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ASSESSMENT OF LOSSES AND INTEGRATED MANAGEMENT QF RED ROT (*Colletotrichum falcatum* Went.) OF SUGARCANE (*Saccharum officinarum* L.) UNDER SOUTH GUJARAT CONDITIONS

A

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ABSTRACT

ASSESSMENT OF LOSSES AND INTEGRATED MANAGEMENT OF RED ROT (*Colletotrichum falcatum* Went.) OF SUGARCANE (*Saccharum officinarum* L.) UNDER SOUTH GUJARAT CONDITIONS

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ABSTRACT

Sugarcane is one of the most important cash crops grown extensively in South Gujarat. During 90's, the crop was severely affected by red rot disease causing considerable losses in terms of quality and quantity. Considering seriousness of the problem, the present investigations were carried out on various aspects to provide more information on the problem and to develop suitable management strategies.

The isolation from nodal and internodal tissues of the infected canes revealed the association of *Colletotrichum* sp. which was identified after studying cultural and morphological characters and also confirmed with I. T. C. C., New Delhi-110 012 as *Colletotrichum falcatum* Went. The pathogenicity was confirmed by soil, soil-cum-sett, cotton swabs and plug methods of inoculation with positive results. The

characteristic symptoms were observed in the field on different varieties but the leaves of Cv. CoC 91061 showed red elongated lesions on midrib, reddish patches on leaf sheath and reddish brown speaks on leaf is a new record from this area.

The survey carried out during the year 1999-2000 for occurrence and spread of the disease in South Gujarat revealed that 1.19 per cent area in plant and 2.18 per cent area under ratoon crops was affected by red rot, showing more effect on ratoon crops than the plant crops. In another survey carried out in Sayan, Bardoli and Chalthan sugar factory areas regarding the red rot incidence in different commonly grown varieties. The varieties viz., Co 86002, Co 8208, Mc 707, CoSi 95071, CoC 91061, Co 8338, CoN 91132, Co 86010, etc. were found free from red rot infection while CoC 671 and CoC 86032 found to be infected. The area under these two varieties was about 21 per cent of total sugarcane cultivated area.

A drastic reduction in quantitative and qualitative parameters like cane length (2.15 to 15.31), girth (1.36 to 16.91), number of internodes (2.14 to 29.04) and cane weight (5.00 to 80.60) as well as brix (6.78 to 40.10), pol (7.80 to 51.47), purity (1.13 to 29.00), extraction (6.10 to 64.17) and C. C. S. (9.45 to 65.90) due to red rot infection, which was found negatively correlated with the level of resistance.

Of the twenty five varieties screened for resistance to red rot *in vivo* by plug method, cultivars Co 6806, Co 86249, CoSi 98071, 86 A 146, Co 87263, CoC 92020, CoN 91132, CoLk 8001 and CoN 85134 showed fairly high degree of resistance, while Co 86032, CoC 671, Co 7318, CoN 97134 and Co 91121 proved highly susceptible to the disease.

The cultural filtrates of *Aspergillus flavus* significantly inhibited the growth of *C. falcatum* and *A. niger*, *Trichoderma harzianum*, *Gliocladium virens* were moderately inhibitory. The mechanism behind the antagonism might be due to the production of non-volatile antibiotics.

In a pot culture experiment, *Trichoderma harzianum*, *T. viride* and *Chaetomium globosum* found superior to increase germination as well as reduced disease incidence.

The extracts of gando baval was strongly inhibitory to the growth of *C. falcatum* followed by datura, lantana, kuvadio, mango turmeric, turmeric, pashugandha, Polyalthia, ajmo, vachhnag, garlic, ginger, ajilo, onion and fudina while extracts of Allamanda stimulated the growth of the pathogen. The sporulation was inhibited by the extracts of gando baval, datura, lantana, ginger, onion, ajilo and ajmo, while the extracts of vachhnag was found to stimulate the sporulation.

The extracts of castor cake, poultry manure and pressmud were found to be fungicidal to *C. falcatum* while mustard cake, farm yard manure and neem cake inhibited the fungal growth in varying degrees. The vermi compost extracts stimulated the growth and sporulation of pathogen. The sporulation was not observed in mustard cake while it was inhibited moderately in farm yard manure and neem cake extracts.

The root exudates of brinjal was most effective in reduction of spore germination of *C. falcatum* followed by garlic, chickpea, methi, coriander, onion, mustard, cabbage, sorghum and sesamum and also found to reduce germ tube length.

Fourteen fungicides were screened *in vitro* by poisoned food technique at three different concentrations against *C. falcatum*. In systemic group of fungicides, cent per cent inhibition was observed in San (at 100, 250, 500 ppm), Contaf (250, 500 ppm), Tilt (250, 500 ppm), Ridomil-MZ (500, 1000, 1500 ppm), Bayleton (100, 250, 500 pm), Topsin-M (500, 1000, 1500 ppm), Bavistin (500, 1000, 1500 ppm) and Benlate (500, 1000, 1500 ppm) while in Contaf (100 ppm), Tilt (100 ppm) and Calixin (250, 500, 1000 ppm), there was more than 80 per cent inhibition of mycelial growth of pathogen. Among the non-systemic group, Cuman-L, Kavach, Dithane M-45, Emisan and Blitox at all the three concentrations inhibited cent per cent mycelial growth of the pathogen.

Sett dip treatment with Bavistin (0.1 %) and Emisan (0.2 %) proved better as they increased the germination and reduced disease incidence considerably.

Bavistin (0.1 %) was effective when one eye-budded setts dipped for 10 or 20 minutes and the two eye-budded setts dipped for 20 minutes in eradication of *C. falcatum* from naturally infected setts. It was not effective with three eye-budded setts at 10 or 20 minutes. Emisan (0.2 %) was effective at both the levels of times and different lengths of setts except two and three eye-budded setts dipped for 10 minutes.

For the management of red rot in another pot experiment, sett-dip treatment with Carbendazim or MEMC for 10 minutes found more effective than phyto-extracts and antagonists.

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CERTIFICATE

This is to certify that the thesis entitled **"Assessment of losses and integrated management of red rot (*Colletotrichum falcatum* Went.) of sugarcane (*Saccharum officinarum* L.) under South Gujarat conditions"** submitted by **Shri Tushar Kiritkumar Bhatt** in partial fulfilment of the requirements for the award of the degree of MASTER OF SCIENCE (AGRICULTURE) in the subject of PLANT PATHOLOGY of the GUJARAT AGRICULTURAL UNIVERSITY is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari
Date : January 19, 2001

(Dr. A. N. Sabalpara)
Major Advisor

DECLARATION

This is to declare that the whole of the research work reported in this thesis in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT PATHOLOGY** by the undersigned is the results of investigation carried out by him under the direct guidance and supervision of **Dr. A. N. Sabalpara**, Major Advisor and Associate Professor, Department of Plant Pathology, N. M. College of Agriculture, Gujarat Agricultural University, Navsari Campus, Navsari and that no part of the work has been submitted for any other degree so far.

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INTRODUCTION

I INTRODUCTION

Sugarcane (*Saccharum officinarum* L., Family: Gramineae), a C_4, long duration, clonally propagated plant, is one of the most efficient quantum converters of solar energy, grown in about 102 countries of the world. It is cultivated in both tropical and sub-tropical regions of India, having ability to generate industrialization in rural areas (Agnihotri, 1983).

It is the principal source of sugar, gur and khandsari. Besides this, the by-products like green tops used as cattle feed, baggasse for paper making, pressmud as compost and molasses for preparing ethanol, menthol, aceton, etc., which are used in many industries (Ethirajan and Rao, 1990). In India, total 427 sugar factories are working; among them 249 are on co-operative base (Anon., 2000a).

In India, sugarcane is grown over 4.076 million hectares with an annual cane production of 270.971 million tonnes and sugar production of 15 million tonnes with an average of 9.98 per cent sugar recovery (Anon., 2000a).

In Gujarat, sugarcane is grown over 1.96 lakh hectares with an annual production of 13.56 million tonnes having average cane productivity of 69.10 tonnes per hectare and average sugar recovery of 10.37 per cent. There are seventeen co-operative based sugar factories working in Gujarat. Among them, 13 are located in South Gujarat only (Anon., 2000a).

As per projections of National Commission of Agriculture by 2001 AD, sugar production target has been kept at 18 million tonnes and sugarcane production of 300 million tonnes. In meeting this

projected target; beside abiotic factors, diseases alone constitute serious dram of sugarcane production. According to an estimate of FAO, UN the losses due to diseases alone was estimated to be 19.2 per cent. In India, crores of rupees are lost annually on account of diseases of sugarcane (Shukla and Sinha, 1998).

In the beginning of 20th century, a few diseases were recognised in our country, of these, the most dreaded fungal diseases - red rot (*Colletotrichum falcatum* Went.) was identified in 1901 followed by smut (*Ustilago scitaminea* Sydow) in 1906 and wilt (*Cephalosporium sacchari* Butl. and *Fusarium moniliforme* Sheld.) in 1913. Subsequently, two important bacterial diseases, ratoon stunting disease (*Clavibacter xyli*) and leaf scald (*Xanthomonas albilineans*) were recognised in 1956 and 1961, respectively. The mycoplasmal disease (Grassy shoot disease) was detected in 1919 and mosaic in 1921. These important diseases cause substantial economic losses by scaling down the cane yield and recoverable sugar (Shukla and Sinha, 1998).

Among these, red rot is the most destructive seed-piece transmissible fungal disease of sugarcane (Abott and Hughes, 1961). This disease causes heavy economic losses in yield and thereby reducing juice quality (Rao and Satyanarayana, 1983). Many important commercial sugarcane varieties viz., Red Mauritius, Co 210, Co 213, Co 312, Co 419, Co 453, Bo 3, Bo 11, Bo 17, Bo 54, Co 658, CoC 671, Co 785, CoS 562, Co 62175, CoJ 64 and Co 86032 have been gone out of cultivation due to this destructive disease (Lal and Lal, 1995).

The red rot of sugarcane was observed in sporadic form during 1990-91 crop season (Lal and Singh, 1994) and on large scale

for the first time during *kharif* 1993 in South Gujarat in popular variety CoC 671 (Anon., 1994). Total area affected by red rot (including plant and ratoon crops) was increased from 3380.56 hectares in *rabi*, 1995 to 4091.22 hectares in *rabi*, 1996 posing a serious threat to sugarcane cultivation and sugar industries in this area. In South Gujarat, sugarcane productivity was about 90 tonnes per hectare during 1991-92, which was later found reducing especially due to red rot. All the varieties viz., CoC 671, Co 419, Co 7527, Co 6304, CoC 90063, CoC 92061, Co 86032, etc. grown in this area were proved susceptible to this disease. A most popular, high yielding and widely grown cultivar CoC 671 proved highly susceptible to red rot in association of wilt resulting in severe losses in cane yield and sugar recovery (Lal and Singh, 1998). The disease causes heavy economic losses not only to the farmers by reduction in yield, but also to the sugar factories by deteriorating the juice quality.

No single effective method for controlling red rot disease was available hence the research work on the methods of integrated management of red rot was carried out on the following aspects:

1. Isolation and identification of causal agent, its pathogenicity and symtomatology of disease
2. Survey for occurrence and spread of red rot in South Gujarat
3. Assessment of losses
4. Screening of sugarcane varieties against the pathogen (*Colletotrichum falcatum* Went.)

5. Bio-efficacy of phyto-extracts against *C. falcatum in vitro*

6. Bio-efficacy of cultural filtrate of antagonist *in vitro* against *C. falcatum*

7. Testing efficacy of antagonist in pot culture against red rot

8. Bio-efficacy of organic extracts against *C. falcatum in vitro*

9. Study of the effect of root exudates on spore germination of *C. falcatum*

10. Bio-efficacy of fungicides in vitro against *C. falcatum*

11. Bio-assay of fungicides in pot culture against red rot

12. Efficacy of fungicides with respect to treatment time and length of setts

13. Integrated management of red rot disease in pot culture

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Diseases are the major constraint in sugarcane production resulting in heavy qualitative and quantitative losses. About 130 diseases of sugarcane have been reported from India. Among them, red rot caused by *Colletotrichum falcatum* Went is of major importance (Alexander, 1990). This disease is so devastating in nature that it has been aptly called "Cancer" of sugarcane (Agnihotri, 1983). During recent years, sugarcane red rot has come up as a serious problem posing a serious threat to the sugarcane growers as well as the sugar industry in South Gujarat area. The informations on the red rot of sugarcane available is reviewed and presented here.

2.1 Occurrence

Red rot was first described from Java by Went (1893). He called it 'Het Rood Snot' (Red smut). In the same year, it was reported from Australia (Cobb, 1893) and West Indies (Massee, 1893). Within a decade, it was reported from India (Barber, 1901), Hawaii (Lewton-Brain, 1908) and U. S. A. (Edgerton, 1910) and eventually, it was identified in all sugarcane growing countries of the world but it has been regarded as major importance chiefly in sub-tropical countries, particularly the Southern United States, India and Queensland (Abbott and Hughes, 1961).

Barber (1901) was first to observe the disease in the Cv. Red Mauritius in Godavari deltas of Andhra Pradesh, India. Butler (1906) was first to give name `red rot` for first time. Subsequently, it was reported from all the sugarcane growing states viz., Bihar (1906),

Jammu and Kashmir (1922), Uttar Pradesh (1936), Punjab (1937), Delhi (1957), Haryana (1968), Tamil Nadu (1974), Rajasthan (1975) (Tyagi and Goyel, 1975; Natrajan *et al*., 1977 and Chona, 1980)

In Gujarat, the disease was first time observed during 1990-91 from Madhi, Bardoli, Chalthan and other sugar factory areas in sporadic form (Lal and Singh, 1994) and on large scale during 1993 (Anon., 1994). Since then, it was reported from other sugarcane growing areas viz., Valsad, Maroli, Mahua, Gandevi, Vataria, Kamrej, Pandvai (South Gujarat area), Palaj (Middle Gujarat), Talala and Kodinar (Saurashtra region) (Anon., 1999a).

2.2 Economic importance

This is the most dreaded disease of sugarcane. Occurrence of epiphytotics throughout the country created havoc and forced the growers to abandon cane cultivation (Shukla and Sinha, 1998). The disease causes a great economic loss not only to the growers but also to the sugar factories. The losses caused by red rot are as under.

2.2.1 Poor germination

Poor germination of infected setts reduces the plant stand and ultimately yield (Abbott, 1938; Kar and Verma, 1962; Agnihotri *et al*., 1979; and Sinha, 1979). Red rot also causes deterioration of the stubble with subsequent poor ratoons (Abbott, 1938 and Edgerton, 1955).

2.2.2 Losses of green tops

The green tops of susceptible varieties like Co 213, Co 312, Co 453 etc dry up quickly creating a shortage of fodder in red rot prone area (Agnihotri, 1983).

2.2.3 Deterioration of variety

Many popular valuable varieties have been discarded because of red rot disease. It was the main cause of the loss of noble canes Louisiana Purple, Louisiana Striped and D-74, which nearly ruined the industry in Louisiana in the mid 1920s. Cultivar P. O. J. 213 was considered to be highly resistant to red rot and replaced the noble canes, but met the same fate in early 1930s. The same thing happened to Co 290 in the 1940s (Abbott and Hughes, 1961).

The first documented epiphytotics occurred in India during 1901. Since then, many out breaks have been recorded in the sub-tropical regions resulting rejection of many outstanding varieties as listed in Table 2.1.

A high yielding, high sugared and early maturing variety CoC 671 was grown in 70 to 80 per cent area in South Gujarat. It was severely attacked by red rot during 1993 (Anon., 1994). This variety was deteriorated on account of red rot disease in association with wilt and mosaic in South Gujarat (Anon., 1994; Lal and Singh, 1994 and Lal and Singh, 1998).

2.2.4 Yield losses

Losses in cane yield due to red rot reported to be estimated 12 to 45 per cent (Kar and Verma, 1962 and Sandh *et al.*, 1969). Patel (2000) reported 6.67 to 83.64 per cent loss of cane weight over healthy crop due to red rot in various sugarcane varieties.

2.2.5 Quality loss

Went (1893) was first to observe reduced sucrose content in the red rot infected canes. Over 30 per cent reduction in sucrose have

Table 2.1: Sugarcane varieties deteriorated/chased out due to red rot epidemics in India

Year	State/area	Varieties	Reference
1901	Andhra Pradesh	Red Mauritius	Barber (1901)
1906	Bihar	Co 210	Chona (1980)
1922	Jammu	-	Chona (1980)
1932	Bihar	Co210	Chona (1980)
1936	Eastern U P	Co 213	Chona (1980)
1937	Western & Central U P.	Co 213	Chona (1980)
1938-40	Eastern U P and Bihar	Co 213	Chona (1980)
1946-47 & 1950-60	U. P., Bihar and Punjab	Co 213, Co 312, Co 453, Bo 11, Bo 17, Bo 54	Chona (1980) & Alexander (1993)
1962-63	West Bengal	Bo 11	Agnihotri (1990)
1964-65	U. P and Bihar	Co 453, Bo 11, Bo 17, Bo 54	Alexander (1993)
1968-69	Andhra Pradesh, Tamil Nadu and Pondicherry	Co 997, CoS 562 Co 658, Bo 3	Agnihotri (1990)
1972-75	Tamil Nadu	Co 658	Alexander (1993)
1982-84	Andhra Pradesh	CoC 671	Alexander (1993)
1984-86	Kerala	Co 997, Co 449, Co 785, Co 62-175	Nair *et al.* (1984)
1986-90	Tamil Nadu	CoC 671	Alexander (1993)
1988-92	North-Western U. P	Co 1148, Co 7717, CoJ 64	Alexander (1993)
1991-92	Tamil Nadu	CoC 86062, Co 92062	Alexander (1993)
1993-94	Gujarat	CoC 671	Lal and Singh (1994)

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been observed in India (Kar and Verma, 1962 and Sandhu *et al.*, 1969), which may be upto 50 per cent or more (Abbott, 1938), accompained by lower juice purity and other deleterious chemical changes (Mckaig and Fort, 1936 and Patel, 2000). Rao *et al.* (1984) reported brix, juice purity, C. C. S and recovery of jaggary decreased in red rot infected canes of Cvs. CoC 671 and B 46364 with increased in titrable acidity, moisture, reducing sugar, non-reducing sugar and glucose ratio.

2.3 Causal organism

Asexual (conidial) stage of the fungus was first observed and described as *Colletotrichum falcatum* by Went (1893). Spegazzini (1896) described the perfect stage and named it *Physalospora tucumanensis* Speg. However, Carvajal and Edgerton (1944) in Louisiana was first to recognise the latter as perfect stage of the red rot fungus. The taxonomic status of the red rot fungus was re-examined by Arx and Mueller (1954), who transferred it to genus *Glomerella* as *G. tucumanensis* (Speg.) Arx and Mueller. The disease is mostly caused by imperfect stage, the mycelium of the fungus in host tissues is mostly intracellular and grows mainly in the paranchymatous cells of the pith. The causal agent associated with red rot was also identified as *C. falcatum* from Gujarat (Patel, 2000).

The red rot fungus can be readily isolated from diseased tissues and can be grown on wide variety of media, of which oatmeal decoction agar is widely used. On this media, the fungus produces light to dark grey mycelia, which may be cottony flucose to compact and velvety appearance. The hyphae being hyaline, septate and contain oil globules; conidia produced either on acervuli or directly on the hyphal

tip. The acervuli consist of a mass of short, closely packed conidiophores with numerous dark brown to almost black setae. The spore mass develops in a pink mucilaginous matrix in the acervuli. The typical conidia are produced singly on the conidiophores. They are hyaline, one celled, falcate or sickle-shaped, some times fusoid, usually with one end rounded and another slightly pointed, measuring 16 to 48 µm in length and 4 to 8 µm in width, averaging 25 x 6 µm. A typical poorly developed conidia may also be produced in culture and within plant cells; these are much smaller and are straight or fusoid instead of falcate. The conidium germinates by producing a germ tube from its end (Agnihotri, 1983 and Singh and Singh, 1989). Patel (2000) studied the colonies of *C. falcatum* grew fairly fast on PDA covering whole petriplate within 9 days at room temperature (27 $\pm$ 2^{0}C). Initially the fungus produced cottony white mycellium which turned light grey and finally grey. The conidia were hyaline, one celled sickle or falcate shaped measuring 29.4-41.5 µm x 6.3-8.4 µm in size contained an oil globule. The mycellium is thin, branched, septate, containing oil drops.

Appressoria are frequently formed by hyphae or germ tube when they come in contact with a hard substance. According to Sutton (1968), the appresoria are terminal, rarely inter calary, aseptate, smooth but thick walled and cinnamon buff in colour, firmly attached to the host tissue, and remain viable for sometimes and may serve to perpetuate the fungus when mycelium is unable to develop.

The fruiting body of the perfect stage is perithelium, which measures 100-260 µm x 85-250 µm and containing numerous asci and paraphyses. Asci are clavate, slightly thick end at the apex and measure

70-90 x 13-18 µm The ascospores are hyaline, straight or fusoid, one celled and measure 18-22 x 7-8 µm The paraphyses are delicate structure containing numerous oil like globules. The fungus is homothalic as the peritheeia develop from single ascospore cultures (Carvajal and Edgerton, 1944 and Wang, 1950).

2.4 Symptoms

Went (1893), Butler (1906), Abbott and Hughes (1961), Agnihotri and Budhraja (1974), Chona (1980), Agnihotri (1983), Singh and Singh (1989) and Patel (2000) have described the symptoms of sugarcane red rot. According to them, in the early stage of infection, it was very difficult to recognise the disease in the field although sett rot and death of settling was observed. It had been seen in abundance during and after the South-West monsoon rains when the plant growth slows down considerably and sucrose accumulation starts. The first external symptoms of the disease appeared mostly on the third and/or forth leaf, which withered away at the tip and along the margins. Later on, the whole crown may have withered away within eight to twelve days, in a susceptible variety. Typical symptoms of red rot were observed in the internodes of a stalk by splitting it longitudinally. These included reddening of internal tissues with white spots, which were usually elongated at the right angle to the long axis of the stalk. The presence of these cross wise white patches was considered as a diagnostic character of the disease. Some times these patches were so numerous in a susceptible variety. The diseased canes also emitted a sour smell. In the later stages of the disease development, the stalk became hollow and in its lumen fungus grew luxuriantly and sporulated

abundantly. At that stage, the rind shrunk longitudinally with fruiting bodies of the fungus protruding out of the epidermis.

2.5 Disease cycle

2.5.1 Source of infection

The source of infection differs according to the stage of crop growth. This includes midrib lesions, diseased stalks, infected setts, crop debris, infected soils and possible alternative host plants. Midrib lesions are probably the major source of inoculum during the growing season. Diseased stalks later provide a great deal of inoculum. initially from large profusely sporing acervuli produced through root primordia, and subsequently from the numerous small acervuli produced everywhere on the rind when the stalk dries out (Singh and Singh, 1961). According to Chona and Nariani (1954), *C. falcatum* is capable of growing in the soil and produces abundant acervuli. Singh *et al.* (1977) studied on survival of the pathogen in soil and showed that the pathogen survived for 63 days in winter and 34 days in autumn. So far the fungus is not true soil borne, does not survive for long time, the diseased stalks and stubbles provide a large amount of inoculum to infect the ratoon crop, particularly under humid conditions. Spores washed out into the soil may also produce infection in planted setts (Singh and Singh, 1961). The asexual and sexual structures produced on decaying canes and/or debris causes infection to healthy setts after planting (Chona and Padwick, 1942, Chona, 1950 and Agnihotri *et al.*, 1979).

2.5.2 Dissemination

Singh (1988) showed that inoculum spreaded from the primary focus, infected the nearby plants, which serve as new infection foci in ratoon crop. According to Chona (1956) the spread of the disease within the crop occurred through irrigation water containing spores of *C. falcatum*. However, dissemination of inoculum takes place by rain, dews and irrigation water or in seed cane (Chona, 1950 and Abbott and Hughes, 1961). Dispersal by wind is difficult due to mucilaginous nature of spore mass. However, the occurrence of infection during dry periods on the upper nodes and young midribs indicates that wind borne infection may possibly carrying the inoculum either from the dried, mucilaginous, conidiospore matrix (Singh *et al*. 1983 and Singh and Lal, 1996).

2.5.3 Mode of infection

The pathogen mainly infects stalks through the leaf scare, growth ring, root primordia and buds, which are the points of entry for the pathogen (Steib and Chilton, 1951; Srinivasan and Alexander, 1964 and Singh *et al*., 1977). Entry into the nodes may also be gained by first infecting the inner epidermis of the lower part of the leaf sheath. Penetration into nodes by the pathogen may be rapid causing stalk rot. The pathogen can also infect the stalk through growth cracks or borer holes (Singh and Singh, 1989).

Direct penetration through the cut ends of the setts may occur, but it is not considered important. However, when dormant infection is present, the pathogen may invade sett tissue and cause rotting or after germination, it may infect the basal portion of

developing shoot. Dormant infection in bud scales may result in the death of bud or death of young shoots before emergence. When infection is mild, leaf sheath of new shoot may be infected and eventually, nodes are attacked (Steib and Chilton, 1951; Srinivasan and Alexander, 1966; Singh, 1968 and Alfanso, 1976).

2.6 Favourable conditions

Both soil moisture and temperature have marked influence on the extent of red rot injury to planted setts. The disease is favoured by both excessive or greatly deficient soil moisture. When conditions are suitable for early germination of buds, little or no red rot injury may occur even with susceptible varieties (Abbott and Hughes, 1961).

Duttamajmudar *et al.* (1990) concluded that conidia of *C. falcatum* fused and form aggregate that can float easily in water which increased disease spread via irrigation or flood water. Kalaimani *et al.* (1990) also showed that the spread of red rot was favoured by high soil moisture.

Beniwal and Satyavir (1991) reported that red rot development by plug method of inoculation decreased with increased in mean temperature from 21.1 to 31.0^{0}C. Top drying was highly responsive in temperature variation than disease index. The red rot development was optimum between 29.4 to 31.0^{0}C temperature range.

2.7 Pathogenicity

Went (1893) who reported red rot disease for the first time also proved pathogenicity of the fungus, which he isolated from the diseased plants. Howard (1903) concluded by inoculation tests that *C. falcatum* was the main pathogen responsible for the disease.

Grainer and Horne (1924) described plug method as a standard technique for inoculation in apple which was adopted for artificial inoculation of red rot in sugarcane by Chona (1954). According to Singh and Budhraja (1964) the "plug method" is the prevelent inoculation technique for reproducing red rot disease in standing cane. Gupta (1980) and Patel (2000) also proved pathogenicity by plug method.

Besides inoculating standing cane, various workers studied on soil and sett inoculation. Singh *et al.* (1977) reported that the soil inoculated with 0.5 million spores per gram of soil can cause 94 per cent and 72 per cent settling infection in unsterilized and sterilized soil, respectively. The inoculum of red rot pathogen in the soil consisting of conidia, setae, chlamydospores, thick-walled hyphae and ascospres causes infection to healthy setts after planting (Chona and Padwick, 1942; Chona, 1950 and Agnihotri *et al.*, 1979).

Agnihotri *et al.* (1979) showed that the setts may carry internal, external or both type of infection of *C. falcatum* and the mortality of clumps differs with the type of infection viz., setts inoculated just before planting (25.3 %), setts taken from five months old inoculated stalks (43.7 %) and nodal infection (27.2 %) in Cv. Co 312.

2.8 Survey

Chand *et al.* (1975) surveyed sugarcane growing areas of Haryana during crop season of 1971-72 and observed that red rot was commonly prevalent in mild to severe form in all the areas surveyed. They also observed that most of the varieties were infected and variety Co 312 had maximum infection.

Tyagi and Goyel (1975) surveyed different sugarcane growing tracts of Rajasthan and observed that the severity of the disease varying from 10 to 90 per cent and in variety Co 312, the infection was more than 30 per cent. Sporadic occurrence of red rot disease in Cv. CoS 767 was reported by Singh *et al.* (1993b) in Uttar Pradesh.

Lal and Singh (1994) surveyed Bardoli, Madhi and Sayan sugar factory areas of South Gujarat and reported that the disease was in sporadic form during 1990-91 crop season. Results of a roving survey conducted by Department of Plant Pathology, N. M. College of Agriculture, Gujarat Agricultural University, Navsari during 1993 for occurrence and spread of the red rot disease in South Gujarat revealed that 445.41 ha and 433.01 ha area of plant and ratoon crops, respectively was found affected due to red rot and the popular variety CoC 671 noticed as highly susceptible (Anon., 1994).

Lal and Singh (1998) in another survey noticed disease incidence was ranging from 20-80 per cent on cane basis in Bardoli, Madhi and Sayan sugar factories.

Survey of red rot disease done in Gujarat during 1999-2000 revealed that 1.20 and 2.05 per cent area was affected by red rot in plant and ratoon crops, respectively (Anon., 2000b). The incidence of red rot was more in ratoon crop as compared to control (Anon., 1999a and Patel, 2000).

2.9 Loss assessment

Red rot is an important disease of sugarcane as it causes heavy quantitative and qualitative losses in sugarcane production (Martin *et al.*, 1961 and Chona, 1980).

2.9.1 Quantitative losses

The most conspicuous effect of red rot is on the weight of cane (Agnihotri, 1983).

Joshi and Sharma (1968) reported that the average height, girth and weight of red rot affected plants were reduced significantly. Loss in cane yield has been estimated to be 44.1 per cent in CoS 430 (Kar and Verma, 1962) and 12 to 41.5 per cent in Cvs. Co 312, Co 313, Co 453 and Col. 29 (Sandhu *et al.*, 1969). Cane weight reduced by 28.52 per cent in initial infection whereas it was 82.73 per cent when red rot was more than 50 per cent in the Cv. L 116 and B 4360 (Ahmad *et al.*, 1986). Patel (2000) reported 6.67, 10.50, 30.42, 50.75 and 83.64 per cent loss in cane weight of Co 6806, CoN 91132, CoC 91061, Co 6304 and CoC 671 varieties, respectively. The cane length, girth and number of eye bud was also reduce due to disease in varying degree.

2.9.2 Qualitative losses

Went (1893) was first to observe reduced sucrose content in diseased cane, whereas Singh and Waraitch (1981) reported that *C. falcatum* deteriorated the juice quality.

Sandhu *et al.* (1969) reported 2.7 to 21.7 per cent decrease in brix in the juice of Cv. Co 312, Co 313, Co 453 and Col. 29 due to red rot infection while decrease in juice extraction from 24.25 to 90.27 per cent in Cv. L 116, B 4360 and Co 564 was observed by Ahmed *et al.* (1986).

According to Kalaimani and Muthuswami (1989), four different isolates of *C. falcatum* when inoculated reduced the

commercial cane sugar significantly as compared to uninoculated control and the isolate-IV had reduced commercial cane sugar more than the other three isolates.

Rao *et al.* (1984) reported that in red rot infected canes of variety CoC 671 and B 46364, the pH, sucrose, brix, juice, purity, C. C. S. and recovery of jaggary were lower.

According to Beniwal *et al.* (1989b), red rot infected canes have a marked reduction in brix (7.03-32.94 per cent), pol (7.43-38.70 per cent), purity (0.45-8.26 per cent), extraction (4.97-40.79 per cent) and C. C. S. (7.84-43.31 per cent). The adverse effect of red rot on juice quality parameters was least in resistant variety Co 7314 while it was maximum in highly susceptible clones CoL 29 and S 78/560. In the clones viz., S 77/467, CoS 802, Co 1158 and CoJ 64, it was moderate and thus correlated with their level of horizontal resistance.

2.10 Varietal screening

For diseases like red rot, cultivation of resistant varieties seems to be the most appropriate and practical solution of the problem (Chona, 1954).

Different workers suggested various methods of inoculation for screening of sugarcane varieties against red rot viz., Plug method (Chona, 1954), Nodal method (Beniwal *et al.*, 1989a and Kumar *et al.*, 1998) and Whorl method (Beniwal *et al.*, 1989a). Among them, plug method (Chona, 1954) is prevelent and best technique as the environment had a little impact (Singh and Bhudhraja, 1964; Virk and Satyavir, 1989).

Tyagi and Goyal (1976) screened 7 sugarcane varieties against different isolates of *C. falcatum* by plug method and observed that none was resistant. Biswas (1986b) screened 30 varieties by plug method against red rot and observed that only two varieties namely, Co 1148 and Co 7801 were resistant. Of the 156 varieties screened by plug method, 33 were proved resistant while 46 varieties showed moderately resistant reaction to red rot (Methew *et al.*, 1987).

Some 222 sugarcane clones alongwith 13 susceptible checks were screened by Kalaimani and Natrajan (1994) against red rot. Of which, only two clones viz., Co 86249 and C 88011 appeared resistant, 15 moderately resistant and 25 moderately susceptible while remaining genotypes including commercial varieties CoC 671, Co 6304 and CoC 8201 proved susceptible or highly susceptible.

While screening against red rot pathogen by plug method, Sabalpara *et al.* (1999) found CoJn 86141, Co 87010, CoLk 8001, Co 9105 varieties as resistant while Co 8209, Co 86002, Co 87263, Co 91005, CoC 91061, Co 6806, CoLk 8102, CoN 85134, CoN 91132, CoN 94134, Co 89018, Co 91001, Co 91007, Co 91013 and Co 91019 as moderately resistant. Patel *et al.* (1999) reported sugarcane varieties Co 87010, Co 87263, CoLk 8001, CoLk 8102, CoN 85134, CoN 91132 as moderately resistant.

Different genotypes tested by plug method in red rot prone areas of South Gujarat during three years at different three locations revealed that the sugarcane varieties viz., CoS 767, Co 89014, Co 87023, Co 94019, CoN 85134, Co 86042, CoV 94102, Co 95011, CoN 97131, Co 85036 and CoSi 98071 found as moderately resistant (Patel, 2000).

2.11 Biological control

The extensive efforts were made in the 1920s and 1930s for biological control of plant pathogens by introducing antibiotic producing micro-organisms in the soil. The potential use of fungal antagonists as bio-control agents for plant diseases was suggested by Weindling (1932), who for the first time demonstrated the parasitic activity of member of the genus *Trichoderma* against soil borne pathogens. Dennis and Webster (1971) reported the inhibitory effect of non-volatile metabolites of *Trichoderma* sp. against a wide range of fungi.

2.11.1 *In vitro*

The antifungal and antibacterial properties of *Trichoderma* spp. due to trichodermin, dermatin (Godtfredsen and Vangedal, 1965; Pyke and Diets, 1966), suzakacillin and alamethicin (Coka *et al.*, 1966; Mayer and Reusser, 1967) have been reported. Singh (1983) reported 3 isolates of *Trichoderma* and 2 of *Aspergillus* as a strong competitor of *C. falcatum in vitro*. Cultural filtrate of *T. harzianum*, *Acremonium* sp., Isolate-35 (unidentified species) and Isolate-9 of *Penicillium* sp. were found very effective in suppressing spore germination of *C. falcatum* (Iqbal *et al.*, 1994). Revathi *et al.* (1997) investigated the antagonistic behaviour of *T. viride* and observed growth inhibition especially when in combination with *T. harzianum* and *Chaetomium globosum*. These were the most antagonistic to *Glomerella tucumanensis* (Kumar and Satyavir, 1998). The inhibitory effect of *Gliocladium virens* and *Chaetomium globosum* on *C. falcatum* have been reported (Patel, 2000). *Aspergillus* spp are known for their inhibitory effect against

Alternaria solani, *Drechslera oryzae*, *Sclerotium oryzae* (Usmani, 1981; Gupta, *et al.*, 1985; Jariwala *et al.*, 1991). Singh and Singh (1997) reported that non-volatile metabolites of *Aspergillus flavus*, *A. terreus*, *Curvularia pallescens*, *Penicillium citrinum*, *Alternaria alternata* and *Trichoderma viride* were most effective for checking radial growth of *Alternaria solani* at 5 ml per 20 ml of medium, indicating antifungal substance production.

A strain of *Bacillus* inhibited the growth of *Colletotrichum*, *Helminthosporium*, *Alternaria*, *Curvularia*, *Fusarium*, *Rhizoctonia* and *Nigrospora* species *in vitro* (Bravo, 1993). Badel and Kelumu (1994) reported reduction in mycelial growth, germination and conidial production of *C. gloeosporioides* due to the presence of *B. subtilis* in culture media. *Pseudomonas fluorescens* (Isolates P_2, BT_{22} and SDR_2), *P. marginalis* (C_{21}) and *Bacillus subtilis* (B_{16}) inhibited mycellial growth of *C. graminicola in vitro* (Michereff *et al.*, 1994). Fraitus and Pizzinatto (1997) observed majority of *Pseudomonas* including *P. fluorescens* were antagonistic to *C. gossypii* on King's B but not on PDA, indicating possible siderophore involvement.

2.11.2 *In vivo*

Sharma and Sinha (1982) obtained reduction in the incidence of *C. falcatum* and in average lesion length when sugarcane stock were inoculated simultaneously or a week later with *Streptomyces dayalbaghensis* and it was most effective when the antagonist was applied a week before the pathogen. Spore suspension and cultural filtrates of *Streptomyces rochii* reduced the disease development in mango due to *C. gloeosporioides*, on barley *Alternaria alternata* and in

sugarcane *C. falcatum* (Sharma and Gupta, 1983). Shivanna and Shetty (1989) reported that seed treatment with *T. harzianum* and *T. viride* eliminated seed borne inoculum of *Colletotrichum dematium* (Pers. ex Fr.) Grove from cluster bean. *Chaetomium globosum* were also found very effective to get more germination as well as for control of seed borne microflora of cotton (Sohi *et al.*, 1988). Singh and Singh (1990) studied on influence of rhizosphere mycoflora on red rot and reported that *Aspergillus* spp., *Trichoderma viride*, *Rhizopus nigricans* were prominent in healthy and *Aspergillus* spp., *Penicillium variable*, *Fusarium moniliforme* and *Cladosporium herberum* in diseased rhizosphere of sugarcane.

Germination, yield and millable cane increased and disease incidence both on cane and clump basis decreased in *C. falcatum* inoculated setts treated with *T. harzianum* (TR-II) and *C. globosum* over infected (only *C. falcatum* inoculated) setts (Singh, 1994). Revathi *et al.* (1997) investigated the antagonistic behaviour of *T. viride* against *C. falcatum* in a preliminary field trial and observed significant reduction in disease incidence. Sugarcane growers of South Gujarat are recommended to apply *Trichoderma viride*, *T. longibrachyatum* or *T. harzianum* multiplied in seasoned pressmud @ 8 t ha^{-1} for effective management of wilt and red rot complex as well as for getting higher yield (Anon., 1998).

2.12 Bio-efficacy of phyto-extracts *in vitro*

Fungicides are more popular among farmers due to their quicker results in controlling plant diseases. But they create problems of chemical pollution among plants, animals and environment. Further,

plant pathogens also develop resistance against them. Some of plants are known to have germicidal and disease retarding abilities. They neither pollute the environment nor have residual effects.

Extracts of tannin containing plants showed positive inhibition on conidial germination of *Pyricularia oryzae* and *Colletotrichum falcatum* at the concentration of 10.0 g l^{-1} (Janardhan and Ganguly, 1963). Seikh and Agnihotri (1972) reported the antifungal properties of 91 commonly occurring plants *in vitro* against *Alternaria brassicae*, *Colletotrichum papaya* and *Helminthosporium* sp. and observed that extracts of datura and garlic completely inhibited spore germination. Patel (1978) observed that 5 per cent extract of datura (*Datura stramonium*), ginger (*Zingiber officinalis* Rob.), turmeric (*Curcuma longa* L.) and mango turmeric (*Curcuma aromata* L.) were effective for inhibiting mycelial growth of *C. gloeosporioides in vitro*.

Allamanda cathartica and *Artabotrys hexapetala* were found to inhibit the growth completely and *Polyalthia longifolia* found as toxic to *C. falcatum in vitro* (Kishore *et al.*, 1982). The essential oil extracted from seeds of cumin (*Cuminum cyminum*) and dry flower buds of clove (*Syzigium aromaticum*) were fungitoxic to *C. falcatum*. *Curvularia* and *Pericenia atropurpurea in vitro*. These extracts at 1000 ppm were fungistatic and at 2000 and 3000 ppm they were fungicidal (Rao *et al.*, 1992). Pandey *et al.* (1993) reported root, stem, leaf and seed extracts of *Cleome gynandra* inhibitory to mycelial growth of *C. falcatum* and *Pericenia atropurpurea in vitro*.

Singh *et al.* (1998) reported essential oil of *Lippa alba* at 700 ppm or less as fungistatic to *C. falcatum* and *Curvularia pallescens*. but fungicidal at higher concentration, whereas *Pimpenella anisum* oil

at 3000 ppm showed fungicidal activity of *C. falcatum*, *Ceratocystis paradoxa* and *Rhizoctonia solani*.

2.13 Soil amendments

One of the cheapest and effective methods for disease management is altering the soil environment by amending the soil with decomposible organic matter. Besides having direct toxic effect on the pathogen, it indirectly enhances the biological control. Different oil cakes, green manure crops, meats, sawdust, pressmud, farm yard manure, etc. can be used as soil amendments. The decomposition of organic matter helps in altering the physical, chemical and biological conditions of the soil. The various biochemical released during decomposition includes antibiotics and phenols, which in turn induces disease resistance of the root surface as well as tissue when absorbed (Singh, 1984).

In 1952, Stover has proposed the possible mechanisms of the disease control through organic amendment of soil.

Singh (1985) reported that sugarcane bagasse @ 30 q ha^{-1} significantly reduced red rot incidence even though highly susceptible variety Co 312 was planted. The reduction in cumin wilt caused by *Fusarium oxysporum f*. sp. *cumini* was reported by Champawat and Pathak (1988). Application of neem cake @ 1.5 % W/W proved most effective in reducing ashy gray stem blight (*Macrophomina phaseolina*) of cowpea followed by karanj cake (1.5 % W/W) and castor cake (1.5 % W/W) (Ratnoo and Bhatnagar, 1993).

Application of sugarcane bagasse @ 30 and 40 q ha^{-1} and pressmud@40 and 50 q ha^{-1} significantly suppressed the red rot

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incidence in artificially inoculated soil (Saharan *et al.*, 1994). Anadani (1995) conducted laboratory experiment and showed that unsterilized neem oil cake extract was most effective for inhibition of growth of *Fusarium moniliforme* causing wilt of sugarcane followed by castor and mustard oil cake extracts. Vala *et al.* (1997) reported that the application of castor cake @ 25 t ha^{-1}, neem cake @ 25 t ha^{-1}, pressmud @ 50 t ha^{-1} and farm yard manure @ 50 t ha^{-1} reduced wilt incidence and increased in the yield under South Gujarat conditions.

2.14 Effect of root exudates on *C. falcatum*

The root exudates are the chemicals elaborated metabolites released into the root environment (Bansal and Mukerji, 1996). Secondary plant metabolites and their degradation products are important in all agro-ecosystem. The root exudates are one type of secondary plant metabolites which are the by product of primary plant metabolites (Levin, 1976). The plants release the secondary metabolites through decomposition of residues, root exudes, leachates and volatilization. These are also called as allelochemicals and their effect called as allelopathy. Rice (1984) defined the term allelopathy as the direct or indirect, beneficial or harmful effect of one plant (including microorganisms) on another through production of chemical compounds that escape into the environment. The root exudates are one type of compound that affect the growth of microorganisms, such compounds are also called as phytoncide (Mandava, 1985).

Curl (1982) reviewed the influence of root exudates and rhizosphere microflora on the behaviour of pathogens. The growth and reproduction of a pathogen may be affected directly by root exudates of

either host plant or non-host plants or the pathogen may be affected indirectly by microflora and small animals that proliferate in the presence of roots and exudates

Infection of cabbage seedling by *Pellicularia* was reduced when sown in combination with beet root, garlic and onion (Lavroko, 1962). Asparagus root exudates contain a mixture of short chain alkaloids, acids and asparagustic acid which are nematicidal (Rice, 1984).

Singh *et al.* (1993) reported that the red rot incidence was lower (2.2-6.0 per cent) when the sugarcane (Cv. Co.k 7701) was grown as companion crop with linseed, mustard or onion as compared to only sugarcane (23.8 per cent). They also noticed that the red rot incidence decreased when the sugarcane was followed by previous crops like garlic, mustard, coriander, onion or linseed. They suggested that the root exudates of linseed, mustard, garlic, onion and coriander may have some direct or indirect effect on pathogen or host providing protection against the sugarcane red rot.

2.15 Bio-efficacy of fungicides

2.15.1 *In vitro*

Narain and Panigrahi (1971) evaluated the efficacy of fungicidal compound against *Colletotrichum capsici in vitro* and observed that Ziram was the most effective compound to restrict the conidial germination, even at the lowest concentration of 5 ppm. Carbendazim had been reported to reduce the activity of polygalacturonase and cellulolytic enzymes (Garg and Mehrotra, 1975). Among 22 fungicides tested, HMP-MBC (at 1000, 2000, 3000 ppm) and Bavistin (at 500, 1000, 1500 ppm) proved to be significantly better

in restricting the mucelhal growth of *C. gloeosporioides* Penz. *in vitro* (Patel,1978) Saifulla and Ranganath (1978) observed that Thiram, Dithane M-45, Emisan, Captan, Bavistin and Delson-30 completely inhibited *C. graminicola* at 1000 and 2000 ppm *in vitro*.

Khirbat *et al.* (1984) screened 14 fungicides against *C. falcatum* and observed that benzimidazole in general performed best but Plantvax (Oxycarboxin) and Hoe 6053 (Pyracarbolid) also effectively inhibited spore germination. Rahaman *et al.* (1994) claimed that Tilt (Propiconazole) and Knowin (Carbendazim) successfully controlled *C. dematium*, a pathogen of cowpea *in vitro*.

Goswami *et al.* (1996) observed good control of *C. catechu in vitro* by Knowin (Carbendazim) at all the tested concentrations followed by Tilt (Propiconazole), Folicur ((Tebuconazole), Alliete (Fosetyl) and Dithane-M-45 (Mancozeb) at 1000 ppm. Panday and Agnihotri (1996) claimed that Topsin was the most effective fungicide in arresting the growth of *C. falcatum in vitro* whereas, the heavy metals toxicants like Ceresan and Aretan were effective at higher concentrations.

2.15.2 *In vivo*

Pre-plant treatment of sugarcane setts with Benlet and Vitavax increased germination by 50 per cent and controlled *C. falcatum* (Chand *et al.*, 1974). Lewin *et al.* (1976) observed good control of *C. falcatum* by dipping setts in Agallol (0.5 %) for 15 minutes while Bavistin was found less effective. Saifulla and Ranganathan (1978) reported that Bavistin and Emisan were more effective in removing seed-borne infection of *C. graminicola* in sorghum

The best control of sugarcane red rot was obtained by dipping three eye buded, naturally infected setts in 0.5 per cent Bavistin (Carbendazim) for 1 hour (Waraitch, 1983). Saharan and Satyavir (1988) reported that one hour treatments of Bavistin @ 0.25 per cent to the three eye buded setts of Col. 29 variety was effective in reducing the red rot disease. Natrajan *et al.* (1997) recommended pre-plant treatment of Carbendazim 50 WP @ 0.5 g l^{-1} or Carbendazim 25 DS @ 1 g l^{-1} for 5 minutes to the two eye buded setts. Pre-plant treatment to the two eye buded sugarcane setts (CoC 671 variety) with MEMC (Bagalol or Emisan @ 2 g l^{-1}) or Carbendazim (Zoom or Bavistin @ 2 g l^{-1}) for five minutes found effective for increasing germination and yield with decreasing disease incidence (Anon., 1999).

2.16 Integrated disease management

For integrated management of red rot of sugarcane, different methods have been suggested by various workers. According to Chona (1954) for management of diseases like red rot resistant varieties seems to be most appropriate and practical solution.

Natrajan *et al.* (1997) suggested a strategy for the management of red rot in Tamil Nadu. For effective disease management, the diseased setts must be avoided. The nursery even with one per cent disease should be rejected for seed purpose. The setts should be pre-treated with Carbendazim 50 WP @ 0.5 g l^{-1} or Carbendazim 25 DS 1 g l^{-1} for five minutes. They also suggested sett steep treatment of *Trichoderma viride* 4 g l^{-1} and *Pseudomonas fluorescens* 2.5 g l^{-1} for effective control of red rot. The affected clumps should be collected, burnt and the affected area should be

drenched with Carbendazim/OMSD @ 1.0 g l^{-1} to check the spread of the disease. Application of 3000 litressolution per hectare of MEMC (Emisan @ 1 g l^{-1}), Carbendazim (Bavistin @ 1 g l^{-1}) or granular application of Oenantalbisul (Ovis-G 25 kg ha^{-1}) in the sick soil for the management of wilt and red rot complex twice, first at the time of planting and second at 90 days after planting is recommended in South Gujarat (Anon., 2000).

There was no any attempt made to manage red rot disease by integration of all the methods. However, Shukla and Sinha (1998) reviewed and suggested some methods as follows:

1. Physical

Joshi (1954) obtained good control of red rot and smut by HWT at 52°C for 18 minutes, MHAT at 54°C for 2-2.5 hours; most of the pathogen of red rot, smut, leaf scaled, RSD and GSD present in seed material were killed (Srivastava *et al.*, 1977).

2. Cultural

Trash burning: Immediately after harvest the crop debris should be burnt. This practice is helpful in reducing the disease and the insect pest population also.

Use of healthy seeds: Seed material should be obtained from apparently from disease free crop, preferably the plant crop. Since this disease is primarily sett borne and transmitted through setts, it is very necessary to select planting material free from pathogen. For obtaining healthy seeds, Singh (1977) proposed three-tier seed production programme.

Discontinuation of ratooning. After the harvest of the plant crop, the inoculum of many diseases survives in the underground

portion of the stubbles and the infected stubbles serve infection foci in a ratoon crop and resultantly disease incidence becomes higher than the preceding crop.

Crop rotation and intercropping: In sugarcane based cropping system, several recommendations have been made, among them, crop rotation with linseed, mustard, coriander, garlic, onion, etc. found to reduce red rot disease.

Drainage in field: As water logging condition increases chances of infection (Duttamajmudar *et al.*, 1990) and the disease spread is favoured by high soil moisture (Kalaimani *et al.*, 1990) drainage is more important.

3. Biological control

Application of bio-agents like *Trichoderma harzianum*, *T. viride*, *T. longibrachyatum* and *Chaetomium globosum* have been recommended.

4. Chemical

Pre-plant treatment with Bavistin (0.5 %), Agallol (0.5 %) and Benomyl (0.25 %) have been recommended.

MATERIALS AND METHODS

III MATERIALS AND METHODS

3.1 Pathological investigations

3.1.1 Collection of samples

The samples of sugarcane plants Cv Co(C 671 showing red rot symptoms, collected from the Regional Sugarcane Research Station, Gujarat Agricultural University, Navsari were subjected to microscopic examination as well as isolation of the causal agent in the laboratory.

3.1.2 Isolation of pathogen

External as well as microscopic examination of the infected plants was carried out and after confirming the symptoms and association of the fungus in the plant parts, the samples were subjected to tissue isolation from the nodal as well as internodal tissues of the infected sugarcane plants. The tissues were cut into small bits, surface sterilized with 0.1 per cent mercuric chloride for one minute followed by three subsequent washings of sterile distilled water, then aseptically transferred to sterile petriplates containing 20 ml of potato dextrose agar (PDA) medium (peeled potato 200 g, dextrose 20 g and agar agar 20 g in 1000 ml distilled water) and incubated at ambient temperature (27 ± 2^{0}C). The growth of the fungus developed after an incubation period of 48 hours was subcultured to obtain pure which was further purified by single spore isolation technique and isolates were maintained on PDA slants for further studies.

3.1.3 Pathogenicity test

To ascertain the pathogenic nature of the *Colletotrichum* sp. isolated from infected canes, the pathogenicity test was carried out in net house on highly susceptible Cv. CoC 671 by five different methods of inoculation viz., (i) Soil inoculation, (ii) Sett inoculation, (iii) Soil-cum-sett inoculation, (iv) Cotton swab inoculation and (v) Plug method. The spore suspension having 10^8 conidia per ml water prepared from 10 days old pure culture grown on PDA medium was used for inoculation.

Four replications of each method were maintained and equal number of uninoculated pots were kept as control Two eye budded two setts were planted in each pot for each method. Methods of inoculation used in this experiment are as under:

3.1.3.1 Soil inoculation

Healthy two eye budded two sugarcane setts of Cv. CoC 671 were planted in each pot containing eight kg of soil then one liter of conidial suspension having 10^8 conidia per ml of water was poured around the setts and covered with soil.

3.1.3.2 Sett inoculation

Healthy two eye budded setts of CoC 671 variety were dipped in conidial suspension of *C. falcatum* (10^8 conidia/ml) for 30 minutes and were planted in pots.

3.1.3.3 Soil-cum-sett inoculation

First, setts were inoculated (as described in 3.1.3.2) and then soil inoculation was made (as described in 3.1.3.1).

3.1.3.4 Cotton swab inoculation

Healthy two eye budded setts of variety CoC 671 were used. Sterile cotton dipped in spore suspension was placed on the eye bud. Then the setts were planted as such in pots keeping the cotton swab on the eye bud.

3.1.3.5 Plug method (Chona, 1954).

Sugarcane setts of highly susceptible variety CoC 671 were planted in pots (Healthy two eye budded two setts for each pot). In the first week of August, the inoculation was carried out. A small cavity of uniform size was bored into cane in the middle of the third exposed internode from bottom by removing a core of tissues with the help of IISR inoculator. One ml of inoculum was introduced into the cavity of each cane with the help of large hypodermal syringe. The core was replaced and a small pallet of plasticidine was pressed over the injury to cover it.

The inoculated canes were left undisturbed in net house for development of symptoms. Regular watering was done as and when needed. Observations on germination (45 days after planting), mortality (60 days after planting) and per cent red rot incidence were recorded after 10 months of planting. For plug method, observations were recorded after 60 days of inoculation.

3.1.4 Taxonomy and identification

Morphological and cultural characters of the isolated *Colletotrichum* sp. were studied and compared with those given in literature. The pure culture was also sent to Indian Type Culture Collection

(IICC), Division of Mycology and Plant Pathology, I. A. R. I., New Delhi-110 012 for identification.

3.2 Survey for occurrence and spread of sugarcane red rot in South Gujarat

3.2.1 Area affected by red rot

The survey was carried out during 1999-2000 for the occurrence and spread of sugarcane red rot in South Gujarat where sugarcane cultivation is concentrated and mono cropping is followed. The data collected through various sugar factories are presented in Table 4.2.

3.2.2 Varieties infected by red rot

Variety wise data of total area were collected from Sayan, Bardoli and Chalthan sugar factory areas. Red rot incidence was also recorded on these varieties and then percentage area of susceptible varieties grown were calculated.

3.3 Loss assessment

For quantitative and qualitative loss assessment, fifteen sugarcane varieties viz., Co 6806, Co 86249, CoN 91132, 86 A 146, Co 87263, CoC 92020, CoN 95132, Co 86002, CoN 97132, Co 7805, CoN 97134, Co 85019, Co 91121, CoC 671 and Co 86032 having varying degree of resistance i.e. resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible were collected at harvest. In each case, 5 healthy and 5 red rot infected canes were collected randomly. Their cane length, girth, number of internodes

and weight were recorded and then the same were analysed for brix, pol, purity, extraction and C. C. S. percentage.

3.3.1 Quantitative losses

For determining quantitative losses, the observations regarding cane weight, girth, number of internodes and weight of five healthy and five diseased canes from fifteen sugarcane varieties were recorded. The per cent losses due to the disease was calculated by comparing the changes in diseased canes over healthy canes and presented in Table 4.3 (a to d).

3.3.2 Qualitative losses

Five healthy and diseased canes of above varieties were crushed to determine the changes induced in juice quality parameters viz., brix, pol, purity, extraction and C. C. S. by adopting standard methods (Browne and Zerban, 1941 and Spencer and Meade, 1963).

The calculations were made by using following formula:

$$\text{Purity \%} = \frac{\text{Sucrose \%}}{\text{Corrected brix}} \times 100$$

$$\text{Extraction \%} = \frac{\text{Weight of juice (kg)}}{\text{Weight of cane crushed (kg)}} \times 100$$

$$\text{C.C.S. \%} = 1.05 \times \text{Pol \%} - 0.307 \times \text{Original brix}$$

The results of brix, pol, purity, extraction and C. C. S. in case of healthy and diseased canes from each sugarcane variety were recorded and finally per cent losses in diseased canes over healthy was calculated and the results are presented in Table 4.4 (a to e)

3.4 Screening of sugarcane varieties against *C. falcatum* *in vivo*

Twenty five sugarcane varieties viz., Co 6806, CoN 95132, Co 86032, Co 87263, Co 8338, Co 85019, CoC 671, CoLk 8001, 86 A 146, Co 87002, Co 7318, Co 7805, Co 85001, CoSi 98061, CoC 92020, Co 86249, Co, 86002, CoN 85134, CoN 97134, CoN 97132, Co 6415, CoSi 98071, Co 91014, CoC 91121 and CoN 91132 were raised at Tajpor village of Bardoli sugar factory area by road row method using recommended agronomic practices during the year 1999-2000. Five canes of each variety, free from insect-pest and disease were inoculated by standard plug method (Chona, 1954) in the third week of August. Inoculations were made in the middle of third exposed internode from the bottom. In each cane, a hole was made by IISR inoculator and one ml of conidial suspension (10^8 conidia/ml) was injected into the holes. The holes were immediately sealed with plasticidine to avoid contamination and the inoculated canes were labeled. After two months of incubation, the inoculated canes were split open longitudinally along the point of inoculation and graded on the basis of international scale of 0 – 9 (Shrinivasan and Bhat, 1961) as follows:

Scoring of the disease:

1. Condition of the top - Green (G) = 0
   Yellow (Y) or dry (D) = 1
2. Lesion width (LW) - above inoculated internode was assigned the score 1, 2 and 3
3. White spot (WS) - assigned 1 or 2 according to whether it was restricted or progressive

4. Nodal transgression (NT)	-	Number of nodes transgrassed above the inoculated node were counted and given the score as
		If one node crossed 1
		If two nodes crossed 2
		If three nodes crossed 3 (maximum)

Grading:

0.0 to 2	-	Resistant (R)
2.1 to 4.0	-	Moderately Resistant (MR)
4.1 to 6.0	-	Moderately Susceptible (MS)
6.1 to 8.0	-	Susceptible (S)
Above 8.0	-	Highly susceptible (HS)

The mean total of five canes was taken for assigning grade to each variety and reaction of twenty five varieties thus screened against red rot pathogen are presented in Table 4.5.

3.5 Biological control

3.5.1 Testing of cultural filtrates of different antagonists against *C. falcatum in vitro*

3.5.1.1 Fungal antagonists

Fungal antagonists viz., *Trichoderma viride*, *T. harzianum*, *T. longibrachyatum*, *Chaetomium glabosum*, *Gliocladium virens*, *Aspergillus niger* and *A. flavus* were cultured in 250 ml conical flask containing 100 ml of potato dextrose broth (250 g potato, 20 g dextrose, 1000 ml water) medium. After 10 days of incubation, the static culture of above fungi were filtered through funnel containing

sterile cotton and then Whatman filter paper No. 44. These filtrates were autoclaved at 1.2 kg cm^{-2} pressure for 20 minutes. Three levels (5, 15 and 25 per cent v/v) of cultural filtrates were taken under study. For this, the petridish containing 19, 17 and 15 ml of media amended with 1, 3 and 5 ml of fungal filtrate of a fungal species, respectively. Such four replications were made. The petriplate without filtrates served as control. All the petriplates were inoculated centrally with 5 mm block of pathogen cut from the actively growing colony of 10 days old culture and incubated at room temperature (27 $\pm$ 2^0C). The observations on colony diameter were recorded periodically and per cent growth inhibition were worked out by using formula suggested by Arora and Dwivedi (1979) and are presented in Table 4.6

$$\% \text{ inhibition} = \frac{(C - T)}{C} \times 100$$

where, C = growth in control

T = growth in treatment

Observations were also recorded on sporulation as follows

–	=	no sporulation
+	=	1-10 conidia/microfield (10 X)
++	=	11-25 conidia/microfield (10 X)
+++	=	26-40 conidia/microfield (10 X)
++++	=	> 40 conidia/microfield (10 X)

3.5.1.2 Bacterial antagonists

For bacterial antagonists viz., *Bacillus subtilis* (BS) and *Pseudomonas fluoroscence* (PF), the same procedure was followed except that they were cultured in King's B medium (KB) as well as

nutrient broth medium (NB) separately. The cultural filtrates were obtained by the methods described previously. These bacterial cultural filtrates were also tested by poisoned food technique keeping only one level i.e. 5 % V/V (5 ml/15 ml of media) to know their inhibitory effect on *C. falcatum*. Control without cultural filtrate was also kept. All the treatments were repeated for five times and incubated at 27 $\pm$ 2^{0}C. The observations were recorded on mycelial growth of pathogen in mm of radius. Then the data were subjected to statistical analysis. The per cent growth inhibition over control was also calculated by using formula suggested by Arora and Dwivedi (1979) as described earlier. The results are recorded in Table 4.7.

3.5.2 Testing efficacy of bio-agents in pot culture

The healthy sugarcane two eye budded setts of highly susceptible variety CoC 671 were first artificially inoculated by dipping the setts in conidial suspension (10^8 conidia/ml) of *C. falcatum* for 30 minutes and they were kept under shade for 24 hours. Then, these setts were dipped in spore suspension (10^8 c.f.u./ml) of different antagonists. Two setts were planted per pot in each case. The setts without any antagonist treatment and the setts without inoculation with pathogen were also kept which served as infected control and healthy control, respectively.

The treatments were as under:

T_1 = *C. falcatum* + *Trichoderma viride*

T_2 = *C. falcatum* + *T. harzianum*

T_3 = *C. falcatum* + *T. longibrachyatum*

T_4 = *C. falcatum* + *Gliocladium virens*

T_5 = *C. falcatum* + *Chaetomium globosum*

T_6 = *C. falcatum* + *Aspergillus niger*

T_7 = *C. falcatum* + *A. flavus*

T_8 = *C. falcatum* + *Bacillus subtilis*

T_9 = *C. falcatum* + *Pseudomonas fluoroscens*

T_{10} = *C. falcatum* (inoculated check)

T_{11} = Without any inoculation (healthy check)

The observations on germination were recorded after 45 days of planting and disease incidence (cane basis) was recorded periodically upto 10 months after planting. Finally per cent germination and per cent disease incidence were calculated and statistically analysed. Per cent increase in germination over check inoculated and per cent disease control over check were also calculated and presented in Table 4.9.

3.5.3 Bio-efficacy of phyto-extracts against *C. falcatum in vitro*

The extracts of 17 plant species as listed in Table 3.1 were evaluated against *C. falcatum in vitro* by poisoned food technique (Grover and Moore, 1962).

Fresh healthy plant parts as listed in Table 3.1 were collected, washed thoroughly with clean water and finally with distilled sterile water. Fifty grams of leaves, bulbs, seeds or rhizomes were minced with the help of grinder by adding 25 ml sterile water. The extracts were filtered through double layer musline cloth and collected in 150 ml conical flasks. Thus filtered phyto-extracts were autoclaved at 1.2 kg cm^{-2} pressure for 20 minutes to follow the poisoned food technique

Table 3.1: Various plant species used in phyto-extract study against *Colletotrichum falcatum*

Sr. No.	Common name	Botanical name	Family	Plant part used
1.	Ajmo	*Carum copticum* Heirn	Umbelifarae	Leaves
2.	Ajilo	*Apium carri* (L.) Benth & Hook f.ex.C. B. Clerk	Umbelifarae	Leaves
3.	Allamanda	*Allamanda grandiflora* L.	Apocynaceace	Leaves
4.	Datura	*Datura stramoneum* L.	Solanaceae	Leaves
5.	Fudina	*Montha piperita* L.	Menispermaceae	Leaves
6.	Gando baval	*Prosopis juliflora* L.	Menispermaceae	Leaves
7.	Garlic	*Allium sativum* L.	Liliaceae	Bulblets
8.	Ginger	*Zingiber officinalis* Rob	Zingiberaceae	Rhizomes
9.	Kuvadio	*Cassia tora* L.	Leguminaceae	Leaves
10.	Lantana	*Lantana camera* L.	Verbenaceae	Leaves
11.	Mango turmeric	*Curcuma aromata* L.	Zingiberaceae	Rhizomes
12.	Neem	*Azadirachta indica* Juss.	Meliaceae	Seed
13.	Onion	*Allium cepa* L.	Liliaceae	Bulb
14.	Pusha gandha	*Cleome spinosa* L.	Capparidaceae	Leaves
15.	Polylanthia	*Polylanthia longiflora*	Pittosporaceae	Leaves
16.	Turmeric	*Curcuma longa* L.	Zingiberaceae	Rhizomes
17.	Vachhnag	*Gloriosa superba* L.	Liliaceae	Leaves

Autoclaved extracts were individually added in previously sterilized PDA @ 5 per cent at the time of pouring in the petriplates and mixed thoroughly. All the plates containing phyto-extracts were incubated after placing the disc (5 mm) of vigorously growing (10 days old) pure culture of *C. falcatum* and incubated at room temperature (27 $\pm$ 2^{0}C). Four repetitions were made for each treatment. The petriplates without phyto-extracts served as control.

Observations of colony diameter were recorded and statistically analysed and per cent inhibition was also worked out by using formula suggested by Arora and Dwivedi (1979) as described earlier.

3.5.4 Bio-efficacy of organic extracts against *C. falcatum in vitro*

The aqueous extracts of different organic materials viz., neem cake, mustard cake, castor cake, poultry manure, farm yard manure, pressmud and vermicompost were prepared by suspending 30 g of each organic material in 150 ml sterile distilled water in round bottom flask and left for 25 days. The flasks were shaken on alternate day for thorough mixing and dissolution of the content. After 25 days, the flasks were thoroughly shaken and content were filtered through double layered muslin cloth and autoclaved at 1.2 kg cm^{-2} pressure for 20 minutes. These sterile extracts were used for testing their inhibitory effect on *C. falcatum in vitro* by poisoned food technique (Grover and Moore, 1962). The autoclaved extracts were individually added in previously sterilized PDA @ 5 per cent V/V at the time of pouring in petriplates and mixed thoroughly. All the plates were inoculated with 5

mm disc of actively growing 10 days old pure culture of *C. falcatum* The petriplates without extract served as control. All the treatments repeated for five times and incubated at room temperature (27 $\pm$ 2^{0}C). The observations on colony diameter were recorded periodically and per cent growth inhibition was calculated by using formula suggested by Arora and Dwivedi (1979) as described earlier.

The organic extracts in which the growth of the pathogen was completely inhibited were further studied to know their fungicidal or fungistatic effect. The same mycelial disc put earlier was again transferred to the plates with PDA only. They were then incubated at room temperature and periodically observed for their growth.

In other group where partial inhibition of mycelial growth was observed were also further studied. The mycelial discs were re-transferred to simple PDA plates and were incubated at room temperature. The periodic observation on sporulation were recorded as follow:

–	=	no sporulation
+	=	1-10 conidia/microfield (10 X)
++	=	11-25 conidia/microfield (10 X)
+++	=	26-40 conidia/microfield (10 X)
++++	=	> 40 conidia/microfield (10 X)

3.6 Effect of root exudates of various plant species on spore germination of *C. falcatum in vitro*

The root exudates of different plant species as listed in Table 3.2 were studied to know their inhibitory effect on spore germination of *C. falcatum* by hanging drop method To obtain root

Table 3.2: List of plant species used in root exudate study

Sr. No.	Common name	Botanical name
1.	Chickpea	*Cicer aerintinum* L.
2.	Cabbage	*Brassica oleracea* var. *capitata* L.
3.	Brinjal	*Solenum melongena* L
4.	Coriander	*Coriandrum sativum* L.
5.	Mustard	*Brassica juncia* (L.) Czernj and Cass
6.	Onion	*Allium cepa* L
7.	Sesamum	*Sesamum indicum*
8.	Sorghum	*Sorghum bicolor* (L.) Monch.
9.	Garlic	*Allium sativum* L
10.	Methi (Fenugreek)	*Foeniculum vulgare* L.

exudates, the healthy plant species were brought with their roots, washed thoroughly with tap water and finally with sterile distilled water. They were kept in conical flask (250 ml) containing 100 ml sterile distilled water for 24 hrs. After 24 hrs, the water containing root exudates were filtered through double layered muslin cloth in 250 ml flask. Spore suspension of *C. falcatum* was prepared from 10 days old culture, it's concentration was adjusted to 40 (approximately) conidia per microfield under low power (10 X) of microscope. Then one drop from each root exudates and spore suspension was placed in cavity slide. Two drops of spore suspension prepared in sterile water placed in cavity slide served as control. The observations on spore germination were recorded at an interval of 6 hrs upto 24 hrs. Per cent spore germination was calculated and the data were statistically analysed and presented in Table 4.11.

3.7 Chemical control

3.7.1 Bio-efficacy of various fungicides against *C. falcatum in vitro*

To study the bio-efficacy of different fungicides against *C. falcatum in vitro*, the poisoned food technique (Grover and Moore, 1962) was employed. Each fungicide was tested at three different concentrations as listed in Table 3.3 The fungicides were incorporated in autoclaved and molten PDA in required quantities separately before pouring and shaken well for uniform dispersal of fungicides. The medium was poured in petriplates and on solidification of the medium, the plates were aseptically inoculated by placing 5 mm disc of actively growing 10 days old culture of *C. falcatum*. Each treatment was

Table 3.3: Details of fungicides used *in vitro* against *Colletotrichum falcatum*

Sr. No	Trade name	Technical name	Chemical name	Concentration (ppm)			Source (Manufacturer)
				1st	2nd	3rd	
1.	Cuman-L 27 % W/W	Ziram	Zinc dimethyl dithiocarbamate	1000	1500	2000	Novartis India Ltd., Mumbai
2.	Kavach-75 % W. P.	Chlorothalonil	Tetrachloro isophthalonitrite	1000	1500	2000	Novartis India Ltd., Mumbai
3.	Emisan 6 % W P.	MEMC	Methoxy ethyl mercuric chloride	1000	1500	2000	Excel Industries Ltd., Ruvapuri road, Bhavnagar
4.	Dithane M-45 75 % W P	Mancozeb	Zinc and manganese ethylene bis-dithiocarbamate	1000	1500	2000	Indofil Chemicals Ltd, Belvande House. Dr A B Road, Mumbai
5.	Blitox 50 % W. P.	Copper oxychloride	Basic cupric chloride	1000	1500	2000	Rallis India Ltd . Rallis House 21, D. Sukhadvala marg, Mumbai 1
6.	Topsin-M 70 % W. P.	Thiophanate methyl	1, 2 bis C3-Methoxycarbamyl-2-thiouriedobenzene	500	1000	1500	Motilal Pesticides (India) Ltd . X 305. Manjusa, Nehru Palace. New Delhi-19
7.	Bavistin 50 % W P.	Carbendazim	2 (Methoxy carbomyl)-benzimidazole	500	1000	1500	BASF India Ltd . S. K Ahire Road, Bombay

Table 3 3 contd

Sr No	Trade name	Technical name	Chemical name	Concentration (ppm)			Source (Manufacturer)
				1st	2nd	3rd	
8	San-619 F 50 % W P	Cyperconazole	2-(4-chlorophenyl)-3-Cyclopropyl-1-(1 H-1,2,4-triazole-1-Y 1) butan-2-o	100	250	500	Novartis India Ltd., Mumbai
9.	Tilt-25 % EC	Propiconazole	1-[2-(2, 4-dichlorophenyl -4-propyl-1, 3-dioxalan-2, 1, methyl)] 1, 2, 4-triazole	100	200	500	Novartis India Ltd., Mumbai
10.	Contaf 5 % EC	Hexaconazole	(RS)-2-(2,4-dichlorophenyl)-1-(1 H-1,2,4-trazol-1-Y 1) hexon-2-ol	100	250	500	Rallis India Ltd., Rallis House 21, D, Sukhadvala marg, Mumbai 1
11.	Bayleton 25 % EC	Triademefon	1-(4-chlorophenoxy)-3, 3-dimethyl-1-1 H-(1, 2, 4-triazole-1-Y1)-2-butanone	100	250	500	Bayer India Ltd., BG Agrochem, Saroj Chambers, Nr Dinesh Hall, Ashram Road, Amdavad-380 009
12.	Calaxin 50 % EC	Tridemorph	N-trydecyl-2, 6-dimethyl morpholine	250	500	1000	BASF India Ltd., S K Ahire Road, Mumbai
13.	Benlate 50 % W. P.	Benomyl	Methyl (1, butyl carbamoyl 2 benzimidazole-carbamet	500	1000	1500	Du pont India Ltd
14	Ridomil-MZ 78 % W. P.	Metallaxyl + Mancozeb	N (2,6-Dimethyl phenyl)-N (Methoxy acetyl) ester	500	1000	1500	Novartis India Ltd., Mumbai

repeated five times and plates without fungicides served as control. Then the plates were incubated at room temerature (27 ± 2^{0}C). The observations on colony diameter were recorded and per cent growth inhibition was calculated using formula given by Arora and Dwivedi (1979) as described earlier.

3.7.2 Bio-efficacy of fungicides against sugarcane red rot in pot culture

The fungicides found effective under *in vitro* testing were further tested in pot culture. Nine fungicides as listed in Table 3.4 were selected for this trial. Naturally infected two eye budded setts of highly susceptible variety CoC 671 were treated by dipping the setts in fungicidal solution for 30 minutes. Naturally infected setts and healthy setts without any chemical treatment served as diseased control and healthy control, respectively. Two setts of each treatment were planted in a pot. The whole set of treatment was repeated three times and watered as and when needed. The observations were recorded for germination after 45 days of planting and disease incidence was recorded at regular interval upto 10 months of planting. Then, per cent germination and per cent disease incidence was worked out and data were subjected to statistical analysis.

3.7.3 Efficacy of fungicides with respect to treatment time and length of sett

The most effective fungicides found in pot culture experiment were selected to know the eradicant effect with regards to treatment time and types of setts. The naturally infected one, two and three eye budded setts of highly susceptible variety CoC 671 were

Table 3.4: Fungicides used in pot culture as sett-dip treatment

Sr. No	Treatment	Concentration (on product base)
1.	MEMC (Emisan 6 % WP)	0.2 % (2 g l^{-1})
2.	Carbendazim (Bavistin 50 % WP)	0.1 % (1 g l^{-1})
3.	Copper oxychloride (Blitox 50 % WP)	0.3 % (3 g l^{-1})
4.	Thiophenate methyl (Topsin M- 70 % WP)	0.1 % (1 g l^{-1})
5.	Triadimefon (Bayleton 25 % WP)	0.1 % (1 g l^{-1})
6.	Hexaconazol (Contaf 5 % EC)	0.05 % (0.5 ml l^{-1})
7.	Cyproconazole (San 615 F 50 % SL)	0.05 % (0.5ml l^{-1})
8.	Propiconazole (Tilt 25 % EC)	0.05 % (0.5 ml l^{-1})
9.	Benlate (Benomyl 50 % WP)	0.1 % (1.0 g l^{-1})

dipped in two different fungicides viz., Carbendazim (1 g l^{-1}) and MEMC (2 g l^{-1}) for two different times viz., 10 minutes and 20 minutes and were kept in a humid chamber made by taking plastic tub. The setts were placed and covered with wet muslin cloth and finally bound tightly with polythelene. The respective infected setts without fungicidal treatment served as control. All the treatments were repeated three times. After 24 hrs of incubation, isolation was made from the pith of the middle part of the setts in each case. Treatment details was as under:

Fungicides : (i) Carbendazim (F_1)
(ii) MEMC (F_2)

Time : (i) 10 minutes (T_1)
(ii) 20 minutes (T_2)

Types of setts : (i) one eye budded (L_1)
(ii) two eye budded (L_2)
(iii) three eye budded (L_3)

Treatment combinations:

(i) $T_1 = F_1T_1L_1$
(ii) $T_2 = F_1T_1L_2$
(iii) $T_3 = F_1T_1L_3$
(iv) $T_4 = F_1T_2L_1$
(v) $T_5 = F_1T_2L_2$
(vi) $T_6 = F_1T_2L_3$
(vii) $T_7 = F_2T_1L_1$
(viii) $T_8 = F_2T_1L_2$
(ix) $T_9 = F_2T_1L_3$
(x) $T_{10} = F_2T_2L_1$
(xi) $T_{11} = F_2T_2L_2$
(xii) $T_{12} = F_2T_2L_3$
Control
(xiii) $T_{13} = F_0T_0L_1$
(xiv) $T_{14} = F_0T_0L_2$
(xv) $T_{15} = F_0T_0L_3$

The visual observations were recorded in terms of the presence of fungal growth and the resulted obtained are presented in Table 4.13

3.8 Integrated management of red rot in pot culture

The fungicides, phyto-extracts and bioagents found most effective against the pathogen in earlier experiments were selected for this trial. The healthy two eye budded setts of highly susceptible variety CoC 671 were artificially inoculated by dipping in the spore suspension of *C. falcatum* (10^8 spores/ml) for 30 minutes and then, the setts were treated by dipping in the following material for 30 minutes except dipping in Carbendazim and MEMC for 10 minutes.

T_1 = *Lantana camera* @ 5 % W/V

T_2 = *Datura stramoneum* @ 5 % W/V

T_3 = *Prosopis juliflora* @ 5 % W/V

T_4 = *Trichoderma harzianum* @ 1.3 x 10^8 c.f.u./ml

T_5 = Carbendazim (Bavistin 50 % WP @ 1 g l^{-1})

T_6 = MEMC (Emisan 6 % WP @ 2 g l^{-1})

T_7 = Control inoculated

T_8 = Control healthy

Two eye budded two setts were planted in a pot. All the treatments were replicated four times.

Observations on germination were recorded 45 days after planting and disease incidence was recorded periodically. Finally, per cent germination and per cent disease incidence were calculated, statistically analysed and per cent increase in germination over check (inoculated) and per cent disease control over check (inoculated) were also calculated.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

4.1 Pathological investigations

4.1.1 Symptoms

The following symptoms were observed in the naturally infected sugarcane fields of highly susceptible variety CoC 671.

In South Gujarat red rot prone areas, the disease was observed at all the stages of crop growth but more infection was observed in old age crop as compared to the younger crop. In early stage, sett or settling blight was noticed in coastal area and canal command water logged areas. While in rest of the areas, the disease was recorded in old aged crop, especially after onset of monsoon.

With onset of monsoon, the symptoms of disease observed very conspicuously under field condition when plant growth slowed down and sucrose accumulation started i.e. August and onwards.

The first external symptom of the disease appeared mostly on third and/or forth leaf, showing yellowing, dropping and withering at the tips along the margins. Later on, the infected plants became yellow and dried up. Such dried plants could be identified from a distance (Plate-I).

Leaves showed red elongated lesion on the midrib and reddish patches on the leaf sheath. A number of acervuli were produced in the central region of the lesions. Reddish brown speaks on leaf lamina were also recorded in cultivar CoC 91061 during monsoon (Plate-II A, B).



Plate-I: Symptoms of sugarcane red rot under field condition



A



B

Plate-II A & B: Red rot symptoms on leaves (Cv. CoC 91061)

Symptoms were also observed on stalks. The infected stalks showed dark brownish oily lesions near the ground level with shrunken epidermis that some times split up. The colour of whole cane changed, fungal mycelial growth seen coming out of the root primordia. During the later stage, the cane dried up completely and small pin head sized black visible acervuli produced on the rind (Plate-III).

The typical diagnostic symptoms were observed when the stalk split opened longitudinally. Reddening of internal tissues with diffused/progressive white spots observed which were generally elongated at right angle to the axis of the stalk to give the tissues mottled appearance. Some times whole cane became red and rotted due to infection and also showing profuse fungal growth in the pith near the node (Plate-IV).

4.1.2 Collection of specimen and isolation of pathogen

The sample of infected sugarcane plants of cv. CoC 671 showing red rot symptoms collected from the Regional Sugarcane Research Station, Gujarat Agricultural University, Navsari and surrounding area subjected to tissue isolations, yielded pure culture of *Colletotrichum* sp., which was further purified by single spore isolation technique and maintained on potato dextrose agar (PDA) slants for further investigation.

4.1.3 Pathogenicity test

The pathogenicity test was carried out by five different methods of inoculation viz., soil inoculation, sett inoculation, soil-cum-sett inoculation, cotton swab inoculation and plug method of inoculation in pot.



Plate-III: Small pin head sized black acervuli on rind produced after complete drying of cane



Plate-IV: Splitted stalk of sugarcane showing reddening of internal tissues, white spots and fungal growth in the pith

The results presented in Table 4.1 (Plate-V A, B, C, D) showed that the per cent germination was varied with different methods of inoculation The germination was lowest in soil-cum-sett and cotton swab inoculation (56.25 %) followed by sett inoculation (62.50 %) and soil inoculation (75.00 %) while in plug method and check (uninoculated) where, healthy setts were planted, there was 100 per cent germination. The ungerminated setts from different methods of inoculations were digged out and they were found totally rotted by the red rot infection (Plate-VI).

The settlings were died in some treatment showing the symptoms of drying. This was started right from the germination in different methods of inoculation and final observation on mortality was recorded at 60 days after planting. The settling mortality was maximum in soil-cum-sett inoculation (66.66 %) followed by cotton swab (55.60 %), sett inoculation (50.00 %) and soil inoculation (25.00 %). There was no mortality in the treatments where uninoculated healthy (check) setts were planted.

Red rot incidence was recorded 300 days after planting on cane basis. The red rot incidence was cent per cent in plug method and soil-cum-sett inoculation It was 81.25, 80.00 and 69.44 per cent in cotton swab, sett and soil inoculation, respectively. In the check without inoculation, there was no red rot infection.

During the pathogenicity test, varying degrees of symptoms were observed After germination, pre-emergence sett rot was observed. The setts were totally rotted giving fermented odour. On splitting such setts looked totally reddened After germination of setts, the drying of settlings was observed The setting mortality was observed starting

Table 4.1: Pathogenicity of *Colletotrichum* sp. on sugarcane Cv. CoC 671 in pot culture by different methods

Sr. No.	Method of inoculation	Germination % (45 DAP*)	Settling mortality % (60 DAP*)	Red rot incidence % (300 DAP* on cane basis)
1.	Soil inoculation	75.00	25.00	69.44
2.	Sett inoculation	62.50	50.00	80.00
3.	Soil-cum-sett inoculation	56.25	66.66	100.00
4.	Cotton swab inoculation	56.25	55.60	81.25
5.	Plug inoculation	100.00	00.00	100.00
6.	Control (Without inoculation)	100.00	00.00	-

*DAP = Days after planting



A



B

Plate-V: **Symptoms of sugarcane red rot under different methods of inoculation in the pathogenicity test of *Colletotrichum falcatum***

(A. After 45 days, B. After 300 days)

I1 = Soil inoculation
I2 = Sett inoculation
I3 = Soil-cum-sett inoculation
T4 = Cotton swab inoculation
T5 = Control (without inoculation)



C



D

C: Plug method of inoculation (C = Control, 5 = Inoculated by plug method)
D: Splitted stalk showing red rot symptoms



Plate-VI: Ungerminated sett rotted and reddened due to red rot infection

with the germination and it was found increasing rapidly during winter (January and February). Thereafter, the rate of settling mortality was reduced. During the maximum growth stages (March to May), least red rot infection was recorded. While it was actively noticed soon after onset of monsoon.

The plants initially showed marginal drying and upward rolling of the leaves that finally resulted in drying of whole crown within 2 to 3 weeks. Stem splitting was also observed at later stage. Pin head sized acervuli coming out of the epidermis were visible (Plate-VII). On slitting the infected canes, the characteristic reddening with white spots was observed. Near the node, fungal growth was also noticed. The re-isolation made from different inoculation methods yielded pure culture of *Colletotrichum* sp. thus the pathogenicity test of isolated *Colletotrichum* sp. proved positive in producing red rot disease successfully.

4.1.4 Taxonomy and identification

The isolates of *Colletotrichum* sp. obtained by tissue isolation from the nodal and internodal tissues of infected canes were purified by single spore isolation technique. The morphological and cultural characters of the pure culture grown on PDA was studied for identification and taxonomy.

4.1.4.1 Cultural characters

Colonies grew fairly fast on PDA covering whole petriplate within 9 days at room temperature (27 $\pm$ 2^0C). Initially the fungus produced white cottony mycelium, which turned light grey and finally ashy grey. Acervulus produced 12 days after inoculation (Plate-VIII).



Plate-VII: Pin head size black acervuli coming out of rind, observed after complete drying of stalk (inoculated)



Plate-VIII: Pure culture of *Colletotrichum falcatum* isolated from tissues of sugarcane infected by red rot

4.1.4.2 Morphological characters

In all the cases, mycellium was light grey to ashy grey and cottony. The hyphae were thin, branched, hyaline, septate containing oil droplets. Conidia were hyaline, one celled, sickle or falcate shaped and measured 31.5-40.5 µm x 6.5-9.0 µm in size containing oil droplet in the middle (Plate-IX). The acervuli consisted of a mass of short, closely packed, short conidiophores having conidia and dark brown to almost black setae (Plate-X A, B, C).

Further, pure culture was sent for identification to Indian Type Culture Collection (I. T. C. C.), Division of Mycology and Plant Pathology, I. A. R. I., New Delhi-110 012 and was identified as *Colletotrichum falcatum* Went. (ITCC No. 3923-99). The fungus also produced red rot symptoms under pathologenicity tests. Thus *Colletotrichum* sp. under study was identified and confirmed as *Colletotrichum falcatum* Went.

4.2 Survey for occurrence and spread of red rot in South Gujarat

4.2.1 Area affected by red rot

The survey was carried out during 1999-2000 crop season for occurrence and spread of sugarcane red rot in pre-dominant districts viz., Surat, Navsari and Valsad of South Gujarat (Table 4.2 and Map 1). The data clearly indicated that during the year 1999-2000, out of 66,783 ha area under plant crop, 800 ha area i.e. 1.19 per cent area was affected by red rot. Similarly, in ratoon, out of 39,902 ha area, 871 ha i.e. 2.18 per cent was affected by red rot. Thus, the red rot was recorded more in ratoon crops than the plant in each sugar factory area under

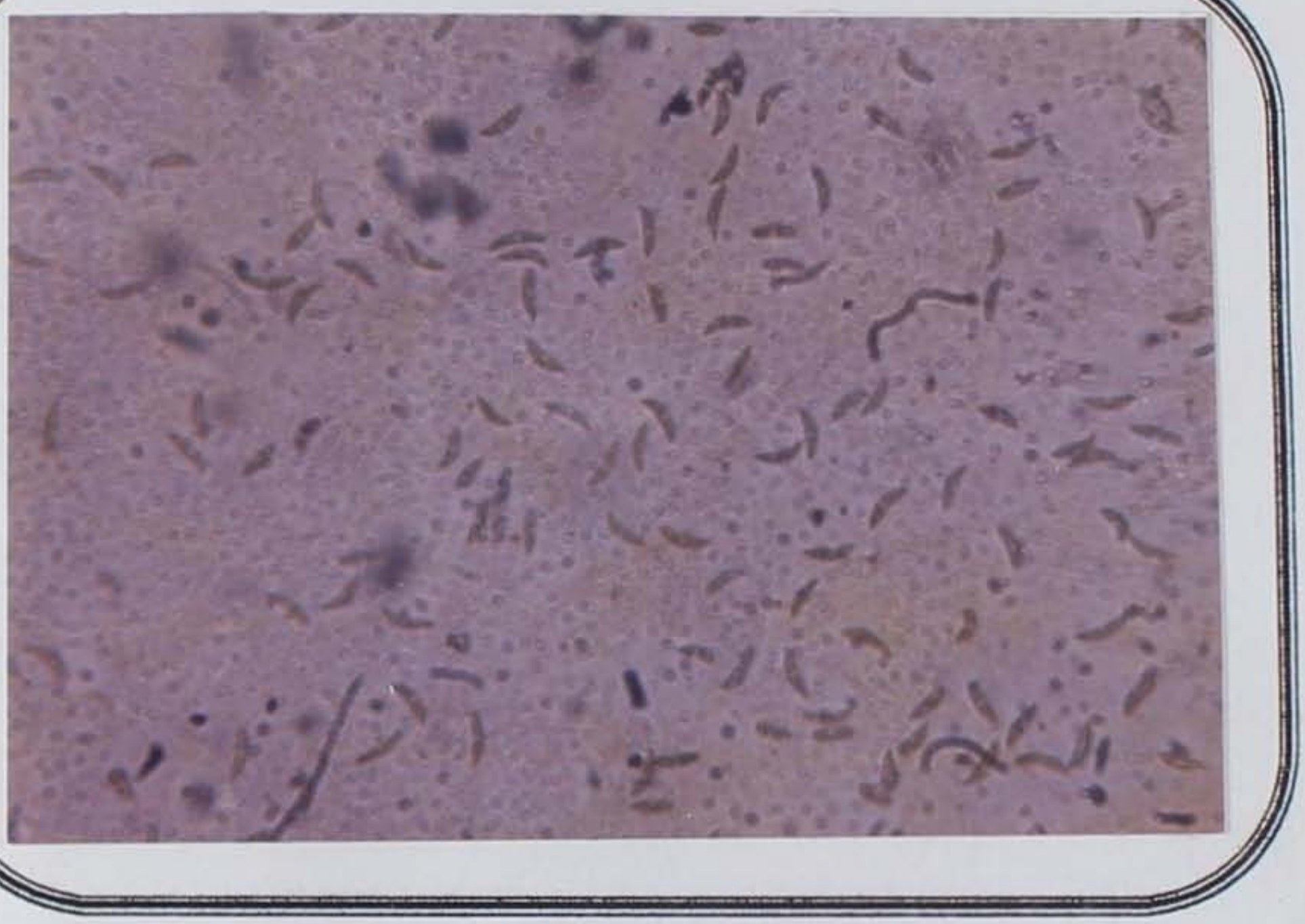
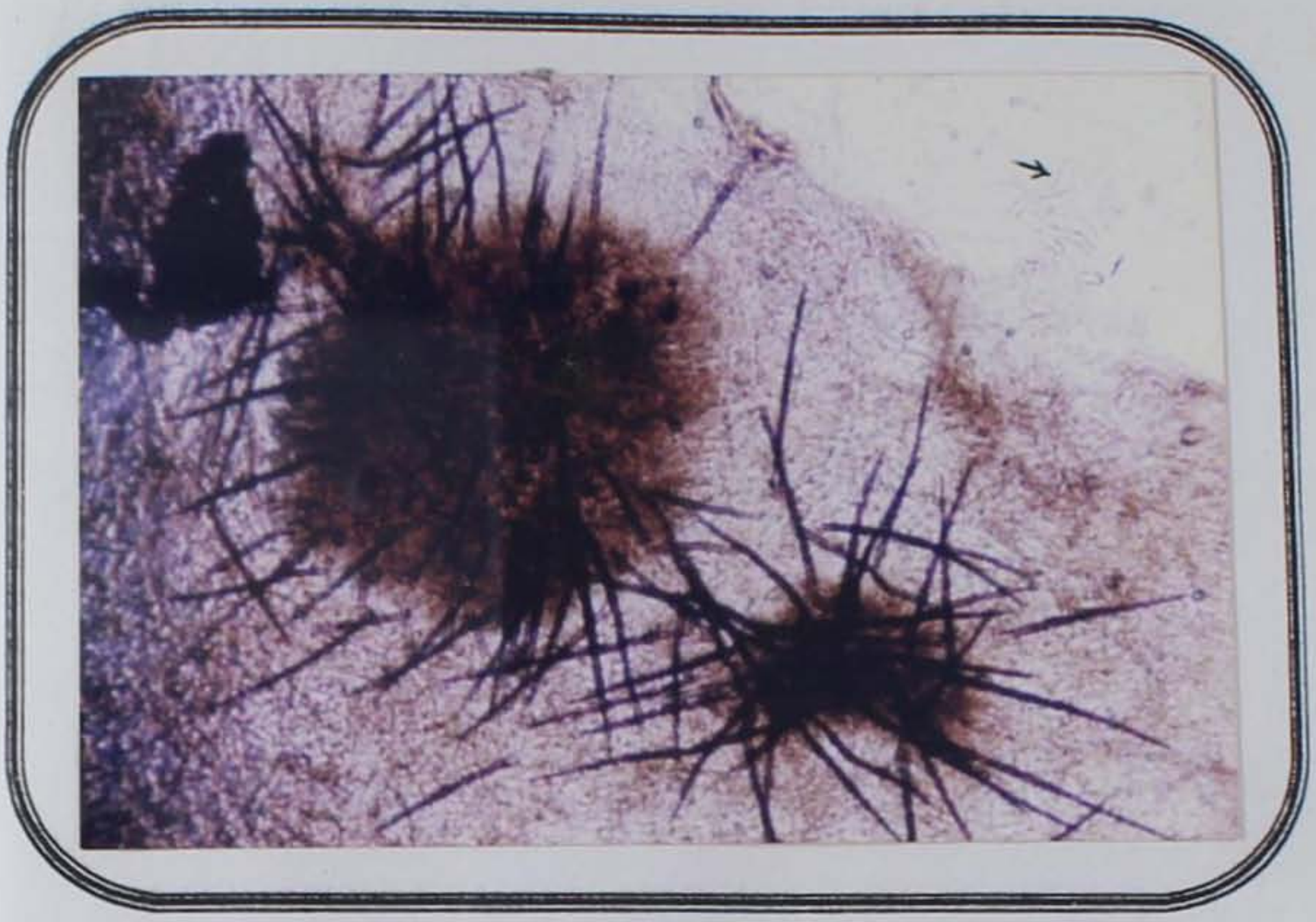
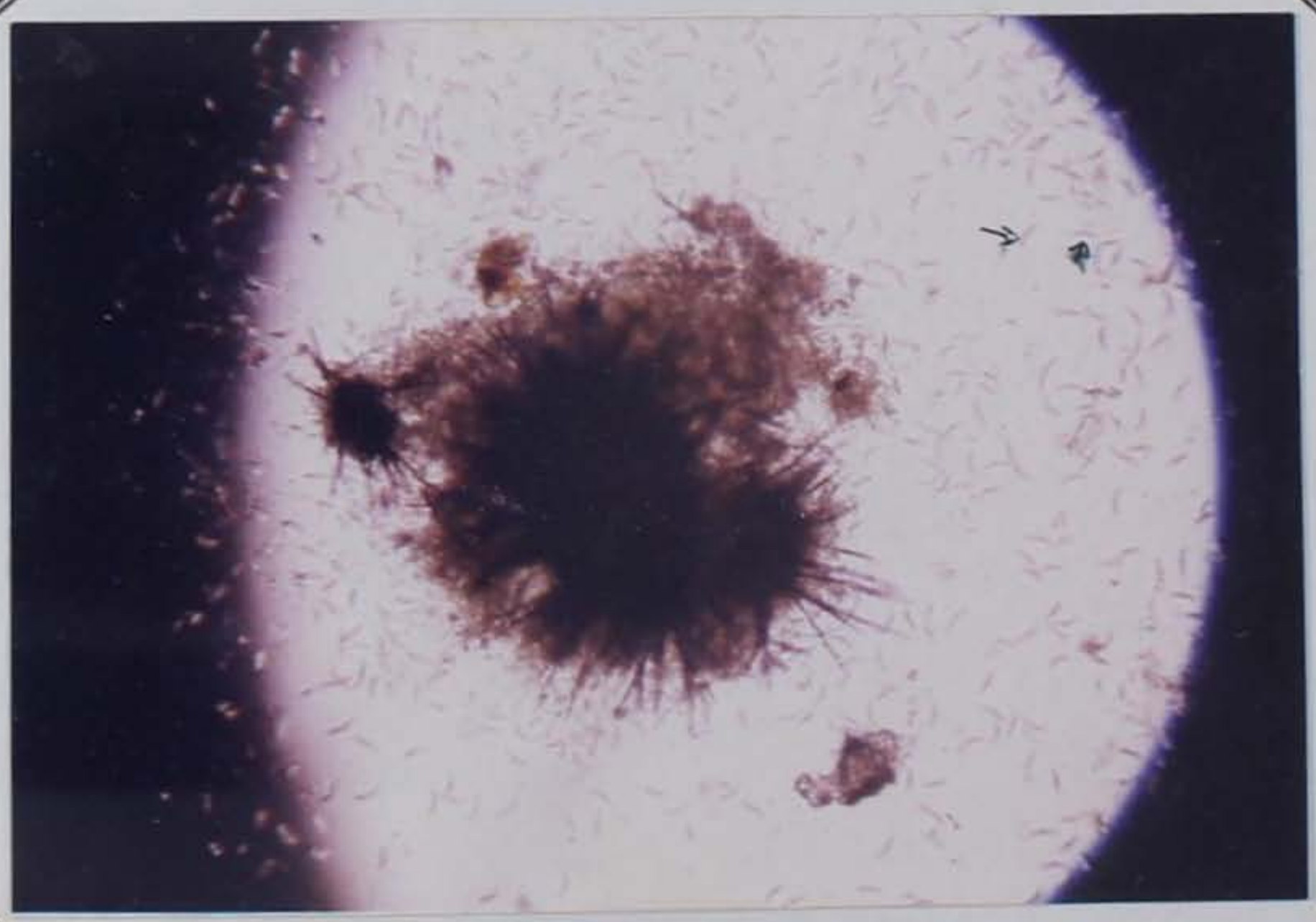


Plate-IX: Conidia of *Colletotrichum falcatum*



A



B

Plate-X: **Acervuli** (Black setae, conidia, conidiophores)

A : From culture medium

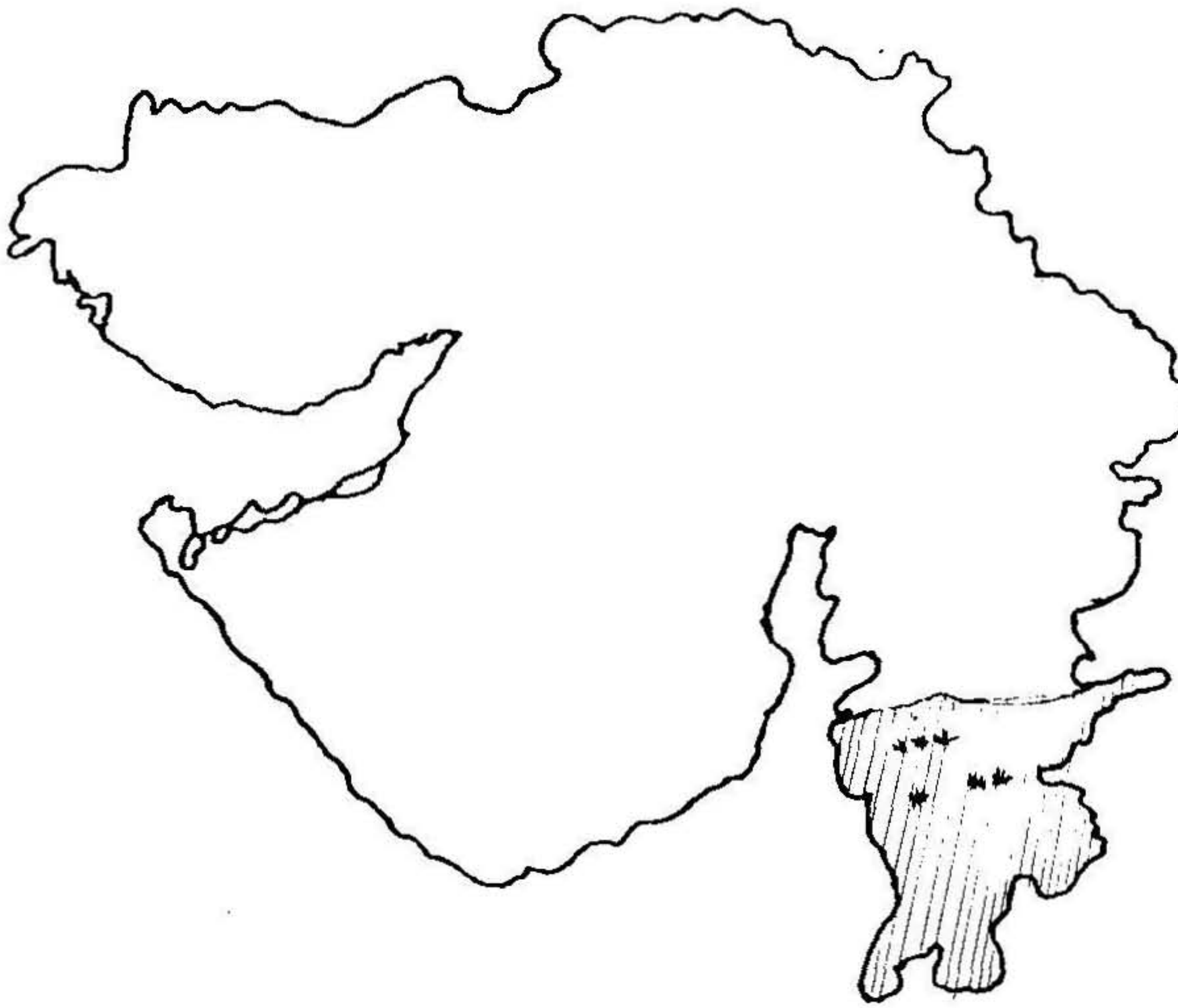
B : From the infected cane rind

arrow showing conidia

Table 4.2: Occurrence and spread of red rot disease in South Gujarat during 1999-2000

Sr. No.	Name of sugar factory	Area under cultivation (ha)			Red rot affected area (ha)			Red rot affected area (%)		
		Plant crop	Ratoon crop	Total	Plant crop	Ratoon crop	Total	Plant crop	Ratoon crop	Total
1.	Madhi	8188	5835	14023	6	13	19	0.07	0.22	0.14
2.	Valsad	8090	3346	11436	3	14	17	0.42	0.42	0.15
3.	Mahuva	7762	3984	11746	554	131	685	7.14	3.29	5.83
4.	Chalthan	9673	5650	15323	43	136	179	0.45	2.41	1.17
5.	Gandevi	9030	4256	13286	76	244	320	0.84	5.73	2.41
6.	Bardoli	15447	7950	23397	0	21	21	0.00	0.26	0.09
7.	Kamrej	4015	3310	7325	75	145	220	2.00	4.00	1.97
8.	Sayan	8578	5571	14149	43	167	213	0.50	2.99	1.48
	Total	66783	39902	106685	800	871	1671	1.19	2.18	1.57

Map 1: Area surveyed for red rot incidence and area covered by susceptible varieties (CoC 671 and Co 86032)



Coloured area surveyed for red rot incidence

* 16.69 per cent area under susceptible varieties (Chalthan)

** 19.20 per cent area under susceptible varieties (Bardoli)

*** 27.85 per cent area under susceptible varieties (Sayan)

survey. Out of total area 1,06,685 ha under plant and ratoon crops. 1671 ha i.e. 1.57 per cent area covered by red rot in different sugar factory areas of South Gujarat surveyed. The maximum red rot area was recorded in Mahuva sugar factory (5.83 per cent) followed by Gandevi, Kamrej, Sayan, Chalthan, Valsad, Madhi and Bardoli sugar factories (0.09 to 2.41 %).

4.2.2 Varieties infected by red rot

The occurrence of red rot disease was also recorded in different varieties grown in three sugar factory areas of South Gujarat during 1999-2000 crop season. The data presented in Table 4.3 revealed that the red rot was observed in plant and ratoon crops of CoC 671 and Co 86032 varieties only in all the three factory areas except in Bardoli where it was not noticed in plant crop of these two varieties. The remaining varieties viz., Co 86002, Co 8208, MC 707, CoSi 95071, CoC 91061, Co 8338, CoN 91132, Co 86010 and other miscellaneous varieties fond free from red rot in all three sugar factory areas surveyed.

The per cent area covered by these two susceptible varieties was 27.85, 19.20 and 16.69 per cent in Sayan, Bardoli and Chalthan sugar factory, respectively which accounted to 20.78 per cent of total area under three factory zones (Table 4.3.1 and Map 1).

Thus, due to replacement of other tolerant varieties in more than 80 per cent area, the severity of disease has slowed down. Otherwise few years before, CoC 671 and Co 86032 were dominant (grown approximately in 70-80 % area) in the area with more disease incidence. This suggests to discourage the growing of the susceptible

Table 4.3 : Area of different cultivars grown under three sugar factories of South Gujarat and infection of red rot (1999-2000)

Sr. No.	Cultivars	Foctorywise sugarcane cultivated area (ha)												Total area (ha) of three factories		
		Sayan sugar				Bardoli sugar				Chalthan sugar						
		Plant	Ratoon	Total	Red rot noticed Yes/No	Plant	Ratoon	Total	Red rot noticed Yes/No	Plant	Ratoon	Total	Red rot noticed Yes/No	Plant	Ratoon	Total
1	CoC 671	75	63	138	Yes	349	**199**	548	Yes	118	58	176	Yes	542	320	862
2	Co 86032	2598	1205	3803	Yes	2473	**1471**	3944	Yes	1584	792	2375	Yes	6655	3468	10123
3	Co 86002	352	60	412	No	3934	1205	5138	No	2841	768	3609	No	7127	2033	9160
4	Co 8208	2569	596	3165	No	381	161	542	No	-	-	-	-	2950	757	3707
5	Mc 707	169	12	181	No	120	3	123	No	1163	126	1290	No	1452	141	1593
6	CoSi 95071	182	15	197	No	1372	95	1461	No	996	108	1104	No	2550	218	2769
7	CoC 91061	683	566	1249	No	-	-	-	-	-	-	-	-	683	566	1279
8	Co 8338	72	121	193	No	422	360	782	No	109	69	178	No	603	550	1153
9.	CoN 91132	883	190	1073	No	1999	221	2220	No	-	1141	1141	No	2882	1591	4433
10.	Co 86010	-	-	-	No	104	41	145	No	-	-	-	-	104	41	145
11.	Others	1017	2743	3738	No	4293	4194	8447	No	2862	2576	5432	No	8170	9507	17677
	Total	8578	5571	14149	-	15447	7950	23397	-	9673	5650	15323	-	33698	19171	52869

Bold numbers indicate absence of red rot from that area

Table 4.3.1: Area covered by susceptible varieties viz., CoC 671 and Co 86032

Sugar factory	Area (ha)	Per cent area
Sayan	3941	27.85
Bardoli	4492	19 20
Chalthan	2551	16.69
Total	10984	-
Average	-	20.78

varieties viz., CoC 671 and Co 86032 and also suggests for avoiding ratooning for the management of red rot in the area.

4.3 Loss assessment

To know the effect of red rot, quantitatively (growth parameters and yield) and qualitatively (brix, pol, purity, extraction and C. C. S.), five healthy and diseased canes from fifteen different varieties viz., C0 6806, Co 86249, Co 91121, Co 92020, 86 A 146, Co 87263, CoN 91132, Co 86002, Co 7805, CoN 97134, CoN 95132, Co 85019, Co 87022, CoC 671 and Co 86032 were selected at harvest and cane length, cane girth, number of internodes, cane weight (Table 4.4 a, b, c, d), brix, pol, purity, extraction and C. C. S. (Table 4.4 a, b, c, d, e) were recorded and presented.

4.3.1 Quantitative loss

The results indicated that there was marked reduction in all the growth parameters due to red rot infection. Reduction in cane length, cane girth, number of internodes and cane weight ranged from 2.15 to 15.31, 1.36 to 16.91, 2.40 to 19.04 and 5.00 to 80.60 per cent, respectively in different varieties tested. Maximum reduction in cane length was observed in CoN 95132 followed by CoC 671, Co 85019, Co 86032, CoN 97134, Co 7805, Co 86002, Co 91121, Co 87022, CoC 92020, Co 91121, CoN 91132, Co 87263, 86 A 146, Co 6806 and Co 86249, while reduction in cane girth was maximum in Co 86032 followed by Co 85019, CoC 671, CoN 95132, Co 86002, CoN 97134, Co 7805, Co 91121, Co 87022, CoN 91132, Co 87263, CoC 92020, Co 86249, Co 6806 and 86 A 146. The number of internode reduced maximum in CoC 671 followed by Co 85019, Co 91121, CoN 97134,

Table 4.4: Effect of red rot on the growth parameters in sugarcane varieties belonging to different categories of resistance (plant crop)

Table 4.4 (a)

Sr No.	Variety	Category of resistance	Cane length (mts)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	2.23	2.18	2.15
2.	Co 6806	R	2.90	2.80	3.48
3.	86 A 146	MR	2.73	2.64	3.50
4.	Co 87263	MR	2.47	3.32	6.15
5.	CoN 91132	MR	3.05	2.84	7.15
6.	CoC 92020	MR	2.43	2.24	7.80
7.	Co 7805	MS	1.88	1.69	9.90
8.	Co 86002	MS	2.99	2.71	9.38
9.	Co 87022	MS	1.81	1.66	8.28
10.	Co 85019	S	2.08	1.80	14.00
11.	CoN 95132	S	2.48	2.10	15.31
12.	CoN 97134	S	2.59	2.33	10.03
13.	Co 91121	HS	2.82	2.58	8.50
14.	Co 86032	HS	2.76	2.17	11.36
15.	CoC 671	HS	2.80	2.40	14.28

R = Resistant
MR = Moderately Resistant
HS = Highly susceptible
MS = Moderately Susceptible
S = Susceptible

Table 4.4 (b)

Sr. No.	Variety	Category of resistance	Cane girth (cm)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	8.36	8.07	3.55
2.	Co 6806	R	3.10	3.01	2.82
3.	86 A 146	MR	9.54	9.41	1.36
4.	Co 87263	MR	4.40	4.15	5.60
5.	CoN 91132	MR	3.43	3.23	5.83
6.	CoC 92020	MR	7.43	7.04	5.20
7.	Co 7805	MS	5.78	5.20	10.03
8.	Co 86002	MS	8.95	7.89	11.88
9.	Co 87022	MS	5.12	4.74	7.53
10.	Co 85019	S	3.72	3.12	16.12
11.	CoN 95132	S	7.80	6.62	15.12
12.	CoN 97134	S	9.20	8.14	11.52
13.	Co 91121	HS	7.16	6.52	8.90
14.	Co 86032	HS	8.75	7.27	16.91
15.	CoC 671	HS	8.73	7.34	16.01

R = Resistant
MR = Moderately Resistant
HS = Highly Susceptible
S = Susceptible
MS = Moderately susceptible

Table 4.4 (c)

Sr. No.	Variety	Category of resistance	Number of internodes		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	25.00	24.40	2.40
2.	Co 6806	R	27.00	26.15	3.15
3.	86 A 146	MR	26.00	25.40	5.30
4.	Co 87263	MR	20.00	18.80	6.00
5.	CoN 91132	MR	27.00	25.50	5.55
6.	CoC 92020	MR	19.60	18.60	5.10
7.	Co 7805	MS	13.00	12.00	7.69
8.	Co 86002	MS	28.00	26.10	6.79
9.	Co 87022	MS	16.00	15.00	5.25
10.	Co 85019	S	15.00	12.30	18.00
11.	CoN 95132	S	21.00	18.00	14.28
12.	CoN 97134	S	25.00	21.00	16.00
13.	Co 91121	HS	21.20	17.50	17.45
14.	Co 86032	HS	17.00	15.00	11.76
15.	CoC 671	HS	21.80	17.65	19.04

R = Resistant
MR = Moderately Resistant
MS = Moderately Susceptible
S = Susceptible
HS = Highly susceptible

Table 4.4 (d)

Sr. No.	Variety	Category of resistance	Cane weight(kg)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	8.00	7.60	5.00
2.	Co 6806	R	1.60	1.46	8.75
3.	86 A 146	MR	11.00	10.03	11.80
4.	Co 87263	MR	5.90	5.20	11.86
5.	CoN 91132	MR	1.60	1.40	12.50
6.	CoC 92020	MR	7.50	6.70	10.60
7.	Co 7805	MS	3.20	2.60	18 75
8.	Co 86002	MS	10.05	8.30	20.95
9.	Co 87022	MS	4.00	3.33	16.65
10.	Co 85019	S	5.70	2.07	63.70
11.	CoN 95132	S	6.40	3.00	53.13
12.	CoN 97134	S	11.60	6.00	40.52
13.	Co 91121	HS	7.50	4.00	46.67
14.	Co 86032	HS	5.20	1.20	76.92
15.	CoC 671	HS	6.70	1.30	80.60

R= Resistant
MR= Moderately Resistant
MS = Moderately susceptible
S = Susceptible
HS = Highly susceptible

Table 4.5: Effect of red rot on juice quality parameters in sugarcane varieties belonging to different categories of resistance (plant crop)

Table 4.5 (a)

Sr. No.	Variety	Category of resistance	Corrected Brix		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	16.32	15.22	6.80
2.	Co 6806	R	15.27	14.23	6.78
3.	86 A 146	MR	18.11	16.49	8.94
4.	Co 87263	MR	18.91	17.03	9.19
5.	CoN 91132	MR	17.89	16.00	10.56
6.	CoC 92020	MR	18.24	16.45	9.81
7.	Co 7805	MS	19.08	16.42	13.95
8.	Co 86002	MS	18.69	16.02	14.27
9.	Co 87022	MS	17.14	14.23	17.00
10.	Co 85019	S	18.40	14.88	19.13
11.	CoN 95132	S	18.88	15.13	19.86
12.	CoN 97134	S	17.43	13.71	21.34
13.	Co 91121	HS	16.60	11.20	32.53
14.	Co 86032	HS	19.26	11.98	37.83
15.	CoC 671	HS	17.75	10.63	40.10

R = Resistant
MR = Moderately Resistant
MS = Moderately susceptible
S = Susceptible
HS = Higly susceptible

Table 4.5 (b)

Sr. No.	Variety	Category of resistance	Pol (%)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	13.42	12.32	8.27
2.	Co 6806	R	13.28	12.25	7.80
3.	86 A 146	MR	15.01	13.32	11.24
4.	Co 87263	MR	15.68	13.74	12.37
5.	CoN 91132	MR	14.86	12.97	12.70
6.	CoC 92020	MR	15.70	13.74	12.48
7.	Co 7805	MS	16.60	13.28	20.00
8.	Co 86002	MS	16.11	12.81	20.47
9.	Co 87022	MS	11.52	8.87	23.00
10.	Co 85019	S	15.66	11.58	26.16
11.	CoN 95132	S	16.52	12.03	27.17
12.	CoN 97134	S	15.30	10.80	29.41
13.	Co 91121	HS	12.50	6.50	48.00
14.	Co 86032	HS	17.10	8.36	51.52
15.	CoC 671	HS	15.59	6.63	51.47

R: Resistant
MR: Moderately Resistant
MS: Moderately susceptible
S: Susceptible
HS: Highly susceptible

Table 4.5 (c)

Sr No	Variety	Category of resistance	Purity (%)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	82.25	80.95	1.58
2.	Co 6806	R	86.95	86.08	1.13
3.	86 A 146	MR	82.88	80.29	2.53
4.	Co 87263	MR	82.88	80.69	2.65
5.	CoN 91132	MR	83.06	81.04	2.43
6.	CoC 92020	MR	86.07	83.60	2.98
7.	Co 7805	MS	87.00	80.86	7.06
8.	Co 86002	MS	86.20	79.96	7.23
9.	Co 87022	MS	67.20	62.29	7.45
10.	Co 85019	S	85.11	77.67	8.75
11.	CoN 95132	S	87.50	79.54	9.10
12.	CoN 97134	S	87.77	75.13	10.25
13.	Co 91121	HS	75.29	58.00	22.96
14.	Co 86032	HS	88.74	69.78	21.30
15.	CoC 671	HS	87.85	62.37	29.00

R = Resistant
MR = Moderately Resistant
MS = Moderately susceptible
S = Susceptible
HS = Highly susceptible

Table 4.5 (d)

Sr. No.	Variety	Category of resistance	Extraction (%)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	69.00	65.20	5.50
2.	Co 6806	R	71.00	67.36	5.10
3.	86 A 146	MR	73.00	67.30	7.81
4.	Co 87263	MR	71.00	65.25	8.10
5.	CoN 91132	MR	63.70	57.60	8.00
6.	CoC 92020	MR	68.00	62.00	8.82
7.	Co 7805	MS	71.00	57.80	18.59
8	Co 86002	MS	69.00	54.80	20.50
9.	Co 87022	MS	62.70	49.20	21.53
10.	Co 85019	S	72.50	51.40	29.10
11.	CoN 95132	S	70.00	48.60	33.42
12.	CoN 97134	S	65.40	42.40	35.17
13.	Co 91121	HS	70.00	37.20	46.85
14.	Co 86032	HS	72.00	28.60	60.29
15.	CoC 671	HS	75.50	26.10	64.17

R = Resistant
MR = Moderately Resistant
MS = Moderately susceptible
S = Susceptible
HS = Highly susceptible

Table 4.5 (e)

Sr. No.	Variety	Category of resistance	C. C. S.* (%)		
			Healthy	Diseased	Per cent reduction
1.	Co 86249	R	9 03	8 15	9.75
2.	Co 6806	R	9.21	8.34	9.45
3.	86 A 146	MR	10.17	8.90	12.48
4.	Co 87263	MR	10.60	9.21	13.11
5.	CoN 91132	MR	10.00	8.72	12.80
6.	CoC 92020	MR	11.39	9.34	17.99
7.	Co 7805	MS	11.53	8.59	22.89
8.	Co 86002	MS	11.17	8.55	23.46
9.	Co 87022	MS	7.20	5.00	30.55
10.	Co 85019	S	10.55	7.17	26.35
11.	CoN 95132	S	11.50	8.00	30.43
12.	CoN 97134	S	10.60	5.25	31.60
13.	Co 91121	HS	8.20	3.44	58.05
14	Co 86032	HS	12.02	5.14	57.23
15.	CoC 671	HS	11.00	3.75	65.90

* C.C.S. – Commercial cane sugar.(%)

R = Resistant
MR = Moderately Resistant
MS: Moderately susceptible
S = Susceptible
HS = Highly susceptible

CoN 95132, Co 86032, Co 7805, Co 86002, Co 87022, Co 87263, CoN 91132, 86 A 146, CoC 92020, Co 6806 and Co 86249. The cane weight reduced drastically in CoC 671 (80.60 %) followed by Co 86032 (76.92 %), Co 85019 (63.70 %), CoN 95132 (53.13 %), Co 91121 (46.67 %), CoN 97134 (40.52 %), Co 86002 (20.95 %), Co 7805 (18.75 %), Co 87022 (16.65 %), CoN 91132 (12.50 %), Co 87263 (11.86 %), 86 A 146 (11.80 %), CoC 92020 (10.60 %), Co 6806 (8.75 %) and Co 86249 (5.00 %).

The maximum losses of cane weight were recorded in susceptible varieties. This was found responsible due to drastic reduction in cane length, girth and number of internodes.

The losses in cane weight due to red rot in different varieties depend upon the susceptibility of the variety.

4.3.2 Qualitative losses

The results revealed that the reduction in brix, pol, purity, extraction and C. C. S. ranged from 6.78 to 40.10, 7.80 to 51.47, 1.13 to 29.00, 6.10 to 64.17 and 9.45 to 65.90 per cent in different sugarcane varieties tested. As shown in Table 4.4, the reduction in all the qualitative parameters were drastic in susceptible and highly susceptible varieties viz., CoC 671, Co 86032, Co 91121, CoN 97134, CoN 95132 and Co 85019, whereas the reduction was lower in resistant and moderately resistant varieties viz., Co 86249, Co 6806, 86 A 146, Co 87263, CoN 91132 and Co 92020.

The maximum reduction in brix was recorded in CoC 671 followed by Co 86032, Co 91121, CoN 97134, CoN 95132, Co 85019, Co 87022, Co 86002, Co 7805, CoN 91132, CoC 92020, Co 87263,

86 A 146, Co 86249 and Co 6806 while maximum reduction in pol per cent was recorded in CoC 671 followed by Co 86032, Co 91121, CoN 97134, CoN 95132, Co 85019, Co 87022, Co 86002, Co 7805, CoN 91132, CoC 92020, Co 87263, 86 A 146, Co 86249 and Co 6806.

Maximum purity was reduced in CoC 671 followed by Co 91121, Co 86032, CoN 97134, CoN 95132, Co 85019, Co 87022, Co 86002, Co 7805, CoC 92020, Co 87263, 86 A 146, CoN 91132, Co 86249 and Co 6806 while, the reduction in extraction was maximum recorded in CoC 671 folloed by Co 86032, Co 91121, CoN 97134, CoN 95132, Co 85019, Co 87022, Co 86002, Co 7805, CoC 92020, Co 87263, CoN 91132, 86 A 146, Co 86249 and Co 6806. The maximum reduction in C. C. S. was recorded in CoC 671 (65.90 %) followed by Co 91121 (58.05 %), Co 86032 (51.23 %), CoN 97134 (31.60 %), Co 87022 (30.55 %), CoN 95132 (30.43 %), Co 85019 (26.35 %), Co 86002 (23.46 %), Co 7805 (22.89 %), CoC 92020 (17.99), Co 87263 (13.11 %), CoN 91132 (12.86 %), 86 A 146 (12.48 %), Co 86249 (9.75 %) and Co 6806 (9.45 %).

Thus the degree of qualitative losses depends upon the susceptibility of the variety.

4.4 Screening of sugarcane varieties against red rot *in vivo*

Twenty five sugarcane varieties were screened against red rot by International Standard plug method. This includes CoC 671 as susceptible and Co 6806 as resistant checks. After 60 days of inoculation, the average score was worked out on the basis of condition of top, lesion width, white spot and nodal transgression and presented in Table 4.6

Table 4.6: Reaction of different varieties of sugarcane against red rot pathogen (plug method)

Sr. No.	Variety	Condition of top G=0 Y or D=1	Lesion width (1,2,3)	White spot 1 or 2	Nodal transgression 1,2,3	Total score	Reaction to red rot
1	CoN 95132	1.0	3.0	2.0	3.0	9.0	HS
2	Co 86032	1.0	3.0	2.0	3.0	9.0	HS
3	Co 87263	0.4	1.6	0.6	0.6	3.2	MR
4	Co 8338	0.4	2.0	1.0	2.0	5.4	MS
5	Co 85019	0.0	2.2	1.4	3.0	6.6	S
6	CoC 671	1.0	3.0	2.0	3.0	9.0	HS
7	CoLK 8001	0.0	1.4	1.0	1.6	4.0	MR
8	86 A 146	0.0	0.8	0.8	1.4	3.0	MR
9	Co 87002	0.0	1.8	1.6	3.0	6.4	S
10	Co 7318	1.0	3.0	2.0	3.0	9.0	HS
11	Co 7805	0.0	1.2	0.8	2.2	4.2	MS
12	Co 85001	0.0	1.2	0.8	2.4	4.4	MS
13	CoSi 98061	0.6	2.0	0.8	2.4	5.8	MS
14	CoC 92020	1.6	0.0	1.0	0.0	4.0	MR
15	Co 86249	0.0	0.8	0.0	0.8	1.6	R
16	Co 86002	0.0	1.4	0.8	2.4	4.6	MS
17	Co 6415	0.4	2.2	0.0	2.0	4.6	MS
18	CoN 85134	0.0	1.0	1.0	2.0	4.0	MR
19	CoSi 98071	0.0	1.0	0.0	1.0	2.0	R
20	CoN 97134	1.0	2.5	2.0	2.6	8.6	HS
21	CoN 97132	1.0	2.8	1.0	2.6	7.4	S
22	Co 91014	0.0	2.2	0.0	2.4	4.6	MS
23	Co 91121	1.0	2.4	2.0	3.0	8.4	Hs
24	CoN 91132	0.0	1.8	0.6	1.6	4.0	MR
25	Co 6806	0.0	1.0	0.4	0.0	1.4	R

Out of twenty five varieties screened, three varieties viz., Co 6806, Co 86249 and CoSi 98071 were resistant, six varieties viz., 86 A 146, Co 87263, CoC 92020, CoN 91132, CoLk 8001 and CoN 85134 were moderately resistant, seven varieties viz., Co 7805, Co 85001, Co 86002, Co 6415, Co 91014, Co 8338 and CoSi 98061 found moderately susceptible, three varieties viz., Co 87002, Co 85019 and CoN 97132 were susceptible and six varieties viz., Co 86032, CoC 671, CoN 95132, Co 7318, CoN 97134 and Co 91121 showed highly susceptible reaction against the red rot.

4.5 Biological control

4.5.1 Testing of cultural filtrates of different antagonists against *C. falcatum in vitro*

4.5.1.1 Fungal antagonists

To test the effect of antibiotic products on *C. falcatum*, seven fungal antagonists with three different concentrations were taken and they were tested by poisoned food technique. The results are presented in Table 4.7 (Fig. 1, Plate-XI).

Significantly lower radial growth of pathogen was recorded in all the cultural filtrates of the different antagonists tested as compared to control. Among these, the filtrate of *Aspergillus flavus* @ 25 % V/V proved significantly superior over the rests. The next best cultural filtrate in order of merit was of *A. niger* @ 25 % V/V followed by *A. niger* @ 15 % V/V, *G. virens* @ 25 % and 15 % V/V, *T. harzianum* @ 25 % V/V, *C. globosum* @ 25 % and 15 % V/V, *A. flavus* @ 15 % and 5 % V/V, *C. globosum* @ 5 % V/V, *G. virens* @ 5 % V/V, *T. viride* @ 25 % V/V, *A. niger* @ 5 % V/V, *T. harzianum* @

Table: 4.7: Bio-efficacy of cultural filtrates of fungal antagonists against *Colletotrichum falcatum in vitro*

Sr. No.	Treatment	Concentration of cultural filtrate (%)	Average of radial growth (mm)	Per cent inhibition over control	Sporulation
1	TV	5	31.00	29.14	+
2	TV	15	28.00	36.00	+
3	TV	25	25.00	42.85	+
4	TH	5	28.00	36.00	+
5	TH	15	27.00	38.29	+
6	TH	25	22.00	49.71	+
7	TL	5	36.00	17.71	++
8	TL	15	32.00	26.86	+
9	TL	25	30.00	31.43	+
10	CG	5	24.00	45.14	+
11	CG	15	23.00	47.43	+
12	CG	25	23.00	47.43	+
13	GV	5	24.00	45.14	+
14	GV	15	22.00	49.71	+
15	GV	25	22.00	49.71	+
16	AF	5	23.00	47.43	+
17	AF	15	23.00	47.43	+
18	AF	25	13.00	70.29	–
19	AN	5	27.00	38.29	+
20	AN	15	21.00	52.00	+
21	AN	25	17.00	61.14	–
22	Control	-	43.75	00.00	+++
	S. Em +		0.67		
	C. D. at 5 %		1.91		
	C. V. %		5.28		

TV = *Trichoderma viride*
TH = *T. harzianum*
TL = *T. longibrachyatum*
CG = *Chaetomium globosum*
GV = *Gliocladium virens*
AF = *Aspergillus niger*
AN = *A. flavus*

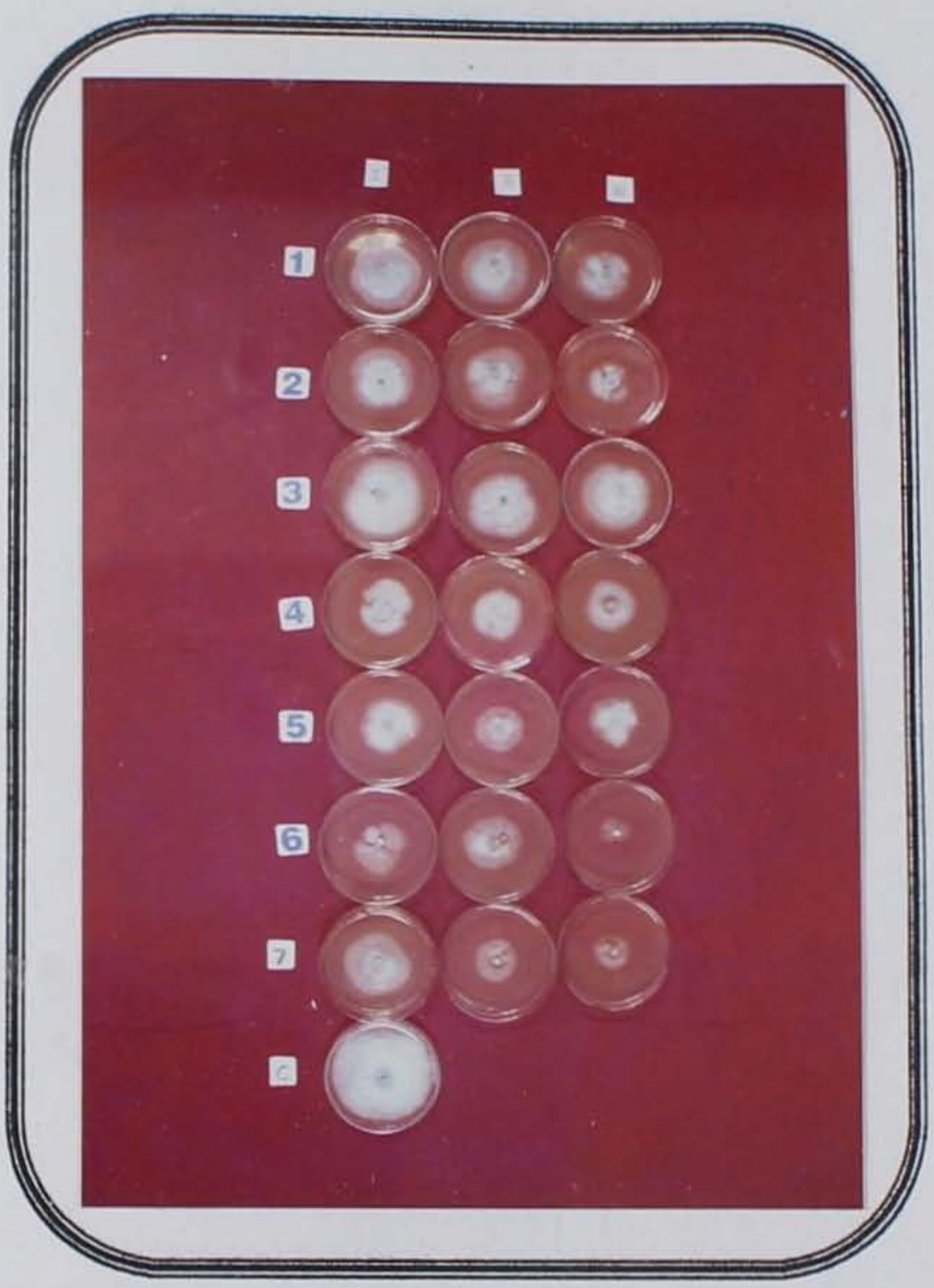
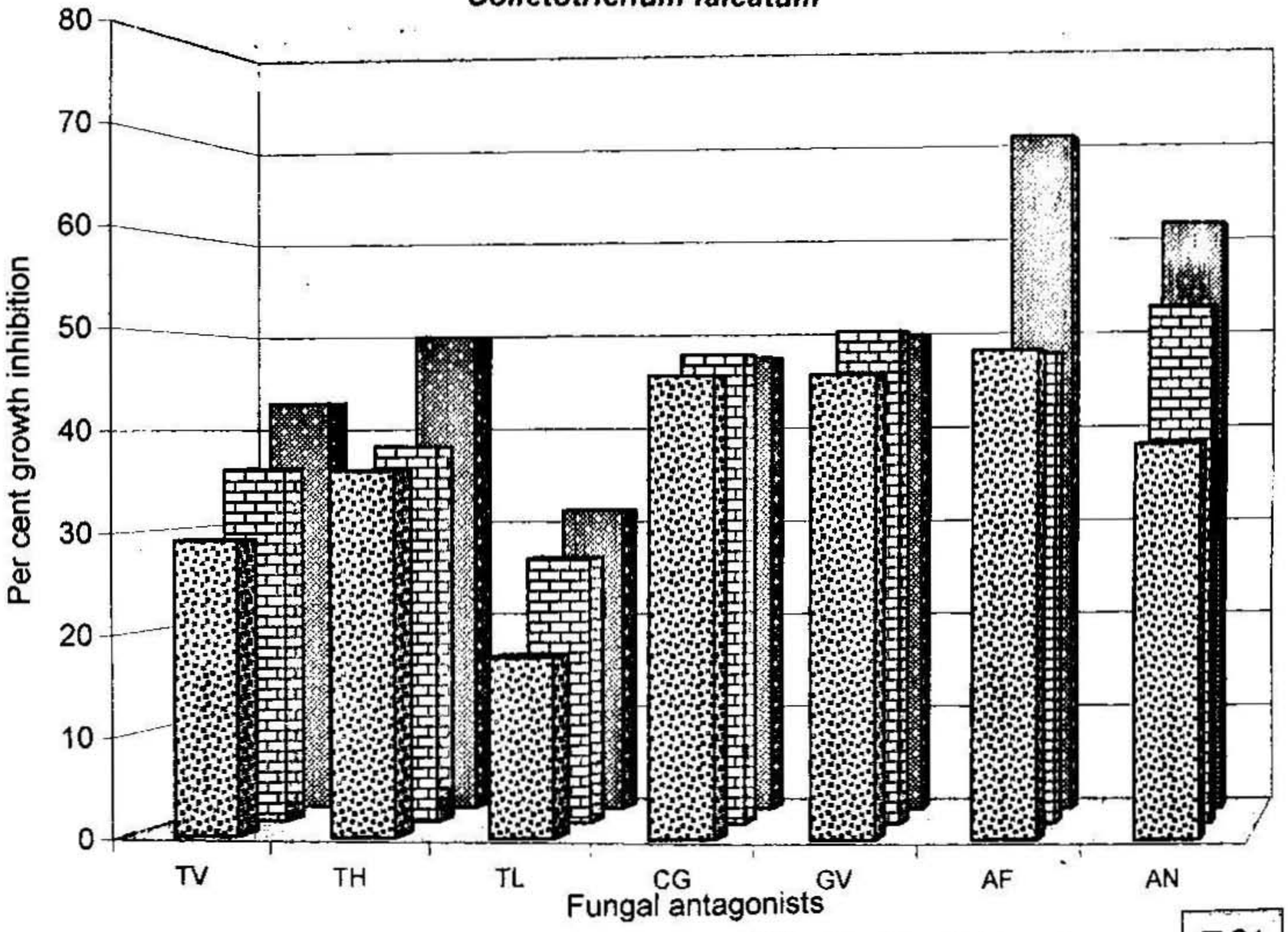


Plate-XI: Effect of various fungal cultural filtrates on *C. falcatum* *in vitro*

1	=	*Trichoderma viride*	I	=	5 % concentration
2	=	*T. harzianum*	II	=	15 % concentration
3	=	*T. longibrachyatum*	III	=	25 % concentration
4	=	*Chaetomium globosum*			
5	=	*Gliocladium virens*			
6	=	*Aspergillus flavus*			
7	=	*A. niger*			
C	=	Control			

Fig. 1 : Effect of cultural filtrates of different fungal antagonists on the growth of *Colletotrichum falcatum*



TV = *Trichoderma viride*
TH = *T. harzianum*
TL = *T. longibrachyatum*
CG = *Chaetomium globusum*
GV = *Gliocladium virens*
AF = *Aspergillus flavus*
AN = *A. niger*

5 % V/V, *T. viride* @ 15 % V/V, *T. harzianum* @ 5 % V/V, *T. longibrachyatum* @ 25 % V/V, *T. viride* @ 5 % V/V, *T. longibrachyatum* @ 15 % V/V and *T. longibrachyatum* @ 5 % V/V.

The per cent inhibition of *C. falcatum* over control was maximum in the filtrate of *A. flavus* @ 25 % V/V (70.29 %) followed by *A. niger* @ 25 % V/V (61.14 %) and *A. niger* @ 15 % V/V (52.0 %). In the rest of the antagonists tested, the per cent inhibition of *C. falcatum* was recorded below 50 per cent as compared to the control.

The sporulation of *C. falcatum* was lower in all the treatments as compared to control. There was no sporulation in the filtrates of *A. flavus* @ 25 % V/V and *A. niger* @ 25 % V/V.

4.5.1.2 Bacterial antagonists

The cultural filtrates of bacterial antagonists were also evaluated for their effect on *C. falcatum*.

The results presented in Table 4.8 (Fig. 2, Plate-XII) revealed that a significant lower radial growth of *C. falcatum* was observed in both the bacterial antagonists cultured on two different media as compared to the control. Among these, the cultural filtrate of *P. fluorescens* cultured in King's B medium proved significantly superior over the rest. The next best filtrate in order of merit was of *B. subtilis* cultured in nutrient broth medium, *P. fluorescens* cultured in nutrient broth and *B. subtilis* cultured in King's B medium.

The maximum per cent growth inhibition of *C. falcatum* was recorded in the cultural filtrate of *P. fluorescens* cultured in King's B medium (57.87 %) followed by *B. subtilis* cultured on nutrient broth

Table 4.8: Bio-efficacy of cultural filtrates of bacterial antagonists against *Colletotrichum falcatum*

Sr. No.	Treatment	Averag colony radial growth (mm)	Per cent inhibition over control	Sporulation
1.	BSKB	32.00	25.93	+
2.	BSNB	24.00	44.44	+
3.	PFKB	18.20	57.87	–
4.	PFNB	24.60	43.06	+
5.	Control	43.20	-	++
	S. Em ±	0.52		
	C.D. at 5 %	1.55		
	C. V. %	4.11		

BSKB = *Bacillus subtilis* cultured on King's B medium

BSNB = *B. subtilis* cultured on nutrient broth medium

PFKB = *Pseudomonas fluorescens* cultured on King's B medium

PFNA = *P. fluorescens* cultured on nutrient broth

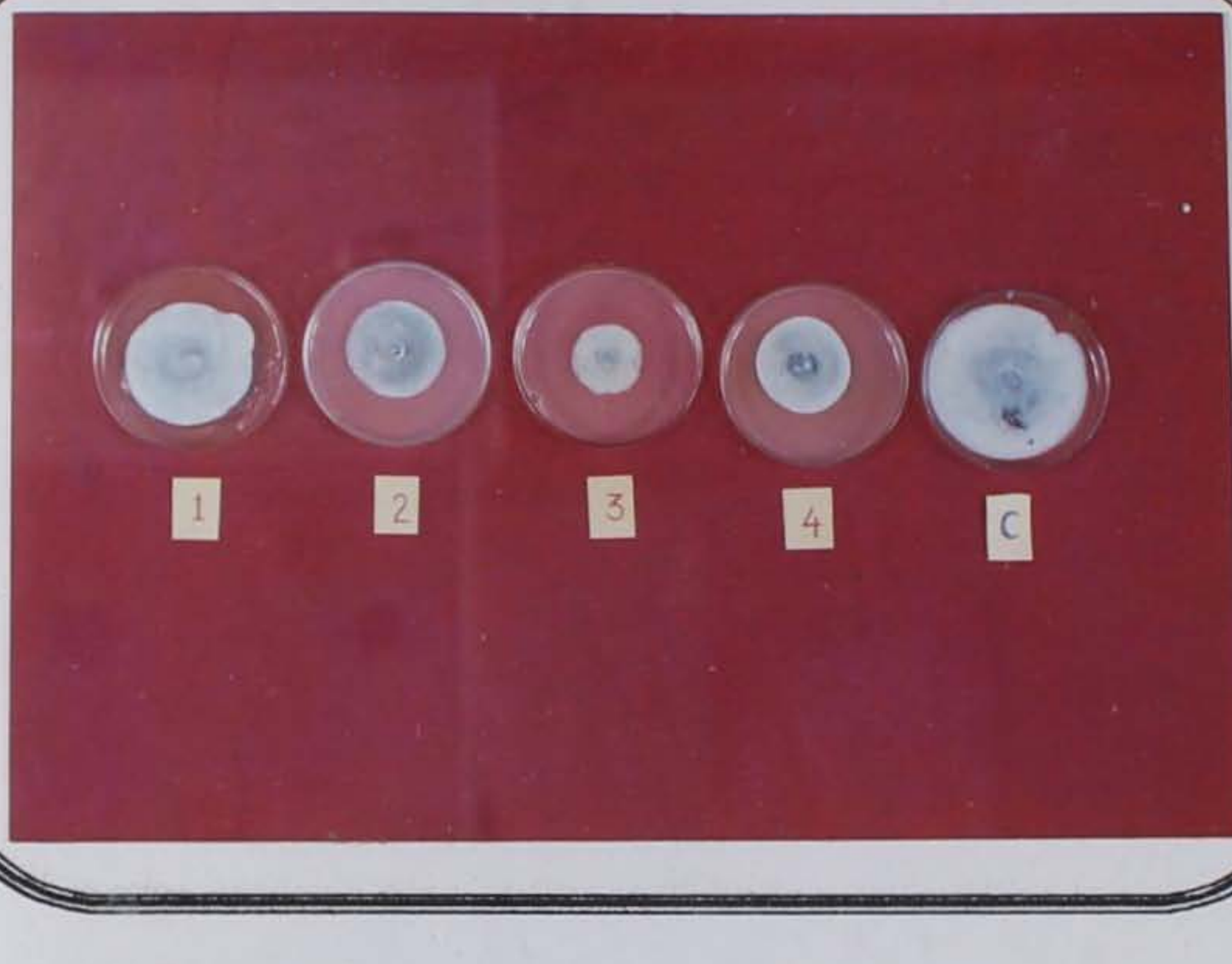
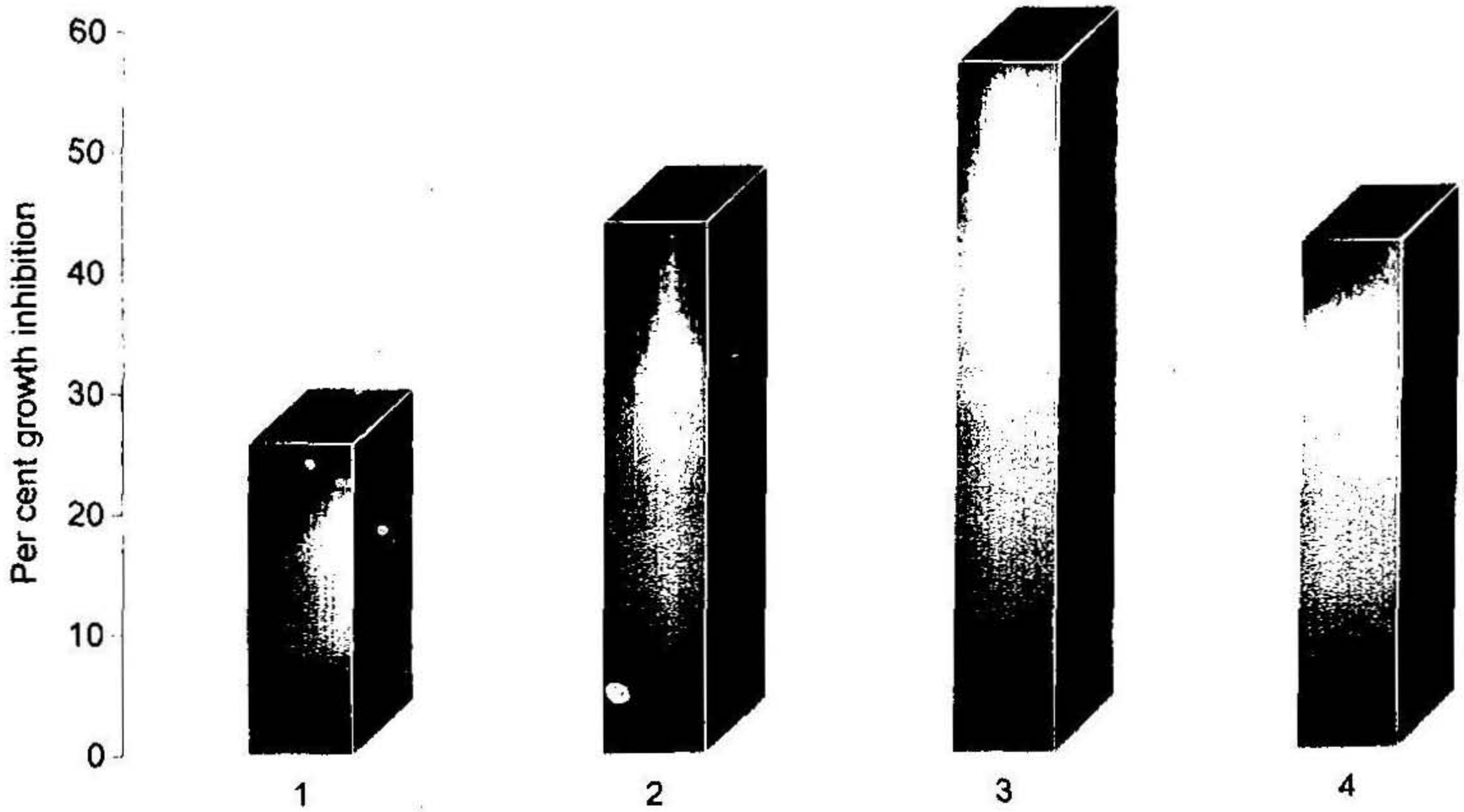


Plate-XII: Effect of various bacterial antagonists cultural filtrates on growth of *C. falcatum*

1 = *Bacillus subtilis* cultured on King's B medium
2 = *B. subtilis* cultured on nutrient broth
3 = *Pseudomonas fluorescens* cultured on King's B medium
4 = *P. fluorescens* cultured on nutrient broth
C = Control

Fig. 2 : Effect of bacterial antagonists on the growth of *Colletotrichum falcatum*



1 = *Bacillus subtilis* cultured on King's B medium
2 = *B. subtilis* cultured on broth medium
3 = *Pseudomonas fl rescens* cultured on King's B medium
4 = *P. flourescens* cultured on nutrient broth

(44.44 %). *P. fl rescens* cultured nutrient broth (43.06 %) and *B. subtilis* cultured on King's B medium (25.93 %).

The sporulation of *C. falcatum* recorded lower in both the bacterial antagonists tested on two different media as compared to the control. There was no sporulation in *P. fl urescens* cultured in King's B medium.

4.5.2 Efficacy of different antagonists against red rot in pot culture

All the fungal and bacterial antagonists tested *in vitro* were further tested in pot culture as sett dip treatment to artificially inoculated setts.

Results presented in Table 4.9 (Fig 3: Plate-XIII A, B) revealed that significantly more germination was recorded in all the treatments as compared to inoculated check except the treatments of *B. subtilis* and *P. fl rescens*. Among them, *T. harzianum* and *A. flavus* were significantly superior (88.53 %) and were at par with *T. viride*, *A. flavus*, *C. globosum* and *A. niger*. The next best in order of merit was *G. viren* followed by *T. longibrachyatum*.

The per cent increase in germination over inoculated check were ranging from 25.01 to 121.43 per cent in different treatments. The maximum increase was recorded in *T. harzianum* and *A. flavus* (121.43 %) followed by *T. viride*, *C. globosum*, *A. niger* (97.62 %), *G. virens* (61.30 %), *T. long brachytum* (50.02 %), *P. fl rescens* (37.52 %) and *B. subtilis* (25.01 %).

Considering the effects of antagonists on the red rot incidence, it was significantly lower in all the treatments as compared

Table 4.9: Efficacy of different antagonists against red rot in pot culture

Sr. No.	Treatment	Germination (%)	Per cent increase in germination over check (inoculated)	Disease incidence on cane basis (%)	Per cent control of disease over check (inoculated)
1.	TV	79.01* (96.36)**	97.62	17.65* (9.19)**	80.13
2.	TH	88.53 (99.93)	121.43	15.20 (6.87)	82.89
3.	TL	59.98 (74.96)	50.02	28.48 (22.74)	67.94
4.	GV	64.49 (81.45)	61.30	29.91 (24.86)	66.33
5.	CG	79.01 (96.36)	97.62	17.79 (94.37)	79.97
6.	AL	79.01 (96.36)	97.62	24.14 (18.05)	71.70
7.	AF	88.53 (99.93)	121.43	27.95 (21.97)	68.54
8.	BS	49.98 (58.64)	25.01	36.48 (33.35)	58.93
9	PF	54 98 (67 06)	37.52	42.26 (45.22)	52.43
10.	Check (inoculated)	39.98 (39 57)	-	88.83 (99.96)	-
11.	Check (healthy)	88.53 (99 93)	121.43	1.17 (0.04)	-
	S. Em. ±	6.80		3.48	
	CD at 5 %	19.97		11.41	
	CV %	16.80		20.00	

1) *Trichoderma viride*
2) *T. harzianum*
3) *T. logibrachyatum*
4) *Gliocladium virens*
5) *Chaetomium globosum*
6) *Asperigillus niger*
7) *A. flavus*
8) *Bacillus subtilis*
9) *Pseudomonas fl...rescens*
10) Control (inoculated)
11) Control (healthy)

* arc sine transformed value

** figures in the parenthesis are re-transformed values



A



B

Plate-XIII: Effect of different antagonists on red rot (A & B in early stage)

1	=	*Trichoderma viride*	5	=	*Chaetomium globosum*
2	=	*T. harzianum*	6	=	*Aspergillus niger*
3	=	*T. longibrachyatum*	7	=	*A. flavus*
4	=	*Gliocladium virens*	10	=	Control (inoculated)



C



D

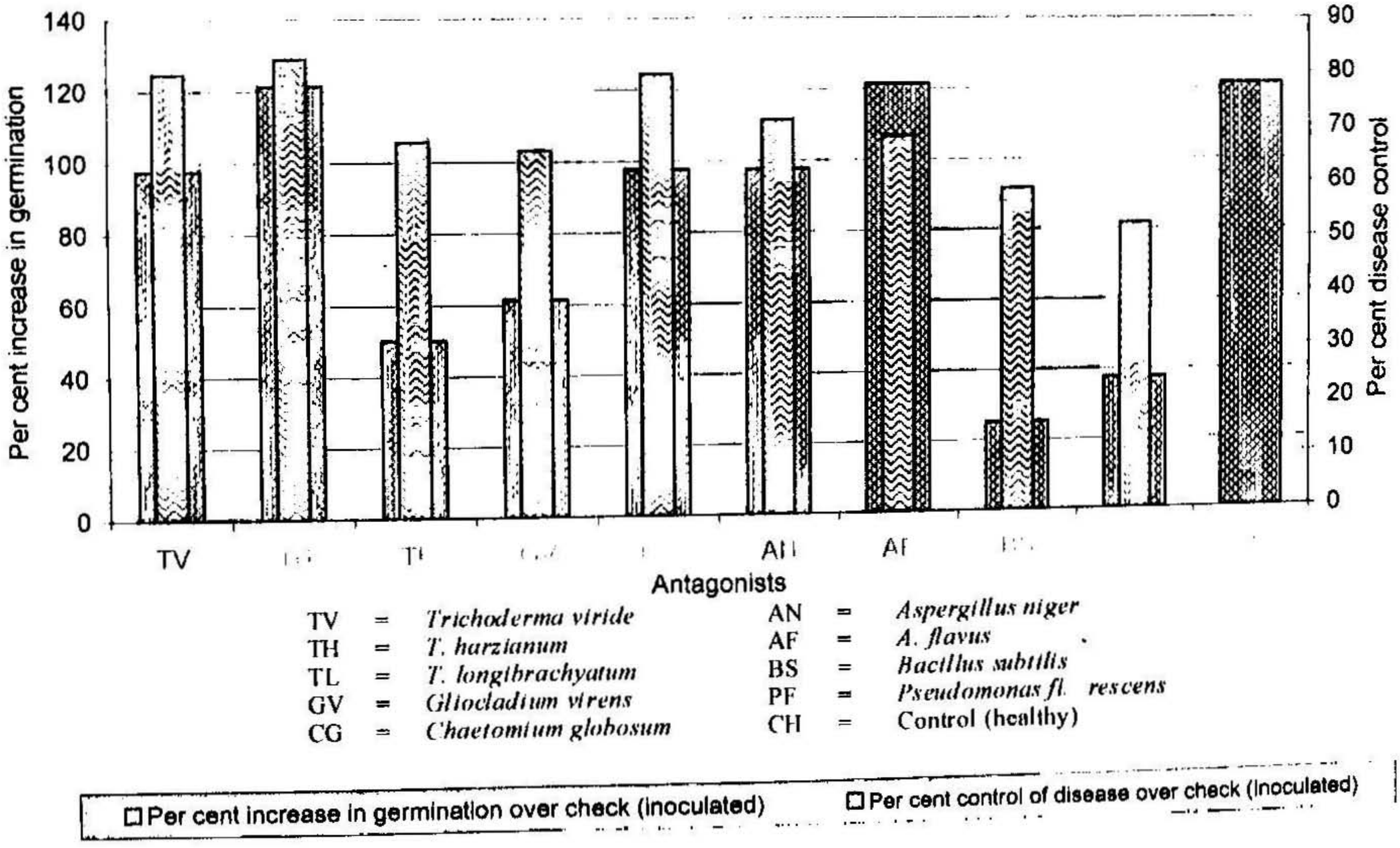
C: In early stage

8 = *Bacillus subtilis*
9 = *Pseudomonas fluorescens*
10 = Control (inoculated)
11 = Control (healthy)

D: In later stage

T_1 = *Trichoderma viride*
T_2 = *T. harzianum*
T_5 = *Chaetomium globosum*
T_{11} = Control (healthy)

Fig. 3 : Efficacy of different antagonists against red rot in pot culture



to the infected control. Among these, it was significantly minimum in the treatment of *T. harzianum* (15.20 %), which was at par with *T. viride* (17.65 %), *C. globosum* (17.79 %) and *A. niger* (25.74 %). The next best in order of merit were *A. flavus* (27.95 %), *T. longibrachyatum* (28.48 %), *G. virens* (29.91 %), *B. subtilis* (36.48 %) and *P. fl· rescens* (42.26 %).

Maximum red rot control over check (inoculated) was recorded in *T. harzianum* (82.89 %) followed by *T. viride* (80.13 %), *C. globosum* (79.97 %), *A. niger* (71.70 %), *A. flavus* (68.54 %), *T. longibrachyatum* (67.92 %), *G. virens* (66.33 %), *B. subtilis* (58.93 %) and *P. flourescens* (52.43 %).

Compared to bacterial antagonists tested, fungal antagonists proved to be better in germination and also in red rot control.

Looking to the effect of antagonistic treatments on germination and red rot control, *T. harzianum* was found most effective followed by *T. viride*, *C. globosum* and *A. niger*.

4.5.3 Bio-efficacy of phyto-extracts against *C. falcatum* *in vitro*

Phyto-extracts of commonly available 17 plant species belonging to 13 different families were evaluated *in vitro* to know their inhibitory effect on the growth and sporulation of *C. falcatum*.

The results presented in Table 4.10 (Fig. 4 and Plate-XIV) clearly indicated that all the phyto-extracts tested reduced colony growth significantly as compared to the control except *Allamanda*. Among these, gando baval (*Prosopis juliflora*) found significantly superior over the rests. The next best in order of merit was Datura

Table 4.10: Bio-efficacy of phyto-extracts against *Colletotrichum falcatum in vitro*

Sr. No.	Treatment	Averag colony diameter (mm)	Per cent inhibition over control	Sporulation
1.	Datura	23.00	72.16	–
2.	Neem seed extract (NSE)	72.02	12.10	+
3.	Pashugandha	69.12	16.34	+++
4.	Gando baval	10.00	87.80	–
5.	Vachhnag	70.25	14.98	++++
6.	Kuvadio	54.88	33.58	+
7.	Ginger	75.62	8.47	–
8.	Lantana	28.12	65.96	–
9.	Turmeric	68.00	17.70	+
10.	Mango turmeric	67.50	18.31	++
11.	Polylanthia	69.50	15.88	+
12.	Allamanda	83.50	1.06	++
13.	Fudina	80.00	3.18	+
14.	Garlic	72.80	11.80	+
15.	Onion	77.38	6.35	–
16.	Ajmo	69.75	15.58	–
17.	Ajilo	76.13	7.87	–
18.	Control	82.62	-	+++
	S. Em ±	0.59		
	C.D. at 5 %	1.68		
	C. V. %	1.85		

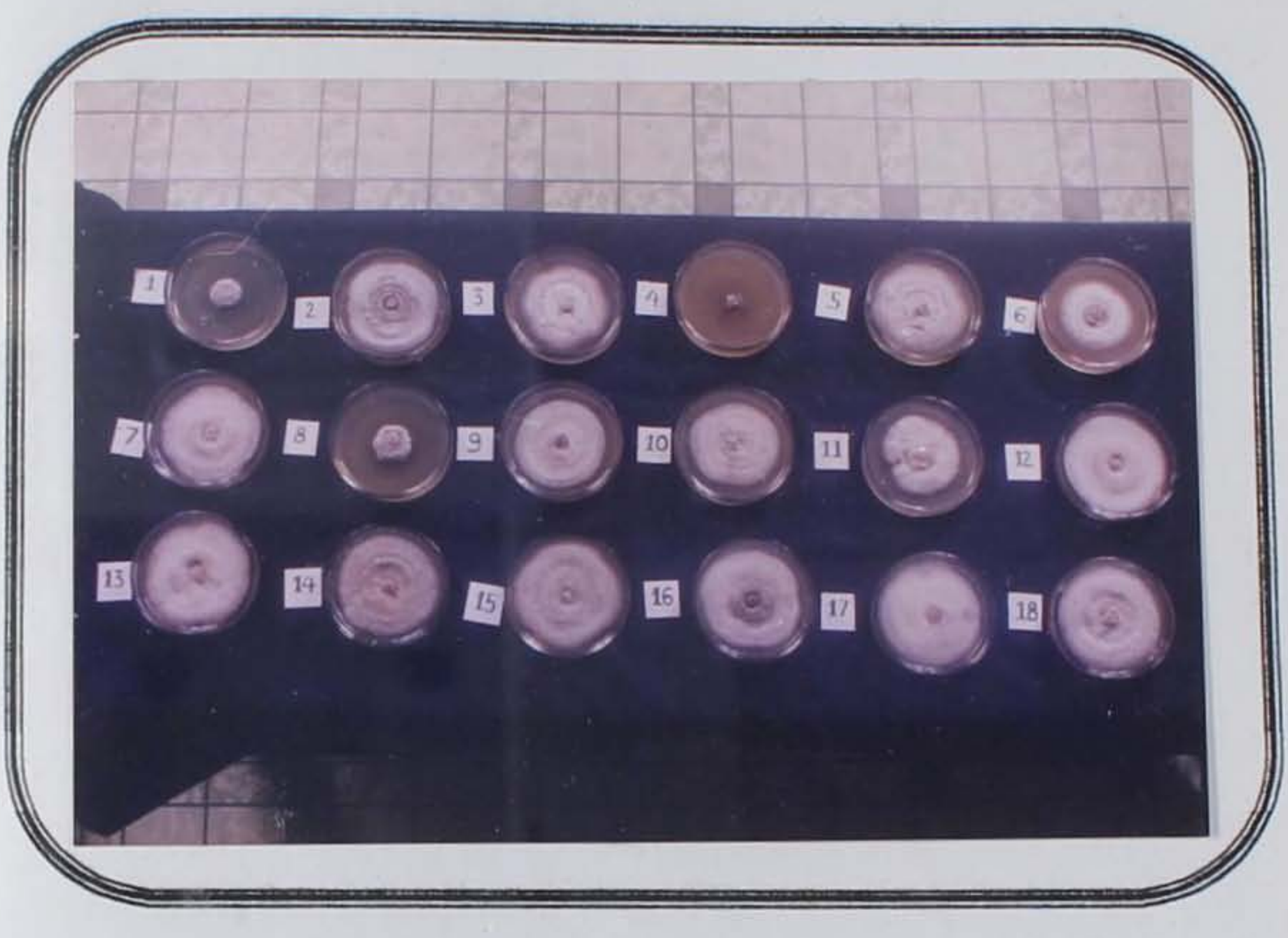
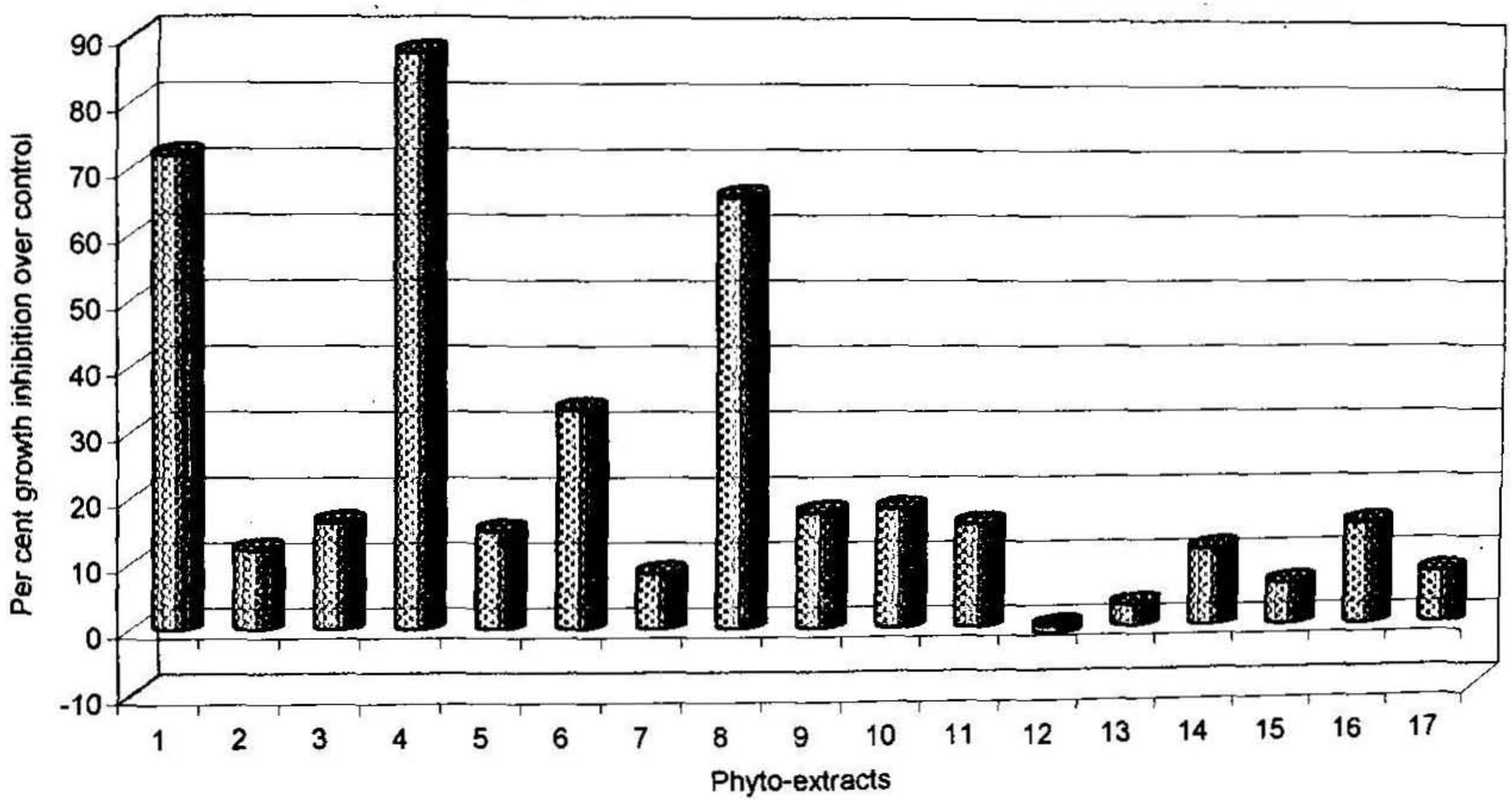


Plate-XIV: Effect of various phyto-extracts on the mycelial growth of *C. falcatum*

1	=	Datura	10	=	Mango turmeric
2	=	Neem seed extract	11	=	*Polylanthia*
3	=	Pashugandha	12	=	*Allamanda*
4	=	Gando baval	13	=	Fudina
5	=	Vacchnag	14	=	Garlic
6	=	Kuvadio	15	=	Onion
7	=	Ginger	16	=	Ajmo
8	=	Lantana	17	=	Ajilo
9	=	Turmeric	18	=	Control

Fig. 4 : Effect of different phyto-extracts on the growth of *Colletotrichum falcatum*



1	Datura	7	Ginger	13	Fudina
2	NSG	8	Lantana	14	Garlic
3	Pasugandha	9	Turmeric	15	Onion
4	Gando baval	10	Mango turmeric	16	Ajmo
5	Vachnag	11	Polylthia	17	Ajilio
6	Kuvadio	12	Alfamanda		

(*Datura stramoneum*) followed by Lantana (*Lantana camera*), Kuvadio (*Cassia tora*), Mango turmeric (*Curcuma aromata*), turmeric (*Curcuma longa*), Pashugandha (*Cleome spinosa*), Polylanthia (*Polylanthia longifolia*), ajmo (*Carum copticum*), Vachhnag (*Gloriosa superba*), neem seed extract (NSE, *Azadirachta indica*), garlic (*Allium sativum*), ginger (*Zingiber officinalis*), ajilo (*Apium carri*), onion (*Allium cepa*) and fudina (*Mentha piperita*). *Allamanda* (*Allamanda cathartica*) found to induce the growth of the pathogen. Maximum inhibition of mycelial growth was found in gando baval (87.80 %) followed by datura (72.16 %) and lantana (65.96 %). In rest of the treatments, the inhibition was less than 50 per cent.

The fungus did not sporulate in the phyto-extracts of gando baval, datura, ginger, lantana, onion, ajmo and ajilo, while in NSE, kuvadio, turmeric, polyalthia, fudina, garlic, mango turmeric and *Allamanda* there was moderate inhibitory effect. There was no effect of the extract of pashugandha while vachhng proved as stimulatory for the sporulation.

4.5.4 Bio-efficacy of organic extracts against *C. falcatum* *in vitro*

The aqueous extracts of different organic sources were evaluated for their effect on *C. falcatum*.

The results presented in Table 4.11 (Fig. 5, Plate-XV) revealed that the extracts of castor cake, poultry manure and pressmud were the most effective as there was no mycelial growth observed. The fungal mycelial bit from these were also transferred to sole PDA plates to know their fungistatic or fungicidal effect and there to the mycelial

Table 4.11: Bio-efficacy of organic extracts against *Colletotrichum falcatum in vitro*

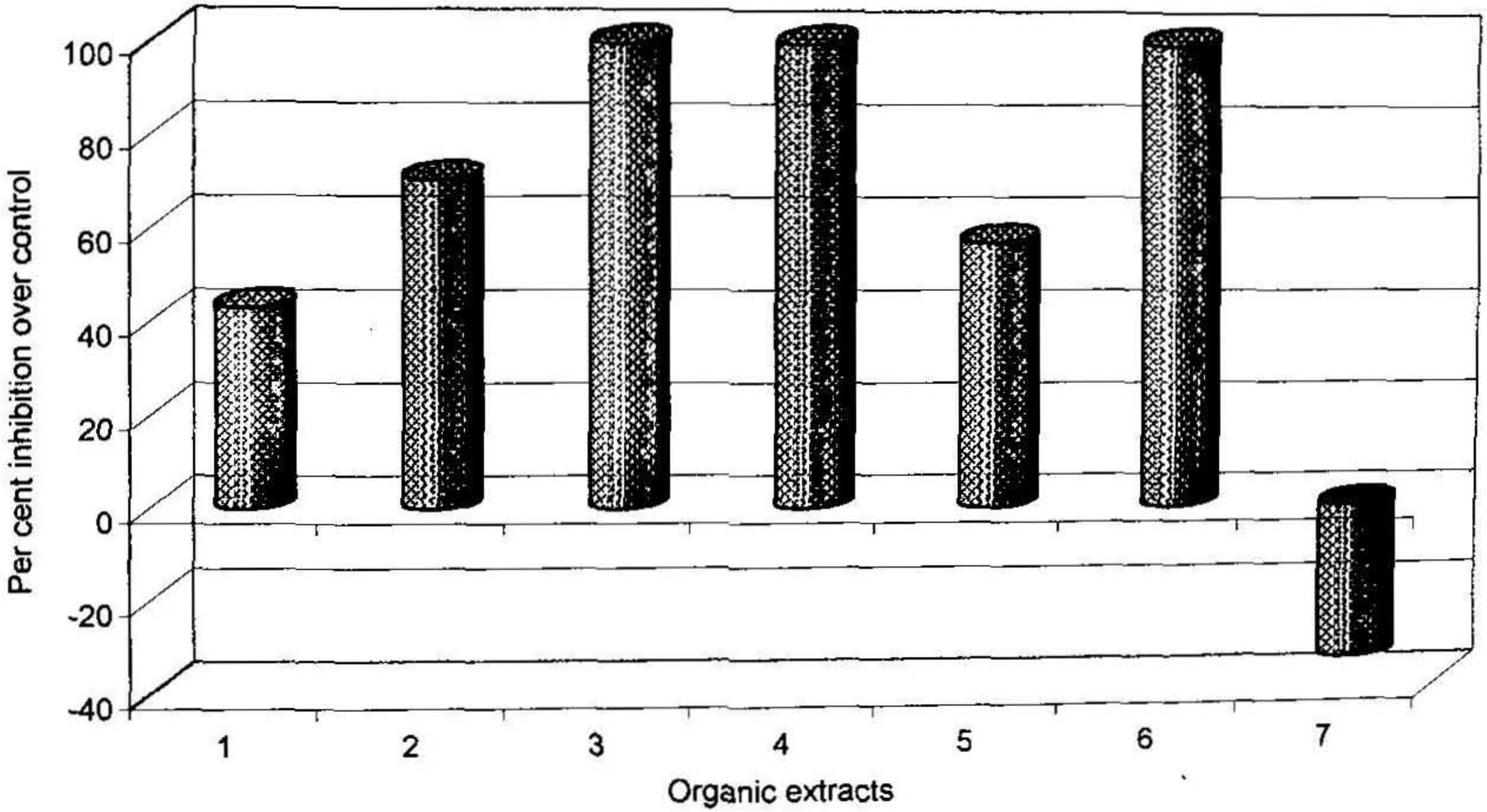
Sr. No.	Treatment	Averag radial growth (mm)	Per cent inhibition over control	Sporulation
1.	Neem cake	18.60	43.29	+
2.	Mustard cake	9.60	70.73	–
3.	Castor cake	0.00	100.00	–
4.	Poultry manure	0.00	100.00	–
5.	FYM	14.00	57.32	+
6.	Pressmud	0.00	100.00	–
7.	Vermicompost	43.80	– 33.53	+++
8.	Control	32.80	–	++
	S. Em ±	0.418		
	C.D. at 5 %	1.20		
	C. V. %	6.30		



Plate-XV: Effect of various organic extracts on the growth of *C. falcatum*

1	=	Neem cake	5	=	Farm yard manure
2	=	Mustard cake	6	=	Pressmud
3	=	Castor cake	7	=	Vermi compost
4	=	Poultry manure	8	=	Control

Fig. 5 : Effect of organic extracts on growth of *Colletotrichum falcatum*



1 Neem cake
2 Mustard cake
3 Castor cake
4 Poultry manure
5 FYM
6 Pressmud
7 Vermicompost

growth was not observed hence, proved as strong fungicidal effect of these organic extracts on *C. falcatum*.

The rest of the treatments were also significantly superior over the control. Among these, the extracts of mustard cake (9.60 mm) found significantly superior over the rest. The next best organic extracts were FYM (14.0 mm) and neem cake (18.60 mm).

In vermicompost, significantly more growth was recorded (43.10 mm) even as compared to the control (32.80 mm).

The highest inhibition of growth of the pathogen over control was observed in the extract of castor cake, poultry manure and pressmud (100 %) followed by mustard cake (70.73 %), FYM (57.32 %) and neem cake (43.29 %).

The sporulation was more in vermicompost extract as compared to control while it was lower in the extract of neem cake and farm yard manure. Total inhibition of sporulation was observed in the extracts of mustard cake, castor cake, pressmud and poultry manure.

Considering the effect of organic extracts on the mycelial growth and sporulation of *C. falcatum*, pressmud, castor cake and poultry manure found most effective showing fungicidal effect.

4.6 Bio-efficacy of root exudates of various plant species on *C. falcatum in vitro*

The data presented in Table 4.12 (Fig. 6) revealed very interesting results.

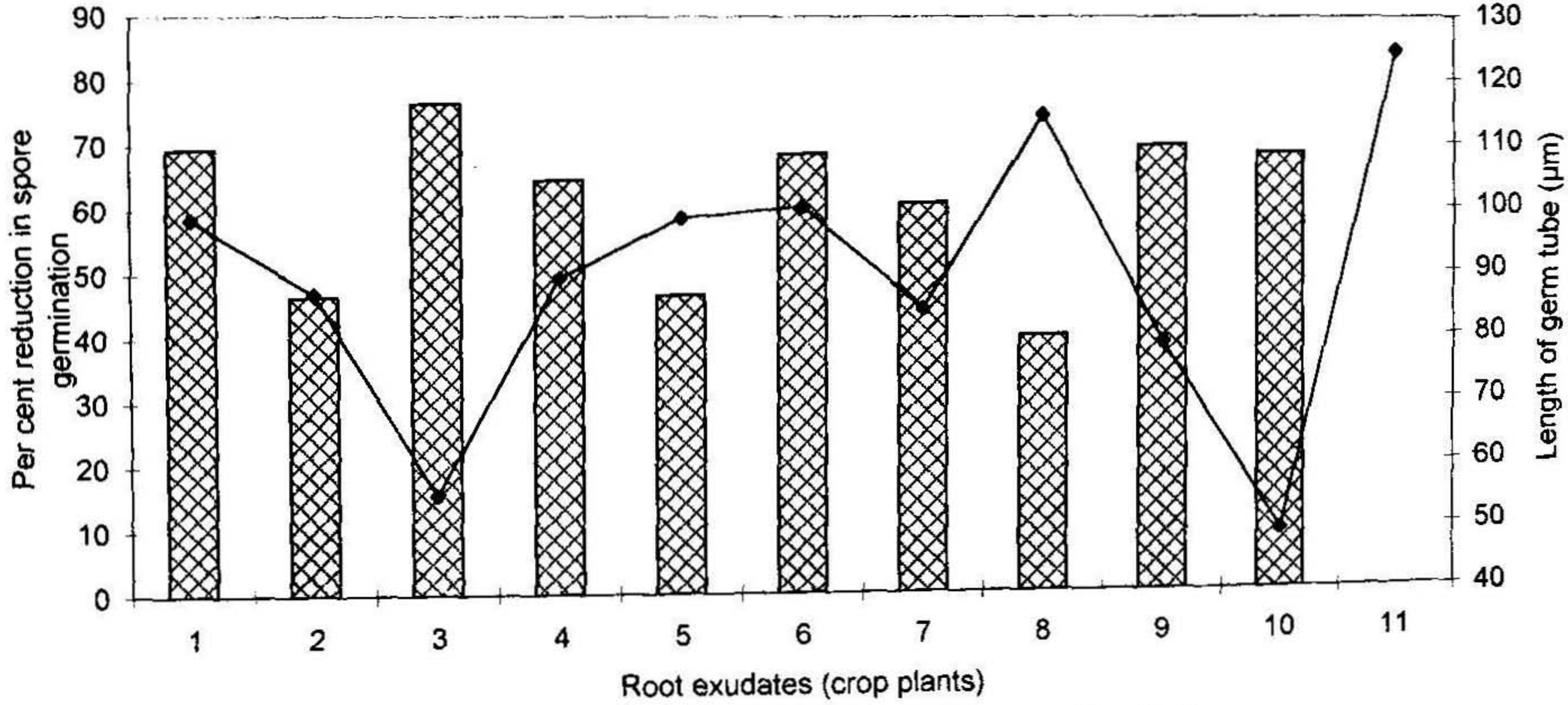
All the root exudates found significantly superior over the control. Among these, root exudate of brinjal gave significantly lower spore germination (11.33 %) over the rest. Next best in order of merit

Table 4.12: Effect of root exudates of different plant species on spore germination and length of germ tube of *Colletotrichum falcatum*

Sr. No.	Treatment	Spore germination (%)	Per cent reduction in spore germination over control	Length of germ tube (µm)
1.	Chickpea	14.66* (6.41)**	69.39	98.49
2.	Cabbage	25.58 (18.64)	46.58	86.97
3.	Brinjal	11.33 (3.86)	76.59	55.62
4.	Coriander	16.90 (8.45)	64.71	89.47
5.	Mustard	25.46 (18.48)	46.83	98.73
6.	Sorghum	28.39 (22.61)	68.68	100.45
7.	Onion	18.68 (10.26)	60.99	84.44
8.	Sesamum	28.57 (22.87)	40.35	114.67
9.	Garlic	14.41 (6.19)	69.91	79.07
10.	Methi	15.00 (6.70)	68.67	49.41
11.	Control	47.89 (55.04)	-	124.60
	S Em ±	0.91		2.73
	C.D. at 5 %	2.67		8.00
	C. V. %	7.01		5.29

* arc sin transformed values
** figures in parenthesis are re-transformed values

Fig. 6 : Effect of root exudates of different plant species on spore germination and *length of germ* tube



were the root exudates of garlic (14.41 %), chickpea (14.66 %), methi (15.00 %), coriander (16.90 %), onion (18.68 %), mustard (25.46 %), cabbage (25.58 %), sorghum (28.39 %) and sesamum (28.57 %).

Maximum inhibition of spore germination over control was recorded in the root exudates of brinjal (76.59 %) followed by garlic (69.91 %), chickpea (69.39 %), sorghum (68.68 %), methi (68.67 %), coriander (64.71 %), onion (60.99 %), mustard (46.83 %), cabbage (46.58 %) and sesamum (40.35 %).

The root exudates were also found to reduce the length of germ tube. In all the root exudates, the length of germ tube found to be significantly lower as compared to the control. Significantly lower length of germ tube was observed in methi (49.41 µm) over the rest which was at par with brinjal (55.62 µm). The next best in order of merit were garlic, onion, cabbage, coriander, chickpea, mustard, sorghum and sesamum.

Looking to the inhibition of spore germination and reduction in the length of germ tube, the root exudates of brinjal was most effective, followed by garlic, chickpea, sorghum, methi, coriander, onion, mustard, cabbage and sesamum

4.7 Chemical control

4.7.1 Bio-efficacy of various fungicides against *C. falcatum* *in vitro*

Fourteen fungicides belonging to different groups were evaluated *in vitro* for their efficacy against *C. falcatum*. Three concentrations of each systemic and non-systemic fungicides were

screened on active ingredient basis using poisoned food technique on PDA. The concentrations of different fungicides are given in Table 4.13.

The results presented in Table 4.13 (Fig. 7, Plate-XVI A & B) showed that all the fungicides screened significantly reduced the growth of *C. falcatum* as compared to the control. Among the systemic fungicides, Cyproconazole (San), Metalaxyl + Mancozeb (Ridomil-MZ), Triadimefon (Bayleton), Thiophanate methyl (Topsin-M), Carbendazim (Bavistin) and Benomyl (Benlate) at all the three concentrations while Hexaconazole (Contaf) and Propiconazole (Tilt) at 250 and 500 ppm showed no mycelial growth of the pathogen. In rest of the systemic fungicides, there also significantly lower mycelial growth was observed. This includes Hexaconazole (Contaf) and Propiconazole (Tilt) at 100 ppm (4.16 mm) and Tridemorph (Calaxin) at 250, 500 and 1000 ppm (8.70, 8.25 and 3.20 mm, respectively).

Among the non-systemic fungicides, there was no mycelial growth observed in any of the treatments at all the three concentrations tested.

The inhibition of mycelial growth of *C. falcatum* was 100 per cent in all the treatments at all the three concentrations except Tridemorph at 1000 ppm (92.62 %), Hexaconazole and Propiconazole at 100 ppm (91.41 %), Tridemorph at 500 ppm (80.99 %) and at 100 ppm (80.32 %).

4.7.2 Bio-efficacy of fungicides against red rot in pot culture

Different fungicides found effective during *in vitro* screening were further tested in pot culture.

Table 4.13: Effect of various fungicides on growth of *Colletotrichum falcatum in vitro*

Sr No	Technical and trade name of fungicides used	Conc. (ppm)	Average radial growth of mycelium (mm)		Per cent inhibition over control
1	Cyproconazole	100	0.71*	(0.00)**	100.00
	(San 619 F 50 % SL)	250	0.71	(0.00)	100.00
		500	0.71	(0.00)	100.00
2.	Hexaconazole	100	2.54	(4.16)	91.41
	(Contaf 5 % EC)	250	0.71	(0.00)	100.00
		500	0.71	(0.00)	100.00
3.	Propiconazole	100	2.54	(4.16)	91.41
	(Tilt 25 % EC)	250	0.71	(0.00)	100.00
		500	0.71	(0.00)	100.00
4.	Tridemorph	250	3.45	(8.70)	80.32
	(Calixin 50 % EC)	500	2.58	(8.25)	80.99
		1000	2.29	(3.20)	92.62
5.	Metalaxyl + Mancozeb	500	0.71	(0.00)	100.00
	(Ridomil-MZ 78 % WP)	1000	0.71	(0.00)	100.00
		1500	0.71	(0.00)	100.00
6.	Triadimefon	100	0.71	(0.00)	100.00
	(Bayleton 25 % WP)	250	0.71	(0.00)	100.00
		500	0.71	(0.00)	100.00
7.	Thiophanate methyl	500	0.71	(0.00)	100.00
	(Topsin-M 75 % WP)	1000	0.71	(0.00)	100.00
		1500	0.71	(0.00)	100.00

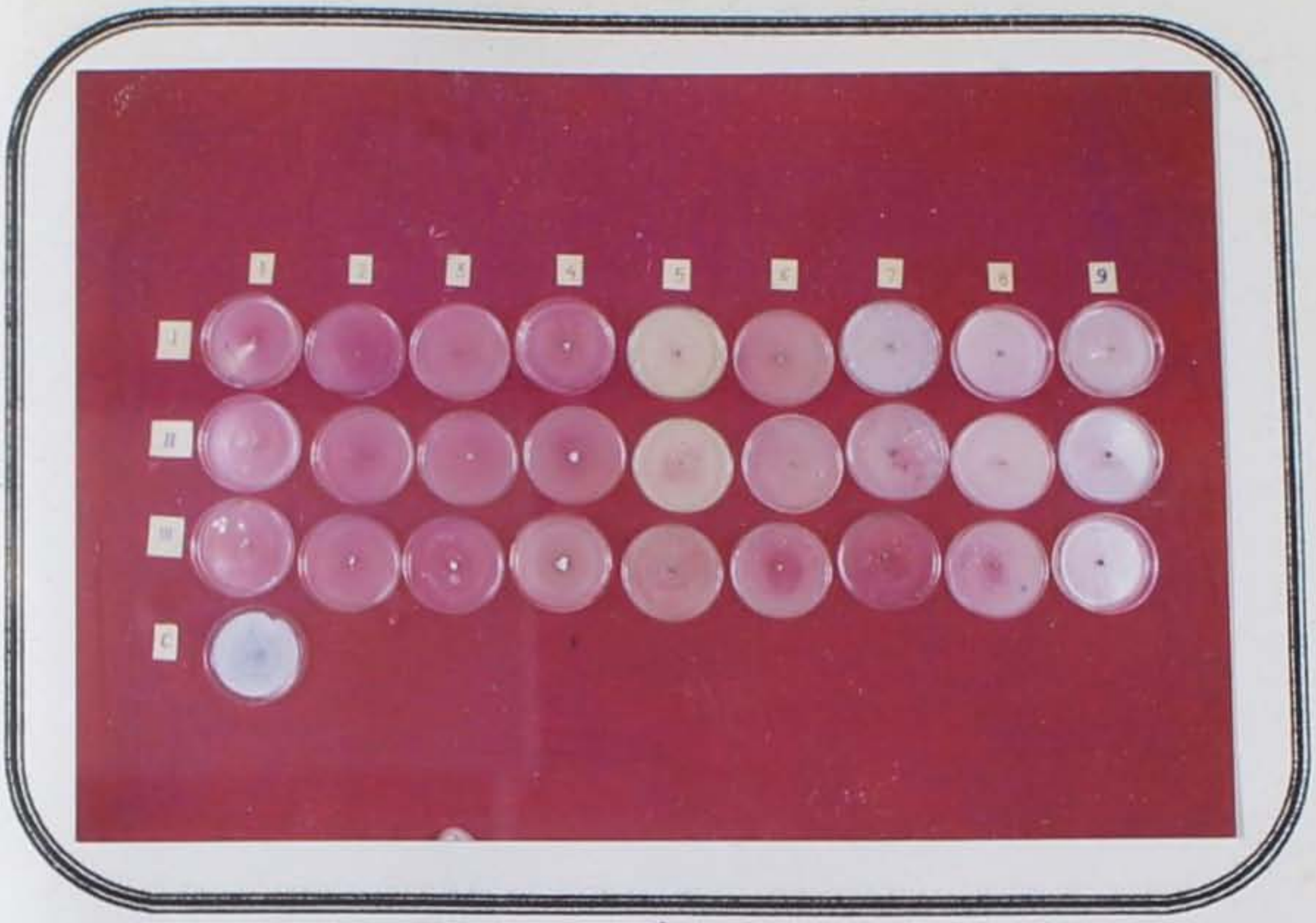
Table 4.13 contd ..

Table 4.13 contd

Sr. No.	Technical and trade name of fungicides used	Conc. (ppm)	Average radial growth of mycelium (mm)		Per cent inhibition over control
8.	Carbendazim	500	0.71	(0.00)	100.00
	(Bavistin 50 % WP)	1000	0.71	(0.00)	100.00
		1500	0.71	(0.00)	100.00
9.	Benomyl	500	0.71	(0.00)	100.00
	(Benlate 50 % WP)	1000	0.71	(0.00)	100.00
		1500	0.71	(0.00)	100.00
10.	Ziram	1000	0.71	(0.00)	100.00
	(Cuman-L 27 % W/W)	1500	0.71	(0.00)	100.00
		2000	0.71	(0.00)	100.00
11.	Chlorothalonil	1000	0.71	(0.00)	100.00
	(Kavach 75 %)	1500	0.71	(0.00)	100.00
		2000	0.71	(0.00)	100.00
12.	Mancozeb	1000	0.71	(0.00)	100.00
	(Dithane M-45 75 % WP)	1500	0.71	(0.00)	100.00
		2000	0.71	(0.00)	100.00
13.	MEMC	1000	0.71	(0.00)	100.00
	(Emisan 6 % WP)	1500	0.71	(0.00)	100.00
		2000	0.71	(0.00)	100.00
14.	Copper oxychloride	1500	0.71	(0.00)	100.00
	(Blitox 50 % WP)	2000	0.71	(0.00)	100.00
		2500	0.71	(0.00)	100.00
15.	Control	-	7.09	(43.40)	-
	S. Em. ±		0.03		
	C. D. at 5 %		0.08		
	C. V. %		5.68		

* SQR + 0.5 transformation values

** figures in parenthesis are re-transformed values



A

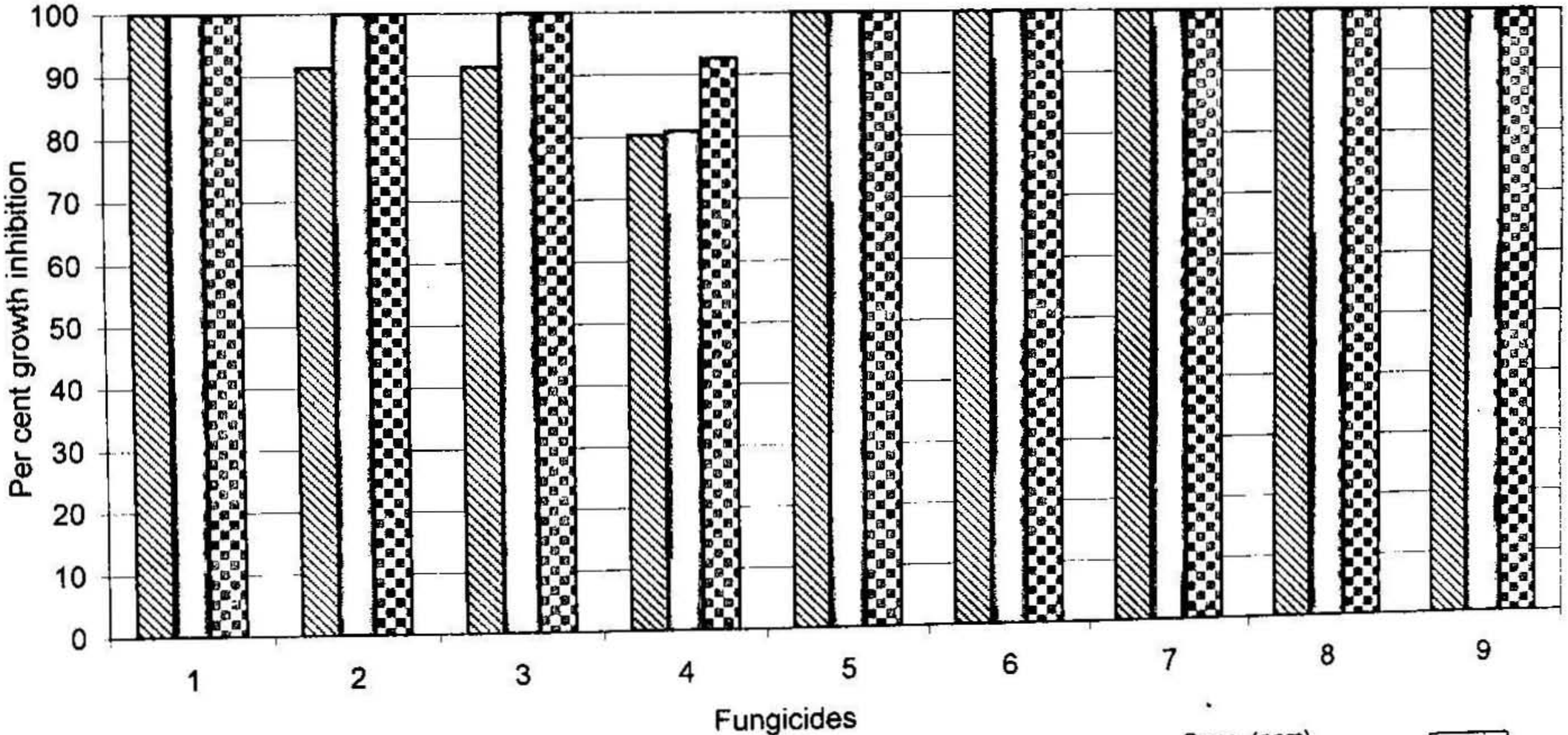


B

Plate-XVI: Effect of various fungicides on growth of *C. falcatum*

A.	Systemic group	Conc. (ppm)			B.	Non-systemic group	Conc (ppm)		
1.	San 619 F 50 % SL	100	250	500	1.	Cuman-L 27 % W/W	1000	1500	2000
2.	Contaf 5 % EC	100	250	500	2.	Kavach 75 %	1000	1500	2000
3.	Tilt 25 % EC	100	250	500	3.	Dithane M-45 75 % WP	1000	1500	2000
4.	Calixin 50 % EC	250	500	1000	4.	Emisan 6 % WP	1000	1500	2000
5.	Ridomil-MZ 78 % WP	500	1000	1500	5.	Blitox 50 % WP	1000	1500	2000
6.	Bayleton 25 % WP	100	250	500					
7.	Topsin-M 75 % WP	500	1000	1500					
8.	Bavistin 50 % WP	500	1000	1500					
9	Benlate 50 % WP	500	1000	1500					

Fig. 7 : Effect of systemic fungicides on growth of *Colletotrichum falcatum*



		Conc. (ppm)					Conc. (ppm)		
		C1	C2	C3			C1	C2	C3
1.	San 619 F 50 % SL	100	250	500	6.	Bayleton 25 % WP	100	250	500
2.	Contaf 5 % EC	100	250	500	7.	Topsin-M 75 % WP	500	1000	1500
3.	Tilt 25 % EC	100	250	500	8.	Bavistin 50 % WP	500	1000	1500
4.	Calixin 50 % EC	250	500	1000	9.	Benlate 50 % WP	500	1000	1500
5.	Ridomil-MZ 78 % WP	500	1000	1500					

C1
C2
C3

The data on germination (45 days after planting) and disease incidence (10 months after planting) on cane basis presented in Table 4.14 (Fig. 8, Plate-XVII A, B) revealed that significantly higher germination was recorded in all the fungicidal treatments as compared to check infected (diseased check) except Triadimefon (Bayleton). Among these, MEMC (Emisan), Carbendazim (Bavistin) and Benlate (Benomyl) found significantly superior over the rest (59.98 % germination). The next best treatments in order of merit were Thiophenate methyl (Topsin-M), Hexaconazole (Contaf), Propiconazole (Tilt), Copper oxychloride (Blitox) and Cyproconazole (San) which were also at par with each other. The lowest germination (29.99 %) was observed in Triadimefon (Bayleton).

Maximum increase in germination over check (infected) was recorded in sett treatments with MEMC, Carbendazim and Benomyl (193.01 %) followed by Thiophanate methyl, Hexaconazole, Copper oxychloride and Propiconazole (117.29 %). Cyproconazole (68.49 %) and Triadimefon (46.51 %).

Red rot incidence was significantly lower in all the fungicidal sett treatments as compared to check (infected). Among these, in Carbendazim treatment significantly lower red rot incidence (26.63 %) was recorded as compared to the rests but it was at par with MEMC (28.75 %). Next best treatment in order of merit was Thiophanate methyl (43.08 %) followed by Benlate (45.0 %), Copper oxychloride (50.00 %), Triademefon (51.49 %), Cyproconazole (51.49 %), Propiconazole (51.88 %) and Hexaconazole (64.95 %).

Considering the disease control over check, maximum disease control was recorded in Carbendazom (70.02 %) followed by

Table 4.14: Efficacy of different fungicides as sett dip treatment on germination and red rot incidence in pot (Naturally infected setts of CoC 671 variety)

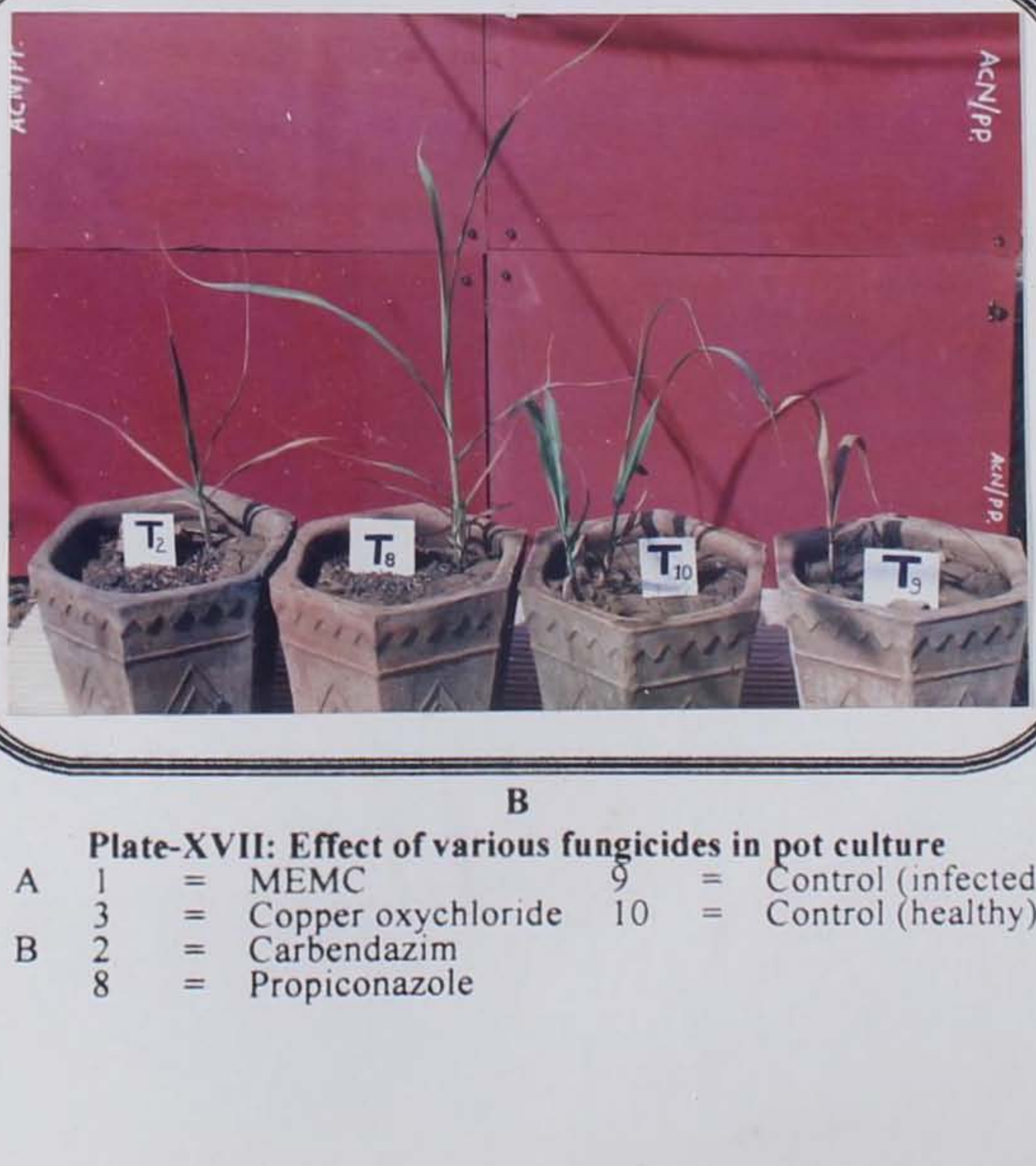
Sr No.	Treatment	Germination (%)		Per cent increase in germination over check (infected)	Disease incidence on cane basis (%)		Per cent disease control over check (infected)
1.	MEMC (Emisan 6 % WP)	59.98*	(74.96)**	193.01	28.75*	(23.14)**	67.64
2.	Carbendazim (Bavistin 50 % WP)	59.98	(74.96)	193.01	26.63	(20.09)	70.02
3.	Copper oxychloride (Blitox 50 % WP)	44.98	(49.96)	117.29	50.00	(58.68)	43.70
4.	Thiophanate methyl (Topsin-M 75 % WP)	44.98	(49.96)	117.29	43.08	(46.65)	51.50
5.	Triadimefon (Bayleton 25 % WP)	29.99	(24.98)	46.51	51.49	(61.23)	42.04
6.	Hexaconazol (Contaf 5 % EC)	44.98	(49.96)	117.29	64.95	(82.07)	26.88
7	Cyproconazole (San 619 F 50 % SL)	34.98	(32.87)	68 49	51.49	(61 23)	42.04
8.	Propiconazole (Tilt 25 % EC)	44.98	(49.96)	117.29	51.88	(81.89)	41.59
9.	Benlate (Benomyl 50 % WP)	59.98	(74.96)	193.01	45.00	(50.00)	49 34
10.	Check (infected)	20.47	(17.23)	-	88.83	(99 96)	-
11.	Check (healthy)	79.01	(96.36)	285.98	1.17	(0.04)	-
	S. Em. ±	4 33			2.74		
	C. D. at 5 %	12.69			8.99		
	C. V. %	15.73			10.42		

* arc sine transformation values

** figures in parenthesis are re-transformed values



A



B

Plate-XVII: Effect of various fungicides in pot culture

A	1	=	MEMC	9	=	Control (infected)
	3	=	Copper oxychloride	10	=	Control (healthy)
B	2	=	Carbendazim			
	8	=	Propiconazole			



C



D

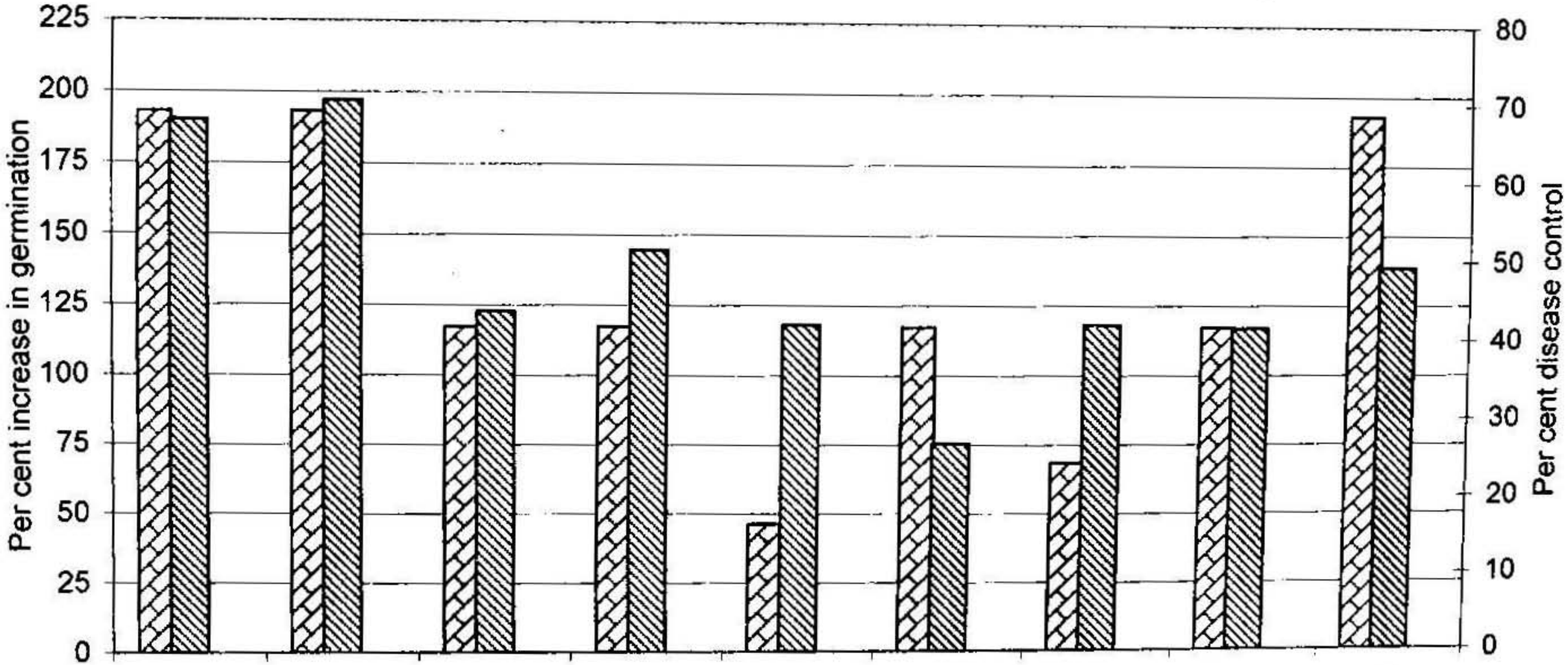
C			D		
7	=	Cyproconazole	4	=	Thiophanate methyl
9	=	Control (infected)	5	=	Triademefon
10	=	Control (healthy)	6	=	Hexaconazole
11	=	Benlate	9	=	Control (infected)
			10	=	Control (healthy)



E

1 = MEMC
2 = Carbendazim
11 = Control (healthy)

Fig. 8 : Efficacy of fungicides as sett dip treatment on red incidence rot in pot culture



1 Emisan 6 % WP
2 Bavistin 50 % WP
3 Blitox 50 % WP
4 Topsin-M 75 % WP
5 Bayleton 25 % WP
6 Contaf 5 % EC
7 San 619 F 50 % SL
8 Tilt 25 % EC
9 Benomyl 50 % WP

Per cent increase in germination over check (infected)
Per cent disease control over check (infected)

MEMC (67.64 %), Thiophanate methyl (51.50 %), Benlate (49.34 %), Copper oxychloride (43.70 %), Tridemorph (42.04 %), Cyproconazole (42.04 %) and Propiconazole (42.04 %). Looking to the effect of fungicides on germination of setts and disease control, Carbendazim and MEMC proved more effective.

4.7.3 Testing of fungicides against red rot with respect to treatment time and length of setts

The most effective fungicides viz., Carbendazim (1 g l^{-1}) and MEMC (2 g l^{-1}) found *in vitro* as well as in pot trial were selected for this trial. The efficacy of these fungicides were further tested keeping two different times (T_1 = 10 minutes and T_2 = 20 minutes on three different types of setts (L_1 = single, L_2 = double and L_3 = triple eye budded setts). Highly susceptible variety CoC 671 was used in this experiment. The treated setts were incubated for 24 hours and then they were split open and isolation from middle part was made to know the presence or absence of the pathogen (Table 4.15).

Carbendazim

After five days of tissue isolation, mycelial growth of the pathogen was not observed in Carbendazim treatment given for 10 minutes in single eye budded setts while in the two and three eye budded setts the fungal growth was observed. In Carbendzim sett treatment for 20 minutes. there was no growth of the pathogen in all the types of setts used. Similar observations were recorded after 10 days of incubation except the growth of the pathogen observed in three eye budded setts treated for 20 minutes.

Table 4.15: Efficacy of fungicides with respect to treatment time and length of sett

Sr. No.	Treatment	Mycelial growth observed (Y/N)	
		After 5 days	After 10 days
1.	$F_1T_1L_1$	N	N
2.	$F_1T_1L_2$	Y	Y
3.	$F_1T_1L_3$	Y	Y
4.	$F_1T_2L_1$	N	N
5.	$F_1T_2L_2$	N	N
6.	$F_1T_2L_3$	N	Y
7.	$F_2T_1L_1$	N	N
8.	$F_2T_1L_2$	N	Y
9.	$F_2T_1L_3$	Y	Y
10.	$F_2T_2L_1$	N	N
11.	$F_2T_2L_2$	N	N
12.	$F_2T_2L_3$	N	N
13.	$F_0T_0L_1$	Y	Y
14.	$F_0T_0L_2$	Y	Y
15.	$F_0T_0L_3$	Y	Y

N = No Y = Yes

MEMC

After five days of tissue isolation, mycelial growth of the pathogen was not observed in MEMC fungicidal sett treatment given for 10 or 20 minutes in all types of setts used except triple eye-buded setts dipped for 10 minutes while after 10 days of incubation the fungal growth was recorded in 10 minutes treatments given to double and triple eye budded setts.

This suggests that eradication of the pathogen present in setts depends upon the treatment time and types of setts used. The eradication of the pathogen was possible through sett treatment with Carbendazim or MEMC for 10 minutes only when single eye budded setts used. Sett treatment for 20 minutes through Carbendazim given to single or double eye budded setts also found effective. While in three eye budded setts, the fungal growth was recorded. In MEMC treatment, for 20 minutes there was no growth in all types of setts used.

In general, the efficacy of fungicides increased with increase in time whereas, efficacy was reduced when the eye buds of the setts increased.

4.8 Integrated management of red rot in pot culture

The most effective three phyto-extracts namely, *Prosopis juliflora*, *Datura stramoneum* and *Lantana camera*; one antagonist *T. harzianum* and two fungicides namely, Carbendazim and MEMC were selected and included for the trial of integrated red rot management in pot. The two eye-buded setts of Cv. CoC 671 were artificially inoculated, incubated for 24 hrs and then treated with the respective material.

The data presented in Table 4.16 (Fig. 9) revealed that germination was significantly higher in all the treatments as compared to the inoculated check except *L. camera*. Among these, MEMC and Carbendazim (88.53 %) proved significantly superior and were at par with *Prosopis juliflora* (81.39 %), *T. harzianum* and *D. stramoneum* (74.25 %). The least germination was observed in *L. camera* (67.11 %). Maximum increase of germination over check inoculated was recorded in MEMC, Carbendazim (68.66 %) followed by *P. juliflora* (55.06 %), *D. stramoneum*, *T. harzianum* (41.46 %) and *L. camera* (27.85 %).

The red rot incidence was observed significantly lower in all the sett treatments except *L. camera* and *D. stramoneum*. Sett treatments with MEMC proved most effective (12.68 %) in managing red rot and it was statistically at par with Carbendazim (18.39 %). Next best treatment in order of merit was *T. harzianum* (26.39 %) and *P. juliflora* (50.32 %).

Per cent disease control (PDC) over check (inoculated) was maximum in MEMC sett treatment (79.72 %) followed by Carbendazim (70.60 %). *T. harzianum* (57.80 %) and *P. juliflora* (19.55 %).

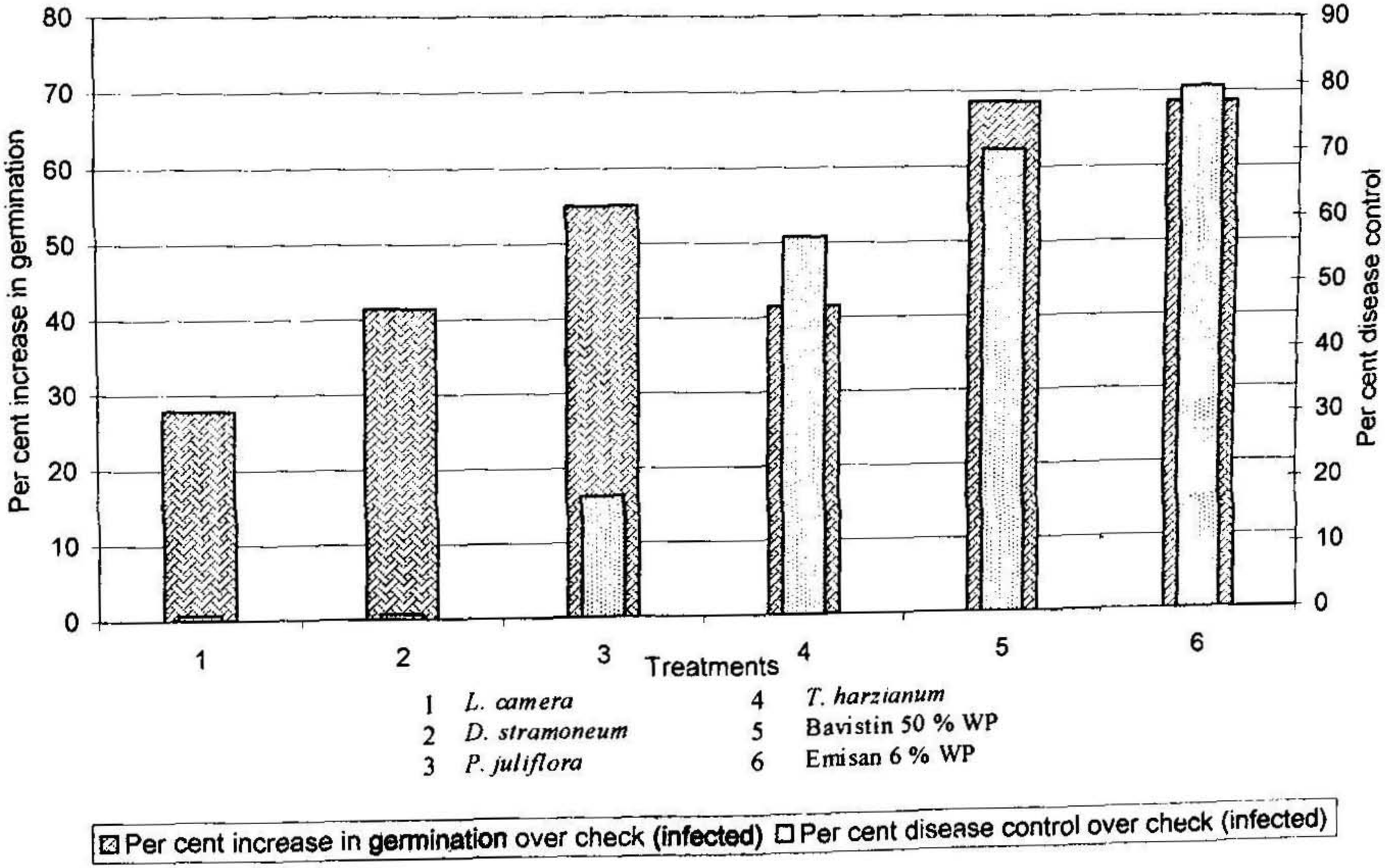
Considering the effect of sett treatment on germination and disease control, sett treatment with fungicides like MEMC and Carbendazim, bio-agent *T. harzianum* and extract of *P. juliflora* are very useful as eradicant.

Table 4.16: Integrated management of red rot in pot culture (artificially inoculated setts of CoC 671)

Sr. No.	Treatment	Germination (%)		Per cent increase in germination over check (inoculated)	Red rot incidence on cane basis (%)		Per cent disease control over check (inoculated)
1.	*Lantana camera* @ 5 % W/V	67.11*	(84 87)**	27 85	61.69*	(76.64)**	1.37
2.	*Datura stramoneum* @ 5 % W/V	74.25	(92.63)	41.46	61.10	(76.64)	2.31
3.	*Prosopis juliflora* @ 5 % W/V	81.39	(97.76)	55.06	50.32	(59.23)	19 55
4.	*Trichoderma harzianum* (1.3×10^8 c.f.u./ml)	74.25	(92 63)	41 46	26.39	(19.75)	57 80
5.	Carbendazim (Bavistin 50 % WP)	88.53	(99.93)	68.66	18.39	(09 95)	70 60
6.	MEMC (Emisan 6 % WP)	88.53	(99.93)	68.66	12.68	(04.82)	79 72
7.	Check (inoculated)	52.49	(62.92)	-	62.55	(77.36)	-
8.	Check (healthy)	88.53	(99.93)	-	01.28	(00.04)	97.95
	S. Em. ±	05.93			03.58		
	C. D. at 5 %	17.44			10.52		
	C. V. %	15.43			19.46		

* arc sine transformation values
** figures in parenthesis are re-transformed values

Fig. 9 : Integrated management of red rot in pot culture



DISCUSSION

V DISCUSSION

Sugarcane is one of the most important cash crops grown throughout the length and breath of India. It is extensively grown in South Gujarat. During early 90s the crop was severely attacked by the red rot disease, which adversely affected the economy of both farmers and the sugar industries. For the management of red rot, chemical control is neither possible nor feasible to apply in the field. Moreover, it is hazardous to environment. Hence, with a view to generate more information on the red rot disease especially on the status of the disease, losses caused by them and to find out cheaper, effective and eco-friendly methods of disease management, the present investigations were carried out.

5.1 Pathological investigations

5.1.1 Symptoms

The symptoms of red rot such as marginal drying of leaves with total drying of crown, change in the colour of stalks, visible acervuli on rind, internal reddening of the cane with white spots, strong alcoholic smell, fungal growth in the pith near the node were found similar to those described earlier by various workers (Went, 1893; Butler, 1906; Abbott and Hughes, 1961; Chona, 1980; Agnihotri, 1983; Singh and Singh, 1989 and Patel, 2000). Early infection causing sett rot and death of settling was also reported during survey in coastal and canal command water logged areas. These symptoms are tallied with the earlier description given by Abbott and Hughes (1961). However, reddish brown speaks on leaf lamina, red elongated lesions on midrib

and reddish patches on the leaf sheath were observed on Cv. CoC 91061 and now it has been reported here for the first time from Gujarat as new information. These symptoms are also tallied with reports of Agnihotri and Budhraja (1974).

5.1.2 Collection of samples and isolation of pathogen

The samples showing typical red rot symptoms on Cv. CoC 671 were collected from Regional Sugarcane Research Station, G. A. U., Navsari yielded pure culture of *Colletotrichum* sp. indicating its constant association with the disease. Went (1893) reported the fungus *Colletotrichum falcatum* Went as the cause of red rot disease of sugarcane which was later on confirmed by Butler (1906).

5.1.3 Pathogenicity test

The pathogenicity of isolated *Colletotrichum* sp. was carried out by five different methods of inoculation viz., soil inoculation, sett inoculation, soil-cum-sett inoculation, cotton swab inoculation and plug method of inoculation. The infection was produced by all the five methods under study. Thus isolated *Colletotrichum* sp. proved pathogenic causing red rot through infected setts. only eye bud or soil, indicating the pathogenic nature of the fungus. In soil inoculation, sett inoculation, soil-cum-sett inoculation and cotton swab inoculation sett rot, settling mortality and typical red rot symptoms on mature canes were observed. These results are tallied with the earlier workers (Singh *et al.*, 1977 and Agnihotri *et al.*, 1979). In plug method also, the infection was produced and typical red rot symptoms were observed. This confirms the results of Chona (1954), Gupta (1980) and Patel (2000). Thus, it is proved that the pathogen is

capable to cause red rot infection by all the inoculation methods tested here.

The germination of setts was adversely affected by different methods of inoculation viz., soil, sett, soil-cum-sett and cotton swab. It may bc due to early infection of the pathogen present on sett and favourable conditions due to planting of setts in the end of December. At this time, the temperature remains below 25^{0}C, which delay the germination. This delay in germination may cause more infection of red rot resulting into sett rotting and poor germination. The settling mortality was more especially in winter months and after that the progress of the disease was lower especially during summer. This may be due to sufficient lower temperature prevailing during winter, at this time the vegetative growth of the settling will be slower and at the same time it may not be low enough to prevent growth of red rot fungus. This finding is in conformation with the observation of Abbott and Hughes (1961)

The red rot incidence further started on mature canes after onset of monsoon, may be due to warm and humid climatic conditions favourable for the pathogen and the same time sucrose accumulation have been started in the cane.

These results also indicated that the transmission of the inoculum occurs through sett without showing visible symptoms of the disease. The eye bud may also carry infective propagules of the pathogen that may cause disease. The sick soil also serves as primary source of infection

5.1.4 Taxonomy and identification

The studies on morphological and cultural characters of isolated *Colletotrichum* sp. showed its close identity with *Colletotrichum falcatum* Went. as described by earlier workers (Vasudeva *et al.*, 1958; Bajaj, *et al.*, 1964; Agnihotri, 1983; Singh and Singh, 1989; Kalaimani, 1995 and Patel, 2000). The pure culture of *Colletotrichum* sp. isolated in this study was also identified as *Colletotrichum falcatum* Went (I. T. C. C. No. 3923-99) at Indian Type Culture Collection, Division of Mycology and Plant Pathology, I. A. R. I., New Delhi-110 012. Thus, the cause of sugarcane red rot in South Gujarat was confirmed as *Colletotrichum falcatum* Went.

5.2 Survey for occurrence and spread of red rot in South Gujarat

5.2.1 Area affected by red rot

The survey on spread of the disease was carried out in three major sugarcane growing districts viz., Valsad, Navsari and Surat of South Gujarat. The disease was ranging form 0.09 to 5.83 per cent in different sugar factory areas with an average of 1.57 per cent. The incidence was more in ratoon crop (2.18 %) as compared to plant crop (1.19 %). These observations are also tallied with the observations of earlier workers (Anon, 1999a and Patel, 2000). This suggests to avoid ratooning of susceptible varieties in red rot prone areas.

5.2.2 Varieties infected by red rot

During the survey for red rot in different varieties, the red rot was noticed only on CoC 671 and Co 86032 in Bardoli, Sayan and Chalthan sugar factory areas. The other varieties found free form this

disease. The area covered by CoC 671 and Co 86032 was about 20.78 per cent in Sayan, Bardoli and Chalthan sugar factory areas. These two varieties were reported highly susceptible to the disease earlier (Anon., 1999a). Cultivar CoC 671 was occupying a chief position and cultivated in about 70-80 per cent of total sugarcane cultivated area under South Gujarat during early and mid 90s. Due to monoculturing of this single genotype, the disease became more devastating than wilt in South Gujarat. The incidence was reported form 20 to 80 par cent in some of the fields. The disease incidence was so severe that in epidemic areas, farmers could harvest 5 to 25 t ha^{-1} instead of 90-100 t ha^{-1} (Lal and Singh, 1998).

During recent survey, it was observed that area covered by susceptible varieties viz., CoC 671 and Co 86032 reduced from 70-80 to 20.78 per cent due to replacement of these susceptible varieties by other tolerant and resistant varieties. Hence, the incidence and spread of the red rot disease under South Gujarat also reduced. This also suggest to give more attention on this problem to attain economic return from sugarcane cultivated areas of South Gujarat.

5.3 Loss assessment

5.3.1 Quantitative losses

Marked reduction was observed in all the growth parameters due to red rot infection. Reduction in cane length, cane girth, number of internodes and cane weight was 2.15 to 15.31, 1.36 to 16.91, 2.40 to 19.04 and 5.00 to 80.60 per cent, respectively.

Sugarcane varieties CoC 671 and Co 86032 being highly susceptible and Co 85019 being susceptible were severely affected in all the respects. Cane length was adversely affected in susceptible variety CoN 95132 as compared to other growth parameters while

resistant varieties viz., Co 6806, Co 86249 and moderately resistant varieties CoN 91132, 86 A 146 and Co 87263 were least affected showing very low reduction in all the parameters as compared to other. In general, susceptible varieties affected severely and resistant were affected least. These findings are similar to those reported by earlier workers (Kar and Verma, 1962; Sandhu *et al.*, 1969 and Patel, 2000).

5.3.2 Qualitative losses

The red rot disease adversely affected the juice quality of sugarcane. The per cent reduction in brix, pol, purity, extraction and C. S. S. was ranging from 6.78 to 40.10, 7.8 to 51.47, 1.13 to 29.00, 5.10 to 64.77 and 9.45 to 65.90 per cent, respectively in different sugarcane varieties tested.

The highly susceptible varieties viz., CoC 671, Co 86032 and Co 91121 were severely affected and remarkable reduction in all the juice parameters was observed. The reduction was lower in resistant varieties viz., Co 6806 and Co 86249 and moderately resistant varieties viz., 86 A 146 and CoN 91132 and Co 87263. The extent of loss of quality parameters was correlated with the category of resistance.

These findings are similar to those reported by earlier workers (Kar and Verma, 1962; Sandhu *et al.*, 1969; Singh and Waraitch, 1981 and Rao *et al.*, 1984). Beniwal *et al.* (1989 b) reported least reduction in quality parameters in varieties with high level of resistance and maximum in varieties with low level of resistance. Our findings are in conformity to this.

5.4 Screening of sugarcane varieties against red rot *in vivo*

Twenty five sugarcane varieties were screened against red rot by international standard plug method keeping CoC 671 as susceptible and Co 6806 as resistant check. Only three varieties viz., Co 6806, Co 86249 and CoSi 98071 were resistant, six varieties viz., 86 A 146, C0 87263, CoC 92020, CoN 91132, CoLk 8001 and CoN 85134 were moderately resistant, seven varieties viz., Co 7805, Co 85001, Co 86002, Co 6415, Co 91014, Co 8338 and CoSi 98061 found moderately susceptible, three varieties viz., Co 87002, Co 85019 and CoN 97132 were susceptible and six varieties viz., Co 91121, CoN 97134, CoN 95132, Co 86032, CoC 671 and Co 7318 were highly susceptible.

These results are similar with the results obtained by earlier workers (Patel *et al.*, 1999; Sabalpara *et al.*, 1999 and Patel, 2000).

These sources of resistance can be used in crossing programme or evaluated for agronomical and breeding aspects to find out suitability in the area.

5.5 Biological control

In the present study an attempt was made to find out the eco-friendly, cheaper and effective control method instead of chemical control:

5.5.1 Testing of cultural filtrates of different antagonists against *C. falcatum in vitro*

5.5.1.1 Fungal antagonists

The cultural filtrates of seven different fungal antagonists were taken for this study and tested against *C. falcatum in vitro* at three levels of concentrations by poisoned food technique.

All the antagonists found significantly superior at all the three concentrations of cultural filtrates tested as compared to the control. The cultural filtrate of *Aspergillus flavus* @ 25 per cent proved significantly superior over the rest showing minimum radial growth (13 mm). The next best cultural filtrate was of *A. niger* @ 25 per cent (17 mm) and *A. niger* @ 15 per cent (21 mm). Maximum growth inhibition of *C. falcatum* was recorded in *A. flavus* @ 25 per cent V/V (70.29 %) followed by *A. niger* @ 25 per cent V/V (61.14 %) and *A. niger* @ 15 per cent V/V (52.0 %) The sporulation was not observed in *A. flavus* (@ 25 %) and *A. niger* (@ 25 %). In other treatment, it was partially inhibited as compared to control. The *Trichoderma* spp., *Chaetomium globosum* and *Gliocladium virens* were also effective at higher concentration.

The inhibitory effect of non volatile metabolites of *Trichoderma* spp. against a wide range of fungi has already been reported by Dennis and Webster (1971). The antifungal and antibacterial properties of *Trichoderma* spp. due to trichodermin, dermatin (Godtfredsen and Vangedal, 1965; Pyke and Diets, 1966), suzakacillin and alamethicin (Coka *et al.*, 1966; Mayer and Reusser, 1967) have been reported. The inhibitory effect of *T. harzianum* and *C. globosum* was earlier reported by Iqbal *et al.* (1995) on *C. falcatum*, which is in close conformity with the present results. The suppression of the mycelial growth of *C. falcatum* by *T. viride* has been reported by Revathi *et al.* (1997). *Aspergillus* spp. are known for their inhibitory effect against *Alternaria solani, Drechslera oryzae, Sclerotium oryzae* (Usmani, 1981; Gupta, *et al.*, 1985; Jariwala *et al.*, 1991). *Gliocladium virens* and *Chaetomium globosum* have been reported to check the

mycelial growth of *C. falcatum in vitro* by Patel (2000). These results are in confirmity with the present investigations.

The production of antifungal metabolites might be the main inhibitory factor in the cultural filtrates. Different growth values and inhibition of sporulation were obtained by adding different concentrations of cultural filtrates to the basal medium. Dennis and Webster (1971) reported that the extent of growth inhibition depends on the volume of filtrates used. This could be assigned to nature, quality and quantity of inhibitory substances present.

The present investigation provides information on the inhibitory effect of *Trichoderma* spp., *Aspergillus* spp., *G. virens* and *C. globosum* on *C. falcatum* by production of antifungal substances. These can be used as potential biological control agent of red rot. Further investigations on field efficacy and application is suggested.

5.5.1.2 Bacterial antagonists

The filtrates of both bacterial antagonists obtained after culturing on two different media proved to reduce mycelial growth of *C. falcatum* significantly over control. The filtrate of *Pseudomonas fluorescens* cultured in King's B medium proved most effective.

The sporulation was not observed in *P. fluorescens* cultured on King's B medium, whereas it was moderately inhibited in rest of the treatments as compared to control. Freitas *et al.* (1997) observed that majority of *Pseudomonas* including *P. fluorescens* were antagonistic to *Colletotrichum gossypii* on King's B medium but not on PDA, indicating possible siderophore production.

The antagonism of *B. subtilis* on *Colletotrichum* sp. was showed by Bravo (1993) and Badel and Kelemu (1994). Our results are in line with their findings.

The fungal and the bacterial antagonists tested here for their antagonistic properties against *C. falcatum* are also found as potential antagonists and the mechanism behind the antagonism might be due to production of non-volatile antibiotics. This is a very useful information.

5.5.2 Efficacy of different antagonists against red rot in pot culture

Seven fungal and two bacterial antagonists were tested in pot as set dip treatment using inoculated setts of highly susceptible variety CoC 671.

The germination of setts was significantly higher in all the antagonist treatments as compared to check (inoculated) except bacterial antagonists. Maximum germination was recorded in *Trichoderma harzianum* and *Aspergillus flavus* (88.53 %) followed by *T. viride*, *A. niger* and *Chaetomium globosum* (79.01 %). The next best antagonists were *G. virens* (64.49 %) and *T.longibrachiatum* (59.98 %), which were at par with each other.

Maximum per cent increase in germination was in *T. harzianum* and *A. flavus* (121.43 %) followed by *T. viride*, *C. globosum*, *A. niger* (97.62 %), *G. virens* (61.30 %), *T. logibrachyatum* (50.02 %).

The per cent disease incidence on cane basis was significantly lower in all the bacterial and fungal antagonists as compared to the check (infected). Among these, *T. harzianum* (15.20 %)

found significantly superior over the rest but it was at par with *T. viride* (17.65 %) and *C. globosum* (17.79 %). The per cent disease control over check was maximum in *T. harzianum* (82.99 %) followed by *T. viride* (80.13 %) and *C. globosum* (79.97 %). From these study, it can be suggested that for increasing germination and disease control, *T. harzianum, T. viride* and *C. globosum* are more effective and suggested for further study.

Shivanna and Shetty (1989) reported that seed treatment with *T. harzianum* and *T. viride* eliminated seed borne inoculum of *Colletotrichum dematium* (Pers. ex Fr.) Grove from cluster bean. *Chaetomium globosum* were also found very effective to get more germination as well as for control of seed borne microflora of cotton (Sohi *et al.*, 1988). For improving germination of sugarcane and reducing red rot incidence, *Chaetomium* sp. and *T. harzianum* earlier proved better by Singh (1994). Sett treatment (in artificially inoculated setts) with *T. viride, T. harzianum, T. longibrachyatum* and *C. globosum* proved effective as it increased germination and reduced red rot incidence (Anon., 1997b). The present results are more or less similar with the earlier studies mentioned.

5.5.3 Bio-efficacy of phyto-extracts against *C. falcatum in vitro*

Phyto-extracts of commonly available seventeen plant species belonging to thirteen different families were evaluated *in vitro* to know their inhibitory effect on growth and sporulation of *C. falcatum*.

All the phyto-extracts significantly inhibited the colony growth of the test pathogen over the control except *Allamanda*.

The maximum inhibition (87.80 %) of the pathogen over control was observed in gando baval (*Prosopis juliflora*), the next best treatment in order of merit was datura (*Datura stramoneum*) and lantana (*Lantana camera*). The remaining plant species showed below 50 per cent inhibition of the fungal growth.

There was no sporulation observed in the treatments of gando baval, datura, lantana, ginger, onion, ajmo and ajilo whereas moderate inhibition of sporulation was observed in turmeric, mango turmeric, *Polylanthia*, *Allamanda*, fudina and garlic. In pashugandha no any effect was noticed but in vachhnag stimulatory effect was observed.

Tannin bearing plants showed inhibitory effect on spore germination of *Pyricularia oryzae* and *C. falcatum* at 10.0 g l^{-1} (Janardhan and Ganguly, 1963). Seikh and Agnihotri (1972) reported the antifungal properties of 91 commonly occurring plants *in vitro* against *Alternaria brassicae*, *Colletotrichum papaya* and *Helminthosporium* sp. and observed that extracts of datura and garlic completely inhibited spore germination. Patel (1978) observed that 5 per cent extracts of datura, ginger, mango turmeric and turmeric were equally effective for inhibiting growth of *C. gloeosporioides in vitro*

From this study it can be suggested that gando baval, datura and lantana are very effective phyto-extracts against *C. falcatum* and the botanical fungicides can be developed form these for eco-friendly, economic and effective management of the disease. Further study in detail is suggested. The extract of vacchnag found to produce more sporulation. This findings can be useful to study the physiological and

morphological studies of the pathogen or it can be incorporated in media for the for the multiplication of the pathogen.

5.5.4 Bio-efficacy of organic extracts against *C. falcatum in vitro*

Different organic sources which are commonly used as soil amendments were subjected for extraction and aqueