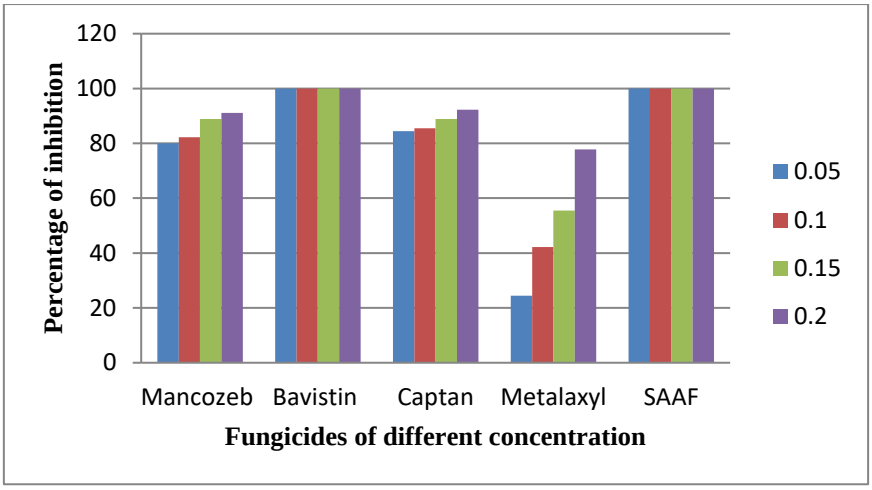


Fig:4.18 *In vitro* evaluation of *Alternaria longipes* using different fungicides

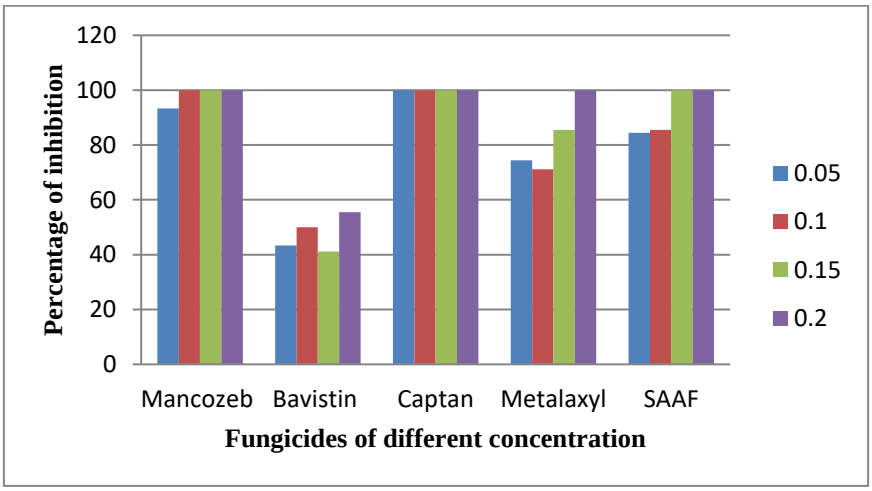


Fig:4.19 *In vitro* evaluation of *Curvularia lunata* using different fungicides

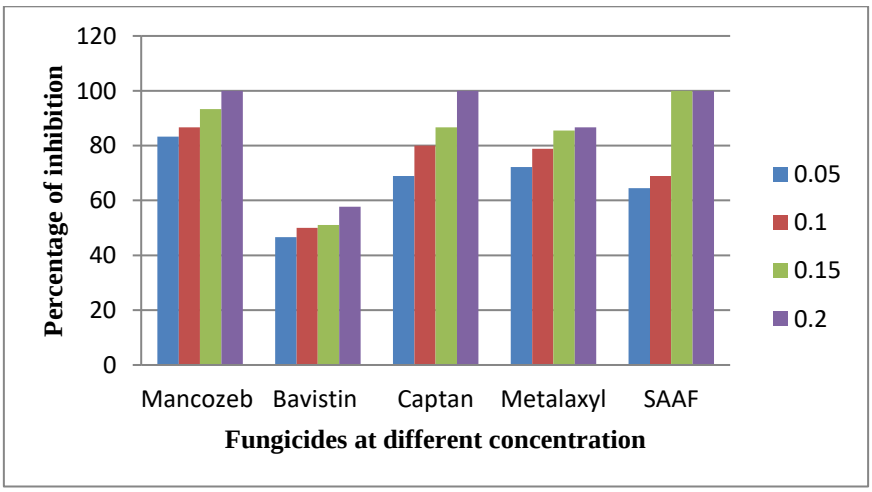


Fig:4.20 *In vitro* evaluation of *Curvularia eleusinicola* using different fungicides

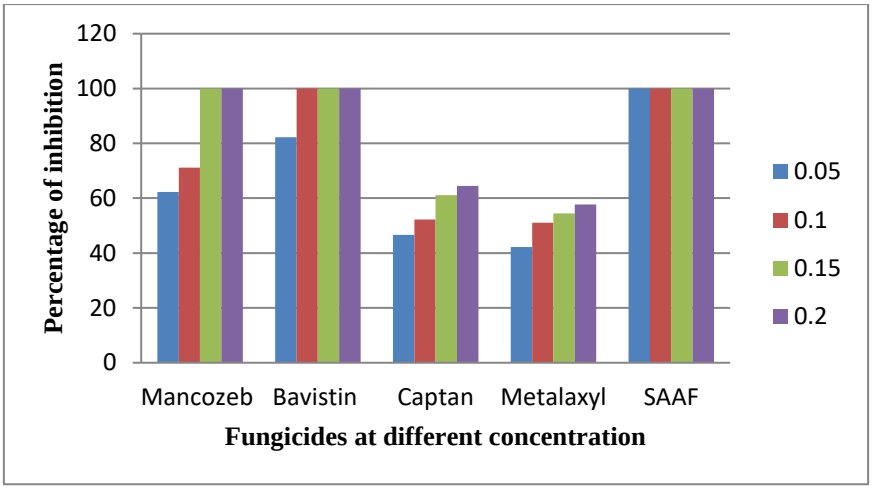


Fig:4.21 *In vitro* evaluation of *Colletotrichum gloeosporioides* using different fungicides

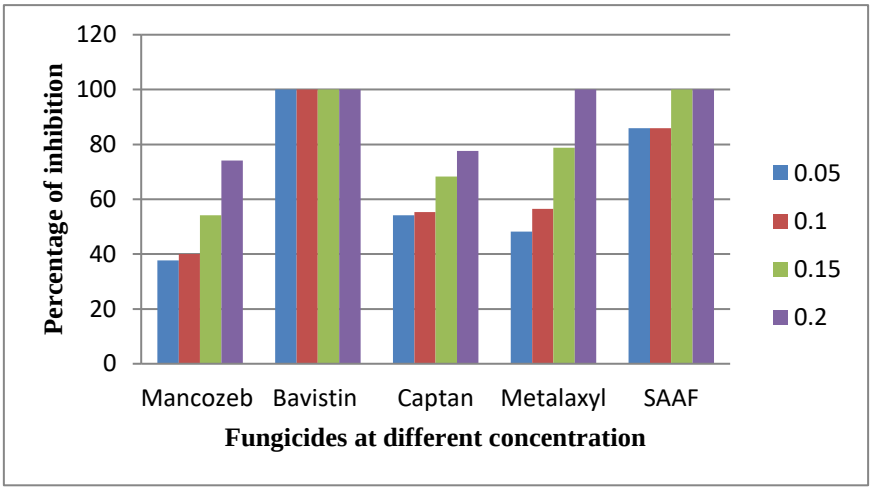


Fig:4.22 *In vitro* evaluation of *Colletotrichum capsici* using different fungicides

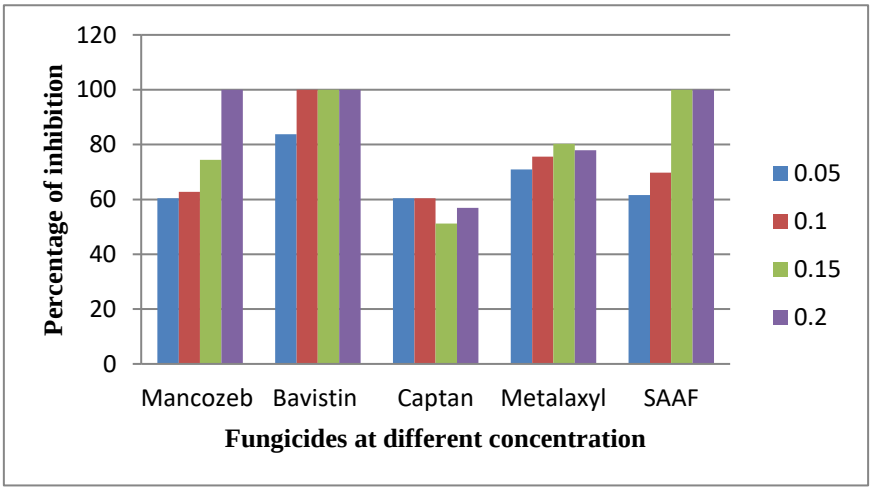


Fig:4.23 *In vitro* evaluation of *Macrophomina phaseolina* using different fungicides

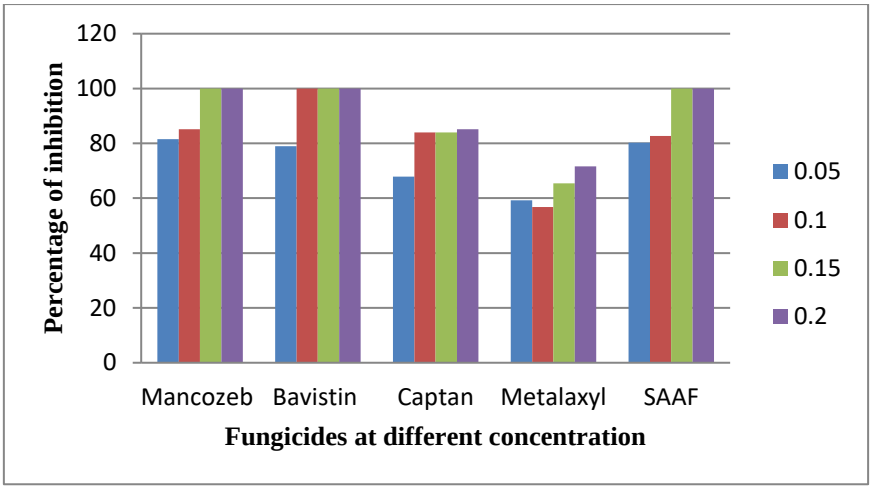


Fig:4.24 *In vitro* evaluation of *Curvularia fallax* using different fungicides

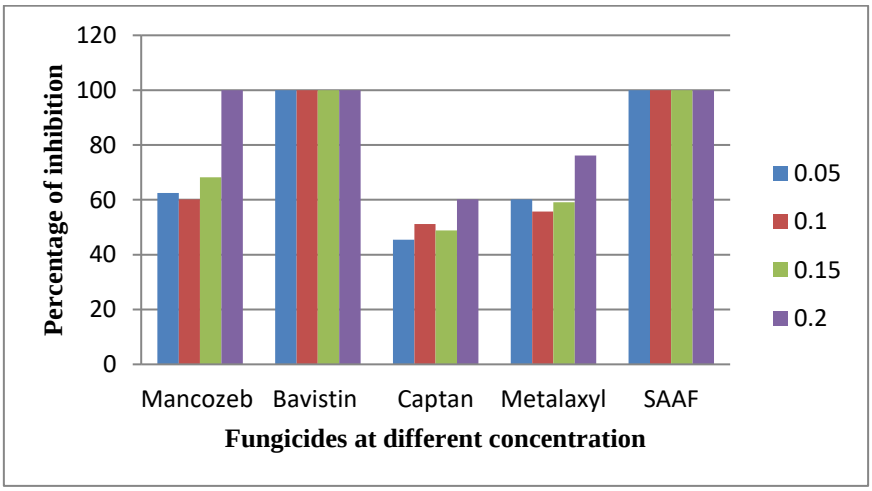


Fig:4.25 *In vitro* evaluation of *Cladosporium cladosporioides* using different fungicides

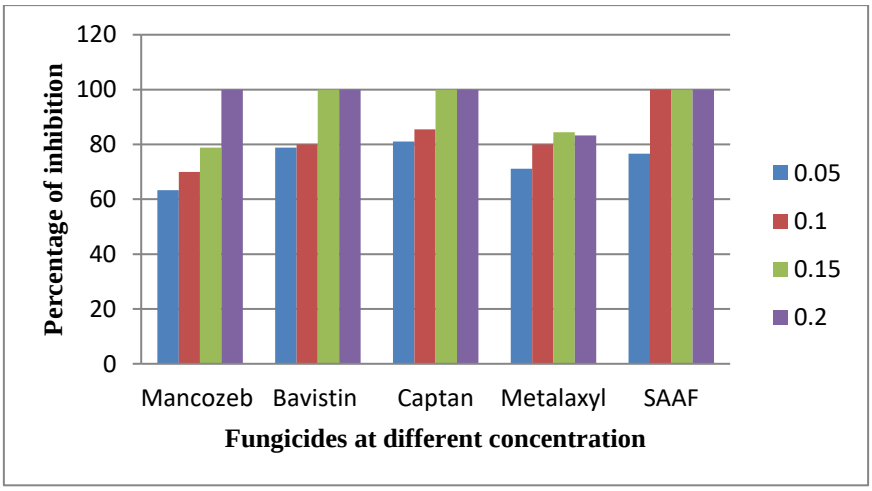


Fig:4.26 *In vitro* evaluation of *Fusarium equiseti* using different fungicides

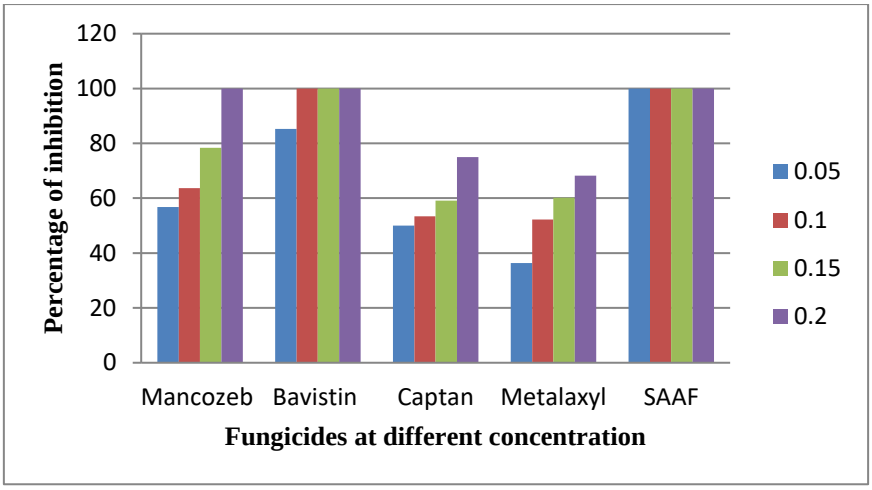


Fig:4.27 *In vitro* evaluation of *Bipolaris sps* using different fungicides

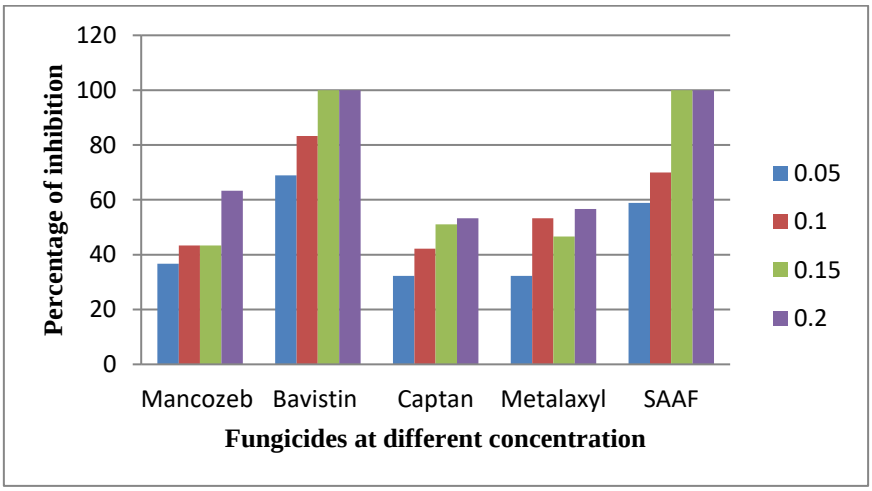


Fig:4.28 *In vitro* evaluation of *Fusarium culmorum* using different fungicides

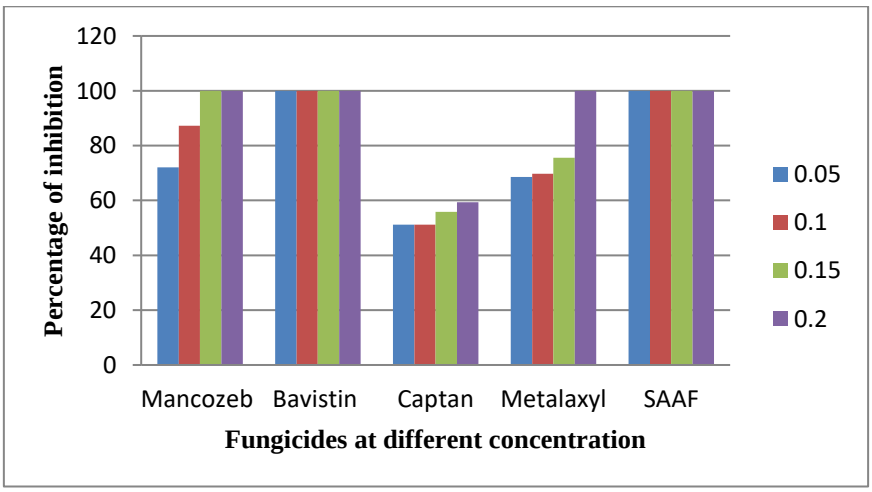


Fig:4.29 *In vitro* evaluation of *Fusarium moniliforme* using different fungicides

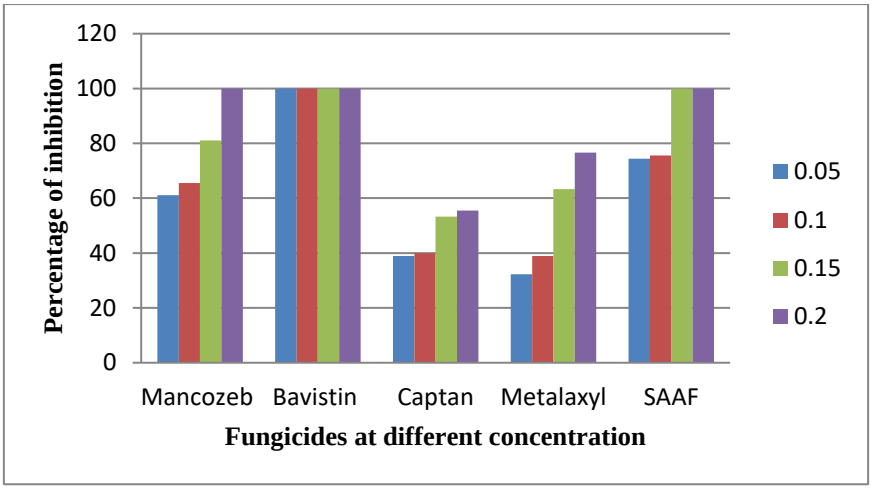


Fig:4.30 *In vitro* evaluation of *Phomopsis vexans* using different fungicides

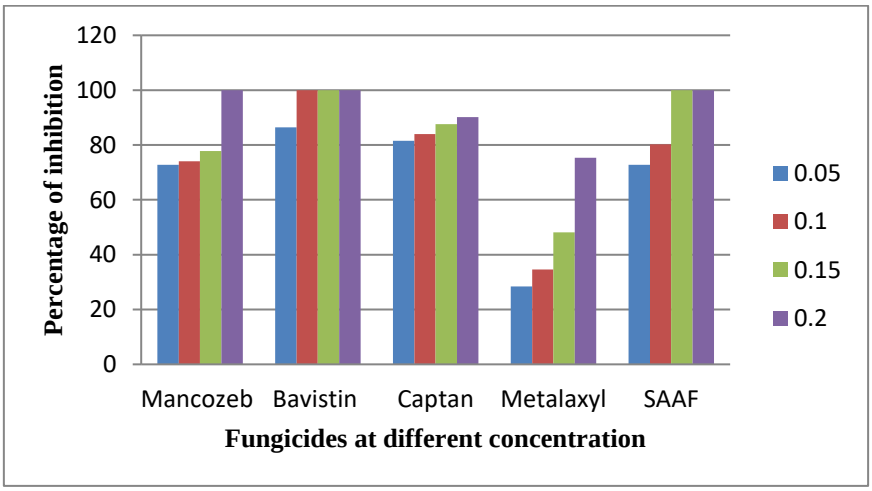


Fig:4.31 *In vitro* evaluation of *Chaetomium globosum* using different fungicides

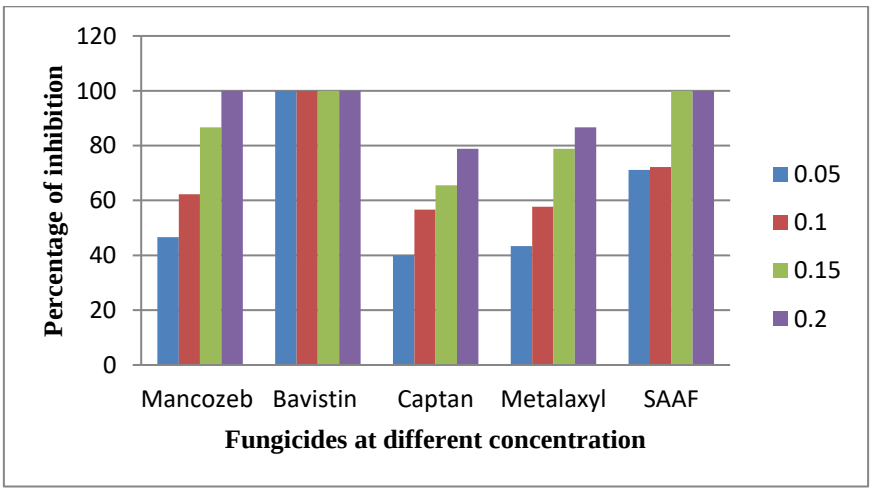


Fig:4.32 *In vitro* evaluation of *Fusarium scirpi* using different fungicides

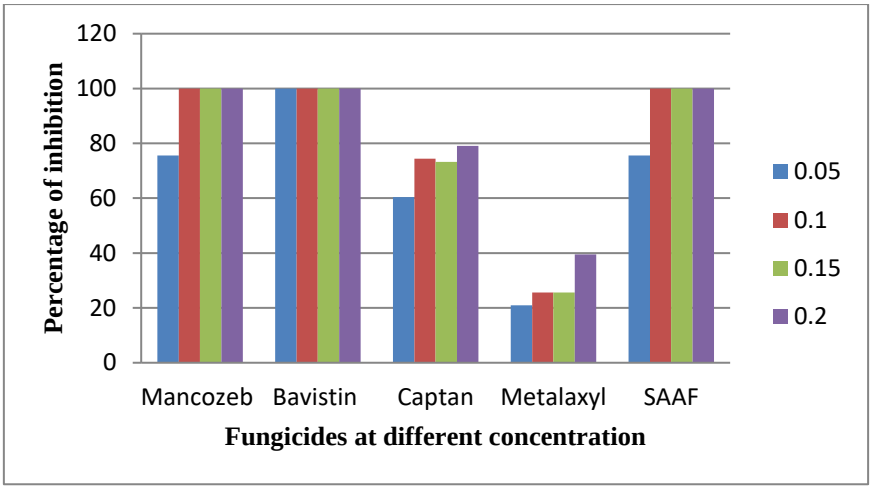


Fig:4.33 *In vitro* evaluation of *Aspergillus flavus* using different fungicides

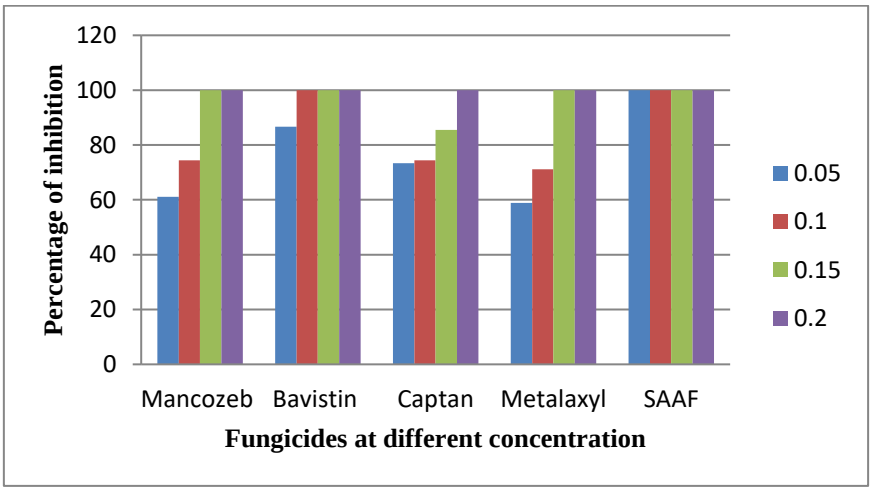


Fig:4.34 *In vitro* evaluation of *Aspergillus niger* using different fungicides

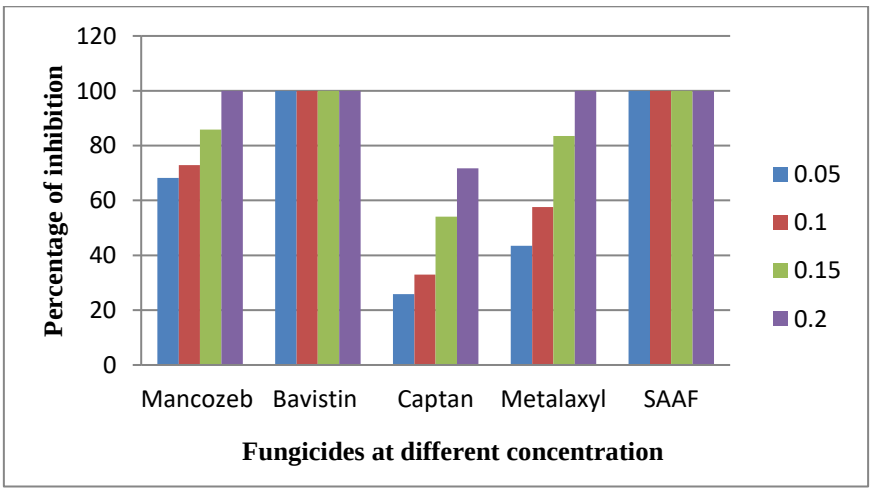


Fig:4.35 *In vitro* evaluation of *Nigrospora oryzae* using different fungicides

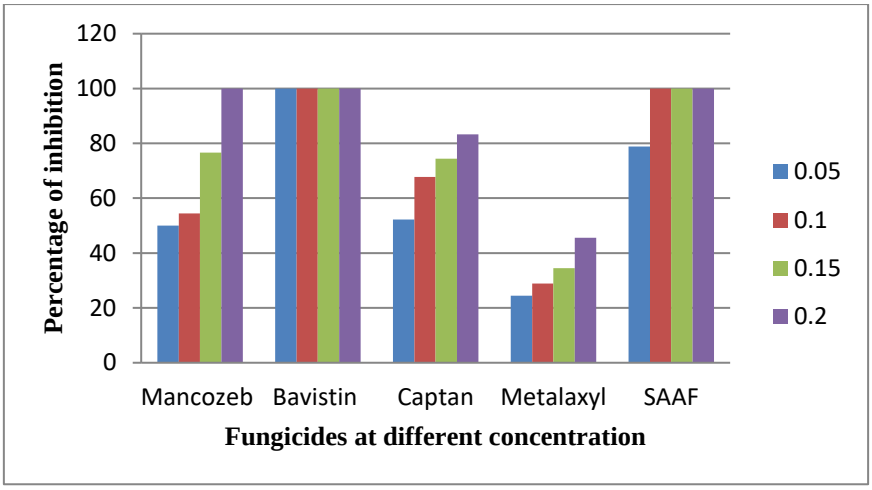


Fig:4.36 *In vitro* evaluation of *Mucor flavus* using different fungicides

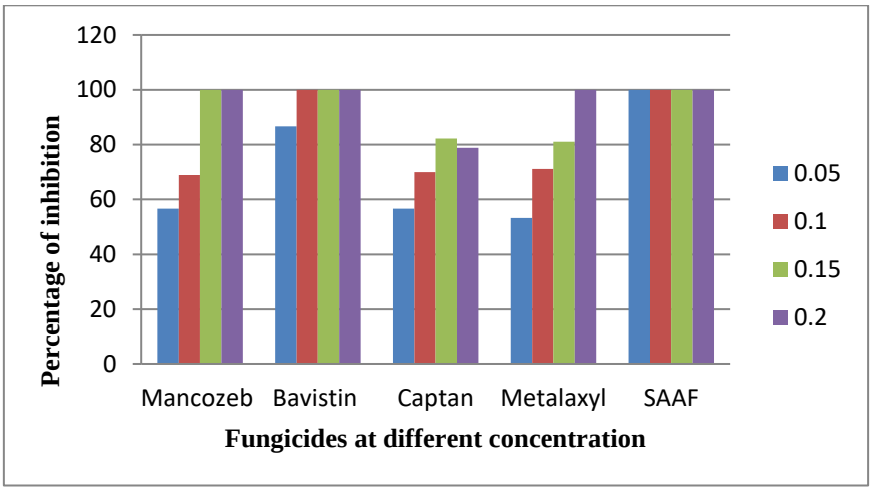


Fig:4.37 *In vitro* evaluation of *Rhizopus stolonifer* using different fungicides

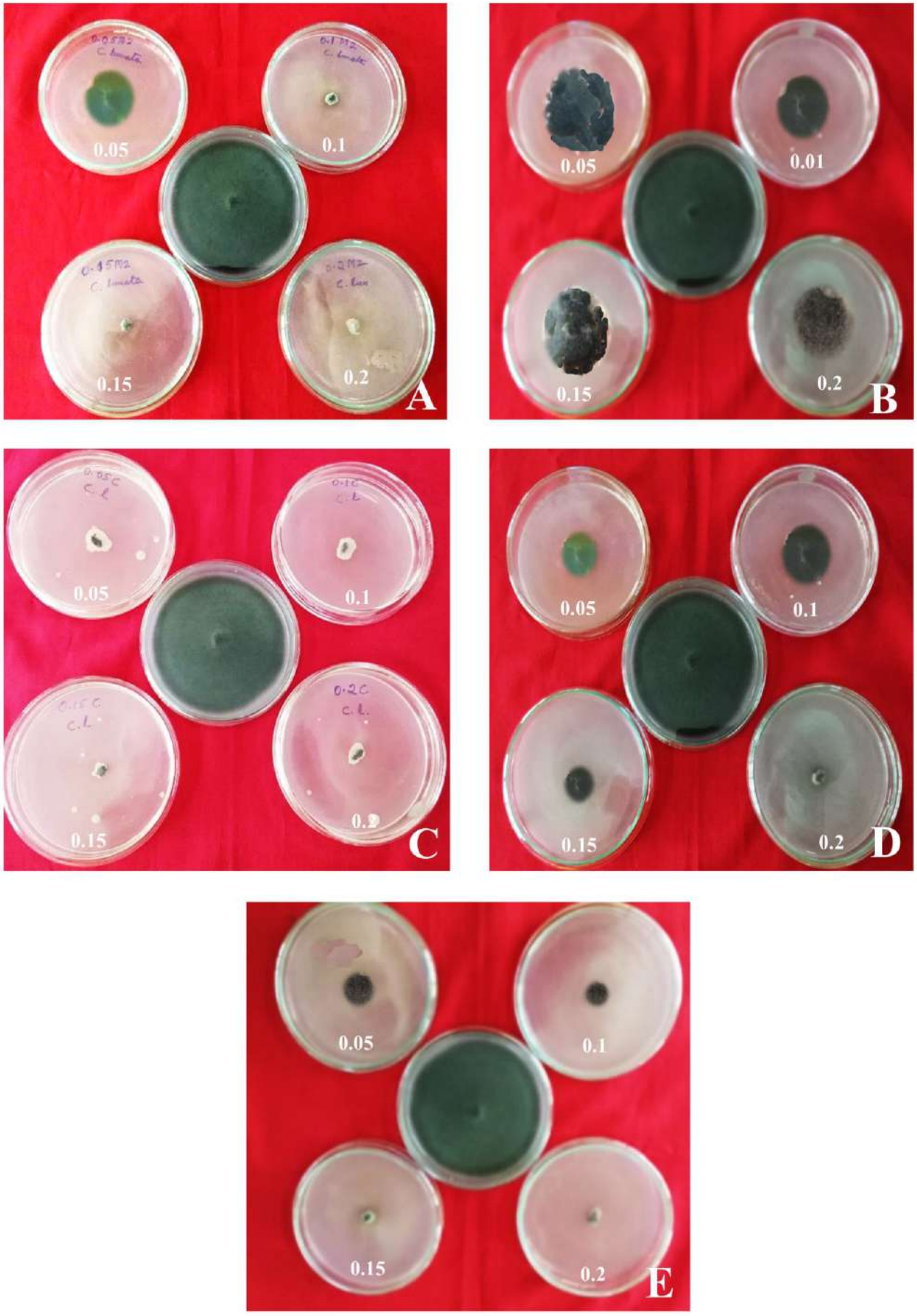


Plate-17: In *vitro* inhibitory effect of *Curvularia lunata* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

Plate-18: In *vitro* inhibitory effect of *Fusarium incarnatum* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

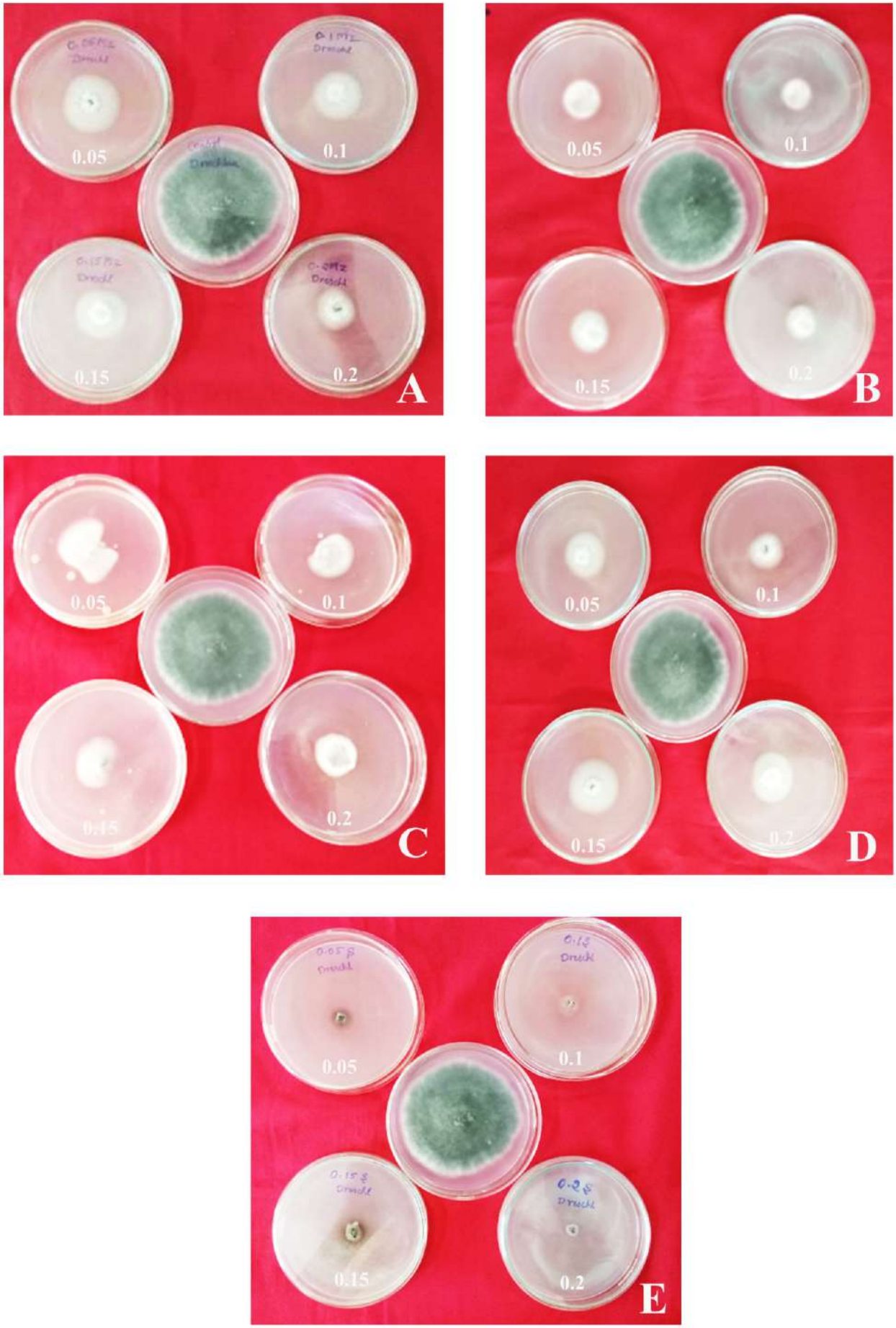


Plate-19: In *vitro* inhibitory effect of *Drechslers halodes* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

Plate-20: In *vitro* inhibitory effect of *Neofusicoccum ribis* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

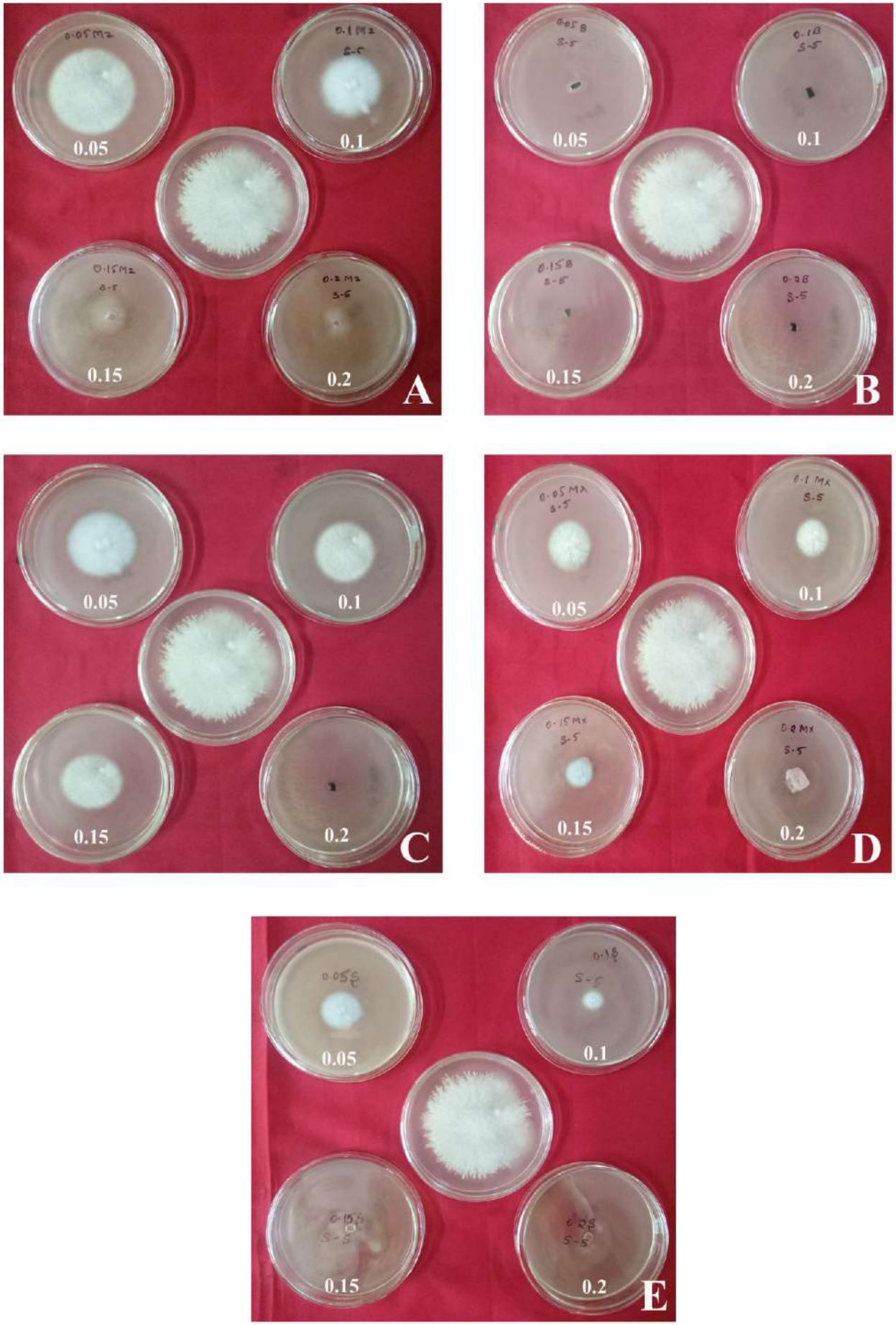


Plate-21: In *vitro* inhibitory effect of *Fusarium solani* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

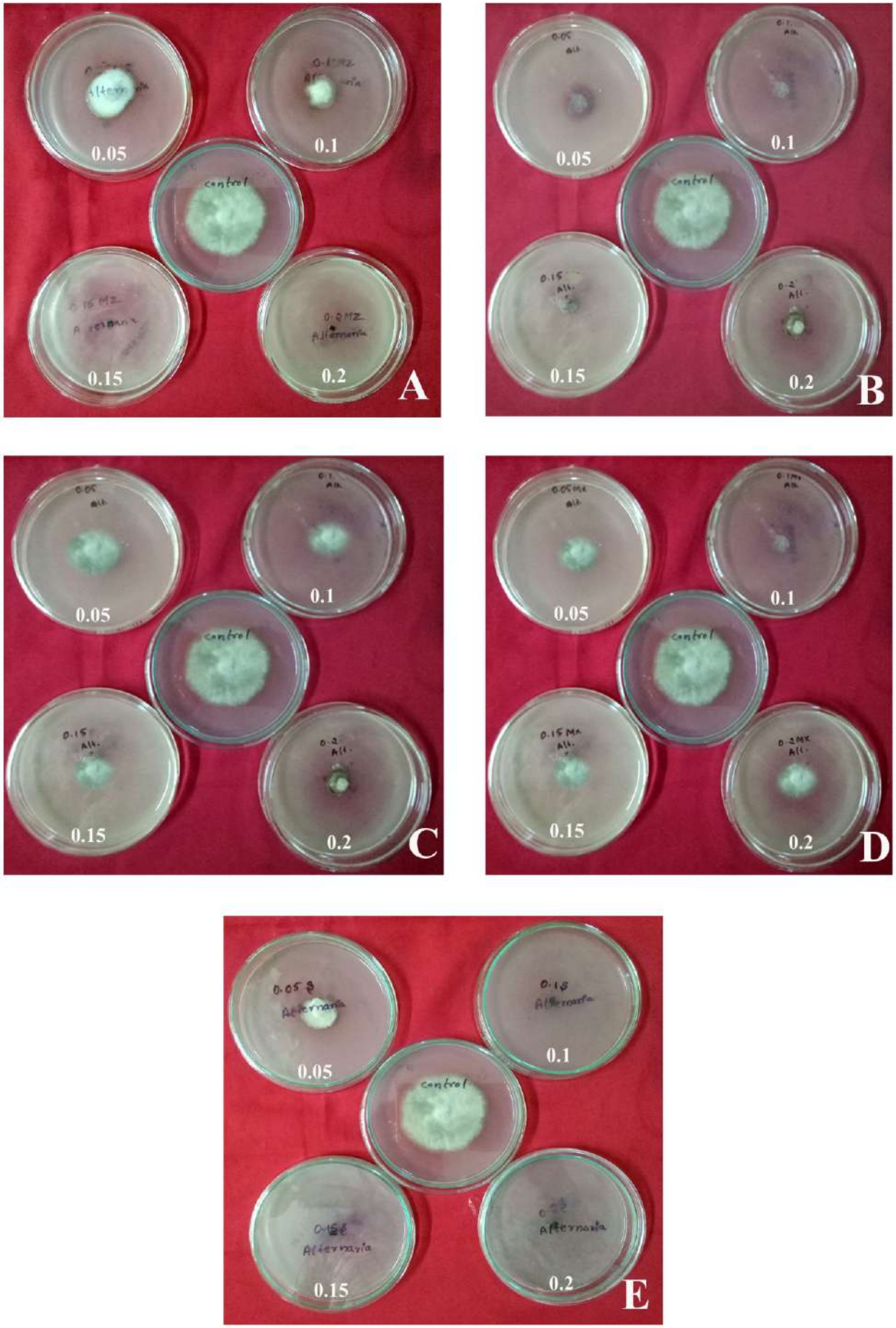


Plate-22: In *vitro* inhibitory effect of *Alternaria alternata* using different fungicides by Poison Food Technique, A- Mancozeb, B-Bavistin, C-Captan, D-Metalaxyl and E-SAAF

Field survey was done in all the six taluks of Chitradurga districts during 2019-2021. During the survey, a total 450 isolates were collected from Chilli, Tomato and Brinjal crop fields. Out of 450 isolates, 143 were recorded in Chilli, 162 isolates recorded in Tomato and 145 isolates were in Brinjal.

Total 34 species belong to 18 genera of 12 families were isolated, identified, morphologically and microscopically characterized. Among all the pathogen *F. oxysporum* and *F. solani* are the most dominant species causes more damage to Chilli in Kharif 2019. *Fusarium oxysporum, Fusarium solani, Alternaria alternata* and *Aspergillus niger* causes more damage to Tomato. *Alternaria alternata, Fusarium oxysporum, Cladosporium cladosporioides, Alternaria solani, Fusarium solani* and *Aspergillus niger* were predominant in Brinjal during Kharif 2019.

Curvularia lunata, Alternaria alternata, Chaetomium globosum, Colletotrichum capsici, Fusarium oxysporum, Alternaria solani, Colletotrichum gloeosporioides were predominant in Chilli during Rabi 2020. *Alternaria solani, Fusarium oxysporum, Fusarium solani, A. alternata, A. longipes, C. cladosporioides, L. theobromae* and *T. harzianum* showed high percentage of occurrence in Tomato. *Macrophomina phaseolina,* followed by *C. cladosporioides, A. alternata, F. oxysporum, F. solani, A. niger and C. lunata* were contribute higher percentage of occurrence in Brinjal.

In Kharif 2020, observed pathogen were *Fusarium oxysporum, Fusarium solani, Fusarium equiseti, Colletotrichum gloeosporioides, C. capsici, Chaetomium globosum* and *Alternaria longipes* having maximum percentage of occurrence in Chilli. In case of Tomato, *Fusarium solani, Fusarium oxysporum, Alternaria alternata, Curvularia lunata, Aspergillus niger* showed highest percentage of

occurrence. In Brinjal, the observed pathogenic fungi were *Alternaria alternata*, *Alternaria solani*, *Curvularia lunata*, *Aspergillus niger* and *Cladosporium cladosporioides* & *Fusarium solani.*

In Chilli, *Colletotrichum gloeosporioides*, *Fusarium oxysporum*, *Alternaria alternata*, *Fusarium incarnatum* were found in higher percentage. In Tomato, the maximum percentage of occurrence recorded in *Fusarium oxysporum*, *Fusarium solani*, *Curvularia lunata* and *Alternaria alternata*. During Rabi season, Brinjal contribute maximum percentage of occurrence recorded in *Alternaria solani* followed by *Aspergillus niger*, *Macrophomina phaseolina* and *Alternaria alternata* & *Fusarium oxysporum* during Rabi 2021.

During two years of survey reports revealed that the *Fusarium*, *Alternaria* and *Curvularia* species were dominant in all the regions in solanaceous vegetable crops like Tomato, Chilli and Brinjal. Among the 34 isolated fungal species *Fusarium oxysporum* contribute total 13.50% of occurrence in two years survey followed by *Fusarium solani* (11.61%), *Alternaria alternata* (9.68%), *Curvularia lunata* (7.17%), *Aspergillus niger* (6.23%), *Alternaria solani* (6.16%) and *Cladosporium cladosporioides* (4.72%).

Priya and Mesta (2018) reported Wilt of Chilli is a major threat in Northern Karnataka. The symptoms of wilt like yellowing and curling of younger leaf, stunting and vascular discoloration were similar to plants exhibiting same symptoms during survey of current study. Acc. to Vidyasekharan and Thiagarajan (1981) *F. oxysporum* cause not only wilting and rot, it also reduces the growth and yield of Chilli. According to Datar and Mayee (1981) the vegetable crops suffer more during kharif season than other seasons. *Alternaria solani* affects the tomato crops at all the stages

in severe epidemic, reducing yield upto 78.51%. Early blight of tomato caused by *Alternaria solani* was the most destructive, widespread disease in temperate, tropical and subtropical regions of the world (Hijmans *et al* -2000). *A. solani* infect all the parts of the plants like leaf blight, fruit lesions, stem and collar rot results in severe damage in all stages of plant development (Abada *et al*-2008). It also causes disease in Potato, Pepper (Chilli) and eggplant (Brinjal) (Najibullah *et al* -2016). According to Manoj Kumar *et al* (2015) *Alternaria* leaf spot was the wide spread, highly destructive disease in chilli. *Fusarium* wilt of Brinjal was a destructive disease of brinjal. *Fusarium* species causes severe wilt and death of upper parts of plants (Banu and Sharada-2018).

Alternaria species were produced cottony growth, dark and grey to black with olivaceous in colour on PDA. Mycelia were hyaline, grey-brownish, multicelled, septate and branched irregularly. Conidiophores are single or in cluster usually 2-6 in number and they are long or short. They were pale olivaceous to brown, straight or curved, slight swollen at the apex. The septation may varied from 2-12. These were similar to characters described by Dipak *et al* -2013; Najibullah *et al* -2016 and Tan Guo *et al* -2013. *Aspergillus* species characters were matched with those who reported earlier (Urooj N *et al* -2019).

Selina *et al*-2019; Valarmathi and Ladhalakshmi-2018 work correlated with the characters of *Bipolaris* species. On Agar plate the colonies were spreading with ash grey colour to dark greenish colour. Mycelium fluffy, aerial and cottony, on reverse it is olivaceous grey to black in colour. Conidiophores are single or in small group, straight having brown colour conidia. Conidia were brown, slightly curved,

wide at middle, tapering ends and base rounded with 7 to 11 pseudosepta having 89-120µm length and 16-20µm breadth.

Curvularia species were grown flattened greyish to brown colour colony on PDA medium and black pigmentation on reverse plate. Hyphae were septate, branched, and smooth. The conidiophores were erect, branched, brown and septate. Chlamydospores were absent; the conidia were fusiform, curved, septate, and present in clusters on the conidiophores. The conidia measured 17-23µm in length and 6-12µm in breadth. These were evident the work of Nor Azizah *et al*-2015; Himashi *et al*- 2021 and Gao *et al*-2012.

According to Oliul Hassan *et al*-2018; Pallem *et al*- 2009 and Rajyasri *et al*-2016 the colony characters were parallel to characters described in the current study. The colonies of *Colletotrichum* species were grown fast in the PDA medium with initially white colour then turns to grey colour. Mycelium was smooth, flat in growth with concentric rings. In reverse creamy yellow or dull-yellow in colour. The conidia were single, one celled, cylindric, straight, few slightly curved and tapering end. The length and breadth of the conidia were 14-20µm and 3-5µm respectively.

The colonies of *C. cassiicola* were dark grey or grey brown in colour with circular smooth margin and thinly hairy with velvety mycelial growth. Conidia were clavate or cylindrical, straight or curved, smooth, septate, brown, solitary, 53.0-230.5 x 7.3-18.5µm, with 2-14 pseudosepta. These characteristics are similar to those described for *C. cassiicola* (Ellis and Holliday 1971, Veera *et al* 2017, Wagner and Louise 2019 and Rajib *et al* 2012)

Colonies of *Cladosporium cladosporioides* on PDA were grey-olivaceous, regular margin, feathery, aerial mycelium, diffuse or abundantly formed. Colony on reverse was olivaceous black and velvety. Conidia were observed in different size and shape. It may subglobose to ovoid in shape without septa but sometimes one septum was found. Sizes of the conidia were 2-13µm length and 1-4µm breadth. These characters were similar to Eman *et al*-2021.

The colonies of *Drechslera halodes* were brown to blackish on PDA with black pigmentation. Conidiophores were septate, cylindrical and brown in colour. Conidia were formed single or in groups, straight, cylindrical or ellipsoid with round ends with transversely septate with 6-8 septum with dark and thick basal septa. Conidia were 30-100µm long, 11-12µm thick and hilum distinctly protuberant. These were correlated with characters described by Hussein and Zubaidi-2019 and Sharma *et al*-2012.

The colonies of majority *Fusarium* species were white in colour and some with becoming pink at maturity (*F. oxysporum*), light orange colour pigmentation (*F. equiseti*), light brown pigmentation (*F. incarnatum*), light orange pigmentation (*F. verticillioides*) and some are colourless. Mycelium was branched, smooth, cylindrical and septate. Conidiophores are short, single and arranged in densely branched clusters. Macroconidia are fusiform, slightly curved, pointed at the tip, mostly 3-7 septate (varied from species to species), basal cells pedicellate and measured 24-40 µm and 4-6 µm in size. Microconidia are abundant, some are in chains or chainless, mostly non-septate, ellipsoidal to cylindrical, straight or often curved and measured 5-16µm length and 2-6µm breadth. Chlamydospores are terminal or intercalary, hyaline smooth or rough-walled and absent in some species. These characters of *Fusarium*

species were similar to those are explained earlier (Leslie and Summerell-2007; Prasannath *et al*-2011; Ullah *et al*-2018; Ammarah *et al*-2021; Laila *et al*-2022; Kiranjot *et al*-2020).

Sangeetha *et al*-2011 and Caciara *et al*-2015 described characters were familiar with the Colonies of *L. theobromae* were grey to black in colour, on reverse it is black in colour. Pycnidia were formed with septate paraphyses between conidiogenous cells. The conidia were hyaline, dark brown with single septa, ellipsoidal to oval in shape, thin wall and measured 20-24 µm length and 10-13 µm width.

The colonies of *M. phaseolina* were dark brown-grey in colour on PDA. The mycelium was semi appraised microsclerotia imbedded within the hyphae. The hyphae were hyaline and thin walled and the aggregation of hyphae formed black coloured microsclerotia measured 100-120 µm in size. Microsclerotia were smooth, irregular to round or oblong in shape. These characters were same as described by Abhay *et al*-2020 and Nagam *et al* -2015.

Nyaka *et al*-2013 described characters were evident for the characters of *N. ribis*. The colonies on PDA were brown to black in colour. White colour fluffy mycelium present at the margins. Conidia were hyaline, aseptate, light brown and later it 1-2 septa formed. The conidia were ellipsoidal with round apices and having truncate base and measured 16-24µm and 3.5-6.5µm in size.

The *N. oryzae* colony characters like mycelium were aerial and dark brown to black in colour. The hyphae were smooth, septate, branched and hyaline. The conidiophores were in sporodochia and hyaline in nature. Conidia were single celled,

subglobose, black and measured 12-14µm and 8-14µm in size and these were similar to Nicolas *et al*-2020.

The *P. vexans* produced white mycelium with dark coloured pycnidia. The pycnidia were dark, immersed and globose. The conidiophores were simple, hyaline, one celled, ovoid to fusoid shape of conidia and measured 20 µm in size. Jayaramaiah *et al*-2013 mentioned the similar characters in their findings.

Colonies of the *Trichoderma* species were green in colour at the maturity but white in initial stage. Mycelia were simple, septate and branched. Conidiophores were hyaline, septate, upright, well branched and measured 2-3 µm × 2-4 µm. Conidia were hyaline, single celled and subspherical to ovoid in shape, born on the terminal clusters. This findings were similar with Yinhui *et al*-2019 and Shamim Shamsi *et al* - 2019.

In Root Dip method, the Chilli, Tomato and Brinjal seedlings of inoculated pathogens like *Alternaria*, *Curvularia*, *Colletotrichum*, *Corynespora*, *Drechslera*, *Macrophomina* and *Neofusicoccum* species exhibit small, oval/round, regular/irregular, black/brown spots on the leaves of the seedlings after the artificial inoculation. But the percentage of disease incidence was varied from one species to another (0 to 100%). In the observation of *Fusarium* species, at early stage symptoms appeared as yellowing of the lower leaves and later drooping of the leaves was observed in the plants. The tip of the younger leaves was curled and in case of severe infection lower leaves were dried and ultimately aerial parts showed turgidity and finally showed wilting. The first sign of wilting and spots were appeared around 8^{th} days after inoculation and gradually increased. In the early stages vascular discoloration also observed and later it extended throughout the plant.

The most virulent pathogen against tomato plants were *F. oxysporum, F. solani, A. alternata, C. cassiicola, C. lunata.* In Chilli, *Fusarium oxysporum, Corynespora cassiicola, Fusarium solani, Alternaria alternata* and *Lasiodiploidea theobromae* are the most virulent and in case of Brinjal *Fusarium solani, Fusarium oxysporum, Curvularia lunata, Lasiodiploidea theobromae* and *Corynespora cassiicola* are the most virulent pathogens. *Trichoderma* species does not showed any disease symptoms on seedlings of Chilli, Tomato and Brinjal.

Sapnesh *et al* (2012) proved pathogenicity of *Drechslera bicolar* on Chilli, Tomato and Brinjal. Initial symptoms were appeared in tip of the young leaves on the 7^{th} day of inoculation as brown spot later develops into blight large patches on the leaves.

Hussein and Zubaidi (2019) found in their studies that, pathogenicity test of *Drechslera halodes* isolates in Tomato plants proved the pathogenicity. The disease incidence ranged between 65-100% compared to control. Disease severity of the shoot and root system were 88.33%, 92.85% respectively.

According to Faisal *et al* (2013) pathogenicity test of Chilli indicated *Rhizoctonia solani* and *Pythium spp* showed higher pathogenicity effect and *Macrophomina phaseolina, Fusarium oxysporum* and *Fusarium solani* exhibited lower pathogenicity.

Rajib *et al* (2012) found similar disease symptoms of *C. cassiicola* inoculated seedlings showed leaf spots with yellow halo at initial stage later spots increased its size and scattered as dark brown spots with oval or irregular shapes. Initial symptoms were noticed in younger leaves and later spread into all the leaves of plant.

Chemical control has been considered as the most effective method for management of diseases of many economically/commercially important crops against various pathogens. Carbendazim and Mancozeb are generally used for the management of fruit and foliar diseases of vegetables. Fungicide like Metalaxyl is recommended for blight disease of Tomato and Potato.

In the current study, five fungicides namely Mancozeb, Bavistin, Captan, Metalaxyl and SAAF were used at four different concentrations (0.05%, 0.1%, 0.15% and 0.2%) to assess the inhibitory effect of fungal pathogens in *vitro*. All the used fungicides showed good inhibition at higher concentration but some of the species recorded maximum inhibition in lower concentration of fungicide.

Majority of the *Fusarium* species showed complete inhibition in all the concentrations of Bavistin (Carbendazim) and SAAF. Metalaxyl and Captan also showed maximum inhibition at higher concentrations. In case of *Curvularia* species, Mancozeb and SAAF were good at 0.15 and 0.2% concentration. This result is in agreement with findings of Bhaliya and Jadeja (2014). They found good mycelial growth inhibition of *F. solani* by Carbendazim, Mancozeb, Zineb and combination of fungicides like Cymoxanil+Mancozeb, Carbendazim+Mancozeb and Tricyclazole+Mancozeb. The effectiveness of Carbendazim to *Fusarium spp* has also recorded by Sony and Verma (2010) and Taskeen *et al* (2011). Iqbal *et al* (2010) found Carbendazim, Hexacanazole and Benlate were most effective and showed 100% inhibition against *Fusarium* spp. Ullah *et al* (2018) in *vitro* evaluation showed fungicide Helonil (Chlorothalonil) was best to control *F. oxysporum f. sp. capsici* at all concentration (100, 200, 300, 400, 500 and 1000ppm). The high effective dose of

Helonil was found at 1000ppm with (61.1%) followed by fungicide Antracol (32%) at 300ppm. Fungicide Ridomil, Desomil and Clipper were least effective.

In *Lasiodiplodia theobromae,* all the fungicide except Metalaxyl inhibits the complete mycelial growth in all the tested concentration. Rehman (2011) reported Carbendazim was the most effective fungicide for controlling the *Botryodiplodea theobromae* in *vitro* condition.

Neofusicoccum ribis also showed complete inhibition in all concentration of Mancozeb, Bavistin and SAAF. In case of *Alternaria* species, they also showed maximum inhibition of mycelial growth at all concentrations of Bavistin and SAAF. Remaining fungicides showed good inhibition when increasing the concentration. Vijay Kumar *et al* (2017) Data on in *vitro* evaluation revealed that most effective fungicide was carbendazim and score at 500 ppm where no growth of fungus mycelium and 100 per cent inhibition of the fungus were recorded followed by the antracol (16.67 mm, 81.48%). These results were in collaboration with the Chohan *et al*., (2015) and Gazanafar *et al*., (2016) who studied the effect of different fungicides under in vitro conditions. The findings of Manoj *et al* (2015) revealed that, Captan and Captol at 0.1% and Ziram and Captafol at 0.2% completely inhibited the growth of *Alternaria alternata* causing leaf spot of Chilli in *vitro* condition. Acc. to Lok Bahadur *et al* (2020), Hexaconazole (100%) proved best fungicides followed by Carbendazim+Mancozeb (SAAF) (93.81%) and Mancozeb (89.05%) to control *Alternaria brassicicola* in *vitro*.

In *Drechslera halodes,* SAAF completely inhibit the fungal growth in all the concentration and Metalaxyl at 0.1% and 0.2% concentration. *Colletotrichum gloeosporioides, Colletotrichum capsici* showed highest percent of inhibition in

Bavistin and SAAF. Kuldeep and Rakesh (2012) found that fungicide Vitavax showed maximum inhibition (100%) of *Drechslera bicolar* followed by Quintal and SAAF respectively. According to Sapnesh *et al* (2012) percentage of inhibition of *Drechslera bicolar* positively correlated with the increase in concentration of fungicides they used. They showed maximum inhibition in Vitavax (98.6%) followed by Thiram (95.6%), Mancozeb (92.1%) and Thiophanate methyl (90.1%) at 1000ppm. Carbendazim and Metalaxyl showed 58.12% and 70.3% at 1000ppm. Yadav (2007) found that Vitavax as the best fungicide followed by Thiram and captan for the control of *Drechslera graminea*.

In Out of four Concentrations, three concentrations of Bavistin, two concentration of SAAF and 0.2% concentration of Mancozeb were showed highest percent of inhibition in *Macrophomina phaseolina.* Bavistin and SAAF completely inhibited the fungal growth of *Cladosporium cladosporioides* in all the tested concentration and Mancozeb at 0.2% conc. also showed 100% inhibition.

Bipolaris showed complete inhibition in all the tested concentration in SAAF and three concentration of Bavistin. Mancozeb at 0.2% also showed 100% inhibition while other three fungicides recorded increased inhibition with increase in the concentration. In *Phomopsis vexans,* Bavistin played a major role which inhibits fungal growth in all the concentration and SAAF also showed 100% inhibition in two higher concentrations (0.15 and 0.2%). Bavistin found to be good fungicide to control *Chaetomium globosum* in *vitro* condition. *Aspergillus flavus, Aspergillus niger* and *Nigrospora oryzae* also showed good inhibition in Bavistin, SAAF and Mancozeb.

The family Solanaceae or Nightshades is an economically important family of flowering plants. Vegetables play a vital role in human nutrition by supplying Vitamins and essential minerals. Vegetable crops cultivating throughout India and more in Karnataka. These vegetable crops were suffering from number of fungal, bacterial and nematodal diseases. Chitradurga is situated in the central dry agro climatic zone and the average temperature during the summer reach up to 42ºC and minimum during winter can be 12ºC. Major part of the land is utilized for the agricultural purpose which includes rabi, kharif and other agricultural plantation and the people of this district depend on rainfall for growing the crops. Here temperature is very high and rainfall is low but the crops were attacked by many fungal diseases hence the present study was carried out on the isolation and identification of the pathogenic fungi and their pathogenicity and management of diseases in *vitro* condition.

Field survey was conducted on all the six Taluks of Chitradurga and repeated visits were made randomly to the farmer fields in Chitradurga District of Karnataka during 2019-2021. Plants that are showing diseased symptoms were collected, bring into the laboratory in a clean sterilized polythene bags for the study of isolation and identification. Later the materials were washed thoroughly with running tap water 2-3 times for removing adhering particles and debris, followed with 1% NaOCl solution for 1 minute and repeatedly washed with distilled water for 2-3 times to remove disinfectants and dried on sterile filter paper. The sterilized pieces were aseptically transferred to Petridishes containing Potato Dextrose Agar (PDA) medium added with ampicillin to check bacterial contamination. The plates were incubated at room temperature (25±2ºC) for 7-10 days for the growth of mycelium and were sub cultured on PDA slants for pure culture maintenance.

A total 34 fungal organisms belonging to 18 genera of 12 families were isolated and identified based on Morphological and microscopic characters. The morphological characters like colony colour, growth characteristics and microscopic characters like mycelia, spore bearing structure, size and shape of the spores were observed and recorded. DNA Extraction, PCR Amplification and sequencing was also done for the confirmation of some identified fungi. Molecular identified fungal pathogens were characterized and deposited to NCBI Genbank to get Accession number. The selected sequences were retrieved from the NCBI GenBank and combined with new sequences to conduct the phylogenetic analysis. The sequences were aligned by MAFFT (Multiple Alignment using Fast Fourier Transform) and maximum likelihood (ML) analysis. The tree was analysed and edited by using one fungus as out group species.

All the isolated pathogenic fungi were subjected to pathogenicity test. Pathogenicity test was performed by two methods viz., Root Dip method and Pricking method. The isolated fungal pathogens were cultured and make a spore suspension then inoculated on susceptible seedlings (25 days old) of Chilli, Tomato and Brinjal by root dip method. In Pricking method, the healthy fruits were collected and pricking by using sterilized scalpel and inoculated with 5 mm actively growing mycelial block of test fungus and were incubated for 7 days. Visual symptoms like typical lesions, small dark brown circular spots, black/brown spots, wilting of leaves, chlorosis, necrosis, defoliation of leaves and mortality of plants also observed and recorded the results everyday upto 45 days after inoculation and percentage of disease incidence was calculated in Root Dip method. In Pricking method, water soaked lesions, rotting, shrinking and drying after 3 days of inoculation was observed and recorded. All the isolated pathogens were exhibited the symptoms of diseases and further confirmation,

the expressed disease symptomatic leaves and fruits were re-isolated in the same culture media with same morphometric and cultural characteristics. This exhibits the Koch's Postulates.

Trichoderma species like *Trichoderma harzianum* and *T. atroviride* were does not exhibiting the disease symptoms in both the pathogenicity tests. It concludes that these are not harmful to the plants and cause any symptomatic diseases.

To control the fungal growth in *vitro* condition, the chemical fungicides namely Mancozeb (75%WP), Bavistin (Carbendazim 60%WP), Captan (Captan 50%), Targon (Metalaxyl 35%) and SAAF (Carbendazim 12%+Mancozeb 63%WP) were used at four different Concentration viz., 0.05%, 0.1%, 0.15% and 0.2% concentration by using Poisoned Food Technique. All the fungicides were effective against fungal pathogens but at not all the concentration. Results showed percentage of inhibition increased with increase in the concentration of some fungicides in some pathogen. On the other hand some of pathogens were showed complete inhibition in the lower concentration also. Bavistin showed maximum inhibition in controlling the majority of pathogen. Majority of the *Fusarium* species were showed complete inhibition in Fungicide Bavistin and SAAF at all the used concentration. All the fungicides showed good inhibition in all pathogens at higher concentration (0.2%). In case of *Lasiodiplodia theobromae* and *Neofusicoccum ribis* Mancozeb, Bavistin and SAAF showed complete inhibition in all the tested concentrations.

Thus, commonly available fungicides were effective against fungal pathogens but not all concentration. It is recommended that Carbendazim and SAAF were used to control the pathogens of Solanaceous vegetable crops instead of other fungicides. It also recommended that these two fungicides were most effective at least

concentration hence this investigation will be very helpful for the local vegetable growers for controlling the fungal diseases in the field.

Finally the Solanaceous vegetable crops of Chitradurga district mainly suffered from Wilt, Leaf Spots, Blight and Anthracnose diseases as per the field studies. The major predominant fungal pathogens were *Fusarium, Alternaria, Curvularia, Lasiodiplodia* and *Macrophomina* sps. All the isolated pathogens are confirmed by pathogenicity tests. In control measures, Carbendazim and SAAF fungicides were most effective at least concentration hence these fungicides are recommended to the farmers of Chitradurga region for controlling the fungal disease.

Outcome of the work

- Wilt, leaf spot, Fruit rot and blight diseases were more common in Chitradurga district as per the field studies.
- Fusarium species in Kharif season and *Alternaria, Curvularia* species in Rabi season were predominant.
- Molecular characterization was helpful for the identification of fungi to species level.
- Pathogenicity test confirmed all the identified fungi are pathogenic except *Trichoderma* species.
- During pathogenicity test *Fusarium, Alternaria, Curvularia, Colletotrichum* and other species were also established the same symptoms in plants and *Aspergillus*, *Rhizopus* and *Mucor* showed in fruits.
- Among five fungicides used, Bavistin (Carbendazim) and SAAF were best to control majority of pathogens in lower concentration in *vitro* condition and Mancozeb at much higher concentration also showed best result
- Captan and Metalaxyl was not much effective but effective in higher concentration for some pathogen.

Future plan of work

- Field survey can be taken up to the other vegetable growing places of Karnataka.
- Some of the hybrids are also showing fungal diseases which has to be taken care.
- Pathogenicity tests like Soil infestation method, Leaf detaching method, Spraying method etc., were conducted for more confirmation and know the severity of disease.
- Fungicides at same concentration were evaluated in *vivo* condition.
- Utilization of botanicals for disease control in the field condition.

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Publications

1. Sowmya G. H., Rajeshwari N., and Ramesh Babu H N (2021) Isolation and identification of some fungal pathogens from Solanaceous vegetable crops of Chitradurga district, Karnataka. *International Journal of Botany Studies*. V:6(5), pp: 1162-1164.
2. Sowmya G. H., Rajeshwari N. and Ramesh Babu. H. N. (2022). Isolation and in *vitro* evaluation of chemical fungicides against *Fusarium solani* causing Wilt of Chilli. *Indian Journal of Applied and Pure Biology*. V: 37(1), pp: 267-270.
3. Sowmya G. H., Rajeshwari N., Ramesh Babu H. N. and Shalini B. R. (2022). In *vitro* evaluation of chemical fungicides against *Corynespora cassiicola* causing Leaf Spots in Tomato. *Journal of Mycopathological Research*. V: 6(2), pp: 279-282.

Conference attended

1. Oral Presentation on **"*In vitro* efficacy of Mancozeb on *Fusarium oxysporum* causing wilt of Chilli"** in 3-Day International e-Conference on Environment and Sustainable Development; Problems, Prospects and Mitigation organized by Department of Botany, Seva Bharati Mahavidyalaya, Kapgari, Jhargram, West Bengal, Department of Botany & Zoology, Government General Degree College, Lalgarh, Jhargram, West Bengal in Collaboration with Department of Zoology, Avinashlingam Institute for Home Science and Higher Education for Women, Coimbatore-641043, Tamil Nadu, India on 26th November, 2021.

2. Oral Presentation on **"Efficacy of Chemical Fungicides against *Alternaria alternata* causing leaf spot in Tomato"** in Impact of Research Development in Life Sciences (IRDLS-2022) organised by Department of Biochemistry and Food Technology, Kuvempu University, Jnanasahyadri, Shankaraghatta, Shivamogga on 30th and 31st of March 2022.

International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 11-09-2021, Accepted: 27-09-2021, Published: 12-10-2021
Volume 6, Issue 5, 2021, Page No. 1162-1164

Isolation and identification of some fungal pathogens from Solanaceous vegetable crops of Chitradurga district, Karnataka

Sowmya G H[1], Rajeshwari N[2], Ramesh Babu H N[2]

[1] Research Scholar, Department of Botany and Seed Technology, Kuvempu University, Sahyadri Science College, Shimoga, Karnataka, India

[2] Professor, Department of Botany and Seed Technology, Kuvempu University, Sahyadri Science College, Shimoga, Karnataka, India

Abstract

The present work deals with the isolation and identification of pathogenic fungi. The fungal isolates were *Fusarium oxysporum, Fusarium solani, Fusarium incarnatum, Carynospora cassiicola, Colletotrichum gloeosporioides, Alternaria spp, Cladosporium cladosporoides, Mucor flavus, Trichoderma spp.* and *Aspergillus Niger*. These were isolated from Solanaceous vegetable crops like chilli, tomato and brinjal and were identified on the basis of colony morphology and microscopic examination on PDA medium. The morphological characteristics of these fungal elements showed various kinds of spores which was identified up to genus/species level. Out of 10 isolated fungi, all were pathogenic except *A. Niger* and *Trichoderma spp* which are saprophytes.

Keywords: isolation, identification, fungal pathogen, vegetable crops

Introduction

Vegetables are most important components of human food since they provide proteins, Vitamins, Carbohydrates and some other essential macro and micro nutrients required by the human body. Fungal diseases cause huge losses to vegetables during cultivation, transportation and storage. Phytofungal pathogens cause serious problems for the agricultural crops including vegetables. The plant is highly affected by adverse climatic conditions. The warm and cool climatic conditions provide an ideal condition for the development of many foliar, stem and soil-borne plant diseases. Fungal diseases are a major limiting factor for vegetable that cause serious yield reduction leading to severe economic losses (Pavankumar *et al*-2018). In addition, many also produce mycotoxins, which are harmful to humans and livestocks and causes a number of diseases like rusts, smuts, rots and downy mildew. Plants are infected by different kinds of microbial pathogens and the required inoculum for infection is present in the soil, water and air, in addition to plant host. Whatever may be the source of inoculum, the susceptible plant species or crop varieties may exhibit clear visible local symptoms in or on the tissues where infection is initiated. If the pathogen is able to find favourable conditions for further development, systemic symptoms are induced in tissues or organs far away from the point of pathogen entry into the plant. When the symptom of infection is not expressed externally, it is termed as latent infection. Some fungal pathogens infecting unripe fruits do not induce any visible symptom as they remain dormant. Detection of microbial pathogens refers to the process of establishing the consistent presence of a particular target organism(s) within the plant or in its environments, irrespective of the development of visible symptoms in the plant suspected to be infected by the pathogen(s) in question. Diagnosis, on the other hand relates to the identification of the nature and cause of the disease Problem under investigation (Digambar and Sahera-2016) [2]. Chitradurga district falls in central eastern parts of the state and covers a total geographical area of 8388 sq. kms. The district is divided into 6 Taluks, namely Chitradurga, Hiriyur, Hosadurga, Holalkere, challakere and Molakalmuru. It lies in the central dry agro climatic zone. The average temperature during the summer reach up to 42ºC and minimum during winter can be 12ºC. Major part of the land is utilized for the agricultural purpose which includes Rabi, kharif and other agricultural plantation. The water bodies cover an area of 384.9 sq. km which is comparatively low area with agricultural land, hence the people of this district depends on rainfall for growing the crops.

The vegetable crops are attacked by many fungal, viral, bacterial, nematodal and some other diseases leads to loss in quality and yield. Out of these diseases fungi causes more loss in field condition and post-harvest condition (Salau and Shehu-2015) [6]. Present investigation aims at identification of the fungi from the plants showing symptoms and were identified based on their morphological characters.

Materials and Methods

Study site and sample collection

Field survey was done in major vegetable growing regions of Chitradurga District from September to November 2020 to estimate the fungal diseases. A purposive and randomized sampling method is used for survey and collection of samples (Zainab and Shinkafi-2016) [8]. The fungal pathogens were able to infect various plant organs such as roots, stems, leaves, flowers and fruits. The infected part shows visible characteristic symptoms like spots, blights, wilts, rots etc. Plant parts with visible symptoms were collected from different vegetable crops in the field

In vitro evaluation of chemical fungicides against *Corynespora cassiicola* causing Leaf Spots in Tomato

G.H. SOWMYA, N. RAJESHWARI , H.N. RAMESH BABU AND B.R. SHALINI

J. Mycopathol. Res. 60(2) : *279-282, 2022;*
ISSN 0971-3719

Department of Botany,
University of Calcutta,
Kolkata 700 019, India

J. Mycopathol. Res. **60(2)** : 279-282, 2022; (ISSN 0971-3719)

In vitro evaluation of chemical fungicides against *Corynespora cassiicola* causing Leaf Spots in Tomato

G.H. SOWMYA[1]*, N. RAJESHWARI [1], H.N. RAMESH BABU[1] AND B.R. SHALINI[2]
[1]Department of Botany and Seed Technology, Kuvempu University, Sahyadri Science College, Shivamogga, Karnataka 577203.
[2]Department of Botany, Tumkur University, Tumkur, Karnataka

Received : 07.03.2022 Accepted : 03.05.2022 Published : 27.06.2022

Pathogenic variability and fungicidal sensitivity of the *Corynespora cassiicola* isolates collected from the major Tomato growing region of Chitradurga district of Karnataka were studied for their pathogenic variability by inoculating to susceptible Tomato variety by root dip inoculation method. Three fungicides viz., Mancozeb, Bavistin and Captan at 0.05, 0.1, 0.15 and 0.2 percent concentrations respectivelywere used against isolated pathogen. The*Corynespora cassiicola* isolates showed complete inhibition in Mancozeb at 0.15% &0.2% concentration. However, Bavistin and Captan showed 80% and 77.64% inhibition respectively in 0.2% concentration.

Key words: *Corynespora cassiicola,* Leaf Spot, pathogenicity, tomato, fungicides

INTRODUCTION

Tomato, scientifically called as *Lycopersicon esculentum* Mill. is a most common vegetable crop grown all over the world. It is an important source of minerals, vitamins, essential amino acids, sugars and dietary fibres. During the cultivation, tomato crop is susceptible to various kinds of diseases and disorders (Mary and Giri- 2017). Among all the diseases fungal diseases are the most severe disease and they reduces maximum crop yield.

It is a cosmopolitan vegetable and widely cultivated in almost all the countries of the world including India. Irreversible investment – production ratio for tomato cultivation in recent Indian agricultural systems arise the question, is there any biotic backlogs responsible for such a production loss.Our present investigation is based on the fact that Target leaf spot disease of tomato which is caused by *Corynespora cassiicola*, one of the serious and emerging diseases in India. This pathogen is the natural barrier for tomato production with a disease severity ranging from 35% to 58% which ultimately causes tremendous loss of tomato foliage and fruits. (Adam*et al* -2018). Studies reveal that there is a major toll in the tomato production due to *C. cassiicola.* From the emerging scenario is the real threat for indigenous cultivars and it have been recorded as emerging disease in the tomato crop under change in climatic condition. Hence the attempt was done to control the *C. cassiicola* at different concentrations of chemical fungicides *in vitro* condition.

*Correrspondence: sowmyagyaralli95@gmail.com

MATERIALS AND METHODS

Study site and sample collection

Field survey was done in major vegetable growing region of Chitradurga District during 2019-2020 to estimate the leaf spot disease of Tomato. A randomized sampling method was used for survey and collection of samples (Zainab-2016). Collection of infected material with symptoms like circular, target board or irregular shaped leaf spots, and are dark brown in colour with light brown centers delimited by dark brown rings and surrounded by a yellow halo symptoms on the leaf (Fig 1) were collected with the pre sterilized knife, forceps and cutter. The collected materials are carried in a pre-sterilized zip-lock cover to the laboratory for the microscopic observation and identification.

Isolation and identification of the fungal pathogen

The freshly collected infected materials exhibiting symptoms were brought to the laboratory for isolation. The infected leaves were dissected and

Indian J. Applied & Pure Bio. Vol. 37(1), 267-270 (2022). **ISSN: 0970-2091**
A web of Science Journal

Isolation and *In vitro* evaluation of chemical Fungicides against *Fusarium solani* causing Wilt of Chilli

[1]G.H. Sowmya, [2]N. Rajeshwari and [2]H.N. Ramesh Babu

[1,2]Department of Botany and Seed Technology, Sahyadri Science College, Kuvempu University, Shivamogga-577203 (India)
Email: sowmyagyaralli95@gmail.com
Email: rajeshwaribabu02@gmail.com

Abstract

Wilt caused by *Fusarium solani* is one of the destructive diseases of Solanaceous plants and causes considerable loss in the yield and quality of the produce. An experiment was conducted to isolate and in vitro evaluation of different chemical fungicides at four different concentrations viz., 0.5%, 0.1% 0.15% and 0.2% and Trichoderma harzianum against *Fusarium solani*. The study was carried out using poisoned food technique for chemical fungicides in Completely Randomized Design (CRD). Among all the chemical fungicide, Bavistin proved to be the most effective chemical fungicide recording 100% growth inhibition at all the tested concentrations and Mancozeb and SAAF (Carbendazim + Mancozeb) which also showed 100% inhibition in 0.15% and 0.2% concentration. Mancozeb at 0.05% concentration was least effective in reducing fungal growth (35%). This study indicated better performance of some chemical fungicides even at lower concentration. So, such effective fungicides could be used to minimize hazardous effect.

Chilli (*Capsicum annuum* L.) is one of the important commercial crops in India. It is one of the most important vegetable and spice crop belongs to family Solanaceae and genus Capsicum. Chilli is a tropical and subtropical crop, is one of the major vegetable and spice crops grown in the country and is popularly known as wonder spice, pepper and hot pepper[7].

Chilli is cultivated both for green and red fruits having various culinary values. India is the leading country in production along with China, Korea, Nigeria, U.S.S.R and Mexico. In India, Andra Pradesh, Orissa, Maharashtra, West Bengal, Karnataka, Rajasthan and Tamil Nadu are the major producing states[13]. In India Chilli occupies an area of 840 thousand hectares with an annual production of 2096M.tonnes. In Karnataka green chilli occupies an area of 45.43 thousand hectares with production of 607.94 M tonnes.

It is susceptible to several diseases and pests, which become major constraints in its production. Among them the most

KUVEMPU UNIVERSITY

EFFECT OF PHYTOFUNGAL PATHOGENS ON SOME SOLANACEOUS VEGETABLE CROPS OF CHITRADURGA DISTRICT, KARNATAKA.

Thesis submitted to Kuvempu University

for the award of Degree of

DOCTOR OF PHILOSOPHY

in

BOTANY

By

Ms. SOWMYA G H M.Sc

Research Guide

Dr. N. RAJESHWARI M.Sc., M.Phil., Ph.D.
Professor
Department of Botany and Seed Technology.
Sahyadri Science College.
Kuvempu University.
Shimoga-577203

Submitted to

The Department of P.G Studies and Research in Applied Botany
Kuvempu University, Jnana Sahyadri, Shankaraghatta – 577 451
Shivamogga District, Karnataka, INDIA

2023

Outcome of the work

- Wilt, leaf spot, Fruit rot and blight diseases were more common in Chitradurga district as per the field studies.
- Fusarium species in Kharif season and *Alternaria, Curvularia* species in Rabi season were predominant.
- Molecular characterization was helpful for the identification of fungi to species level.
- Pathogenicity test confirmed all the identified fungi are pathogenic except *Trichoderma* species.
- During pathogenicity test *Fusarium, Alternaria, Curvularia, Colletotrichum* and other species were also established the same symptoms in plants and *Aspergillus*, *Rhizopus* and *Mucor* showed in fruits.
- Among five fungicides used, Bavistin (Carbendazim) and SAAF were best to control majority of pathogens in lower concentration in *vitro* condition and Mancozeb at much higher concentration also showed best result
- Captan and Metalaxyl was not much effective but effective in higher concentration for some pathogen.

Future plan of work

- Field survey can be taken up to the other vegetable growing places of Karnataka.
- Some of the hybrids are also showing fungal diseases which has to be taken care.
- Pathogenicity tests like Soil infestation method, Leaf detaching method, Spraying method etc., were conducted for more confirmation and know the severity of disease.
- Fungicides at same concentration were evaluated in *vivo* condition.
- Utilization of botanicals for disease control in the field condition.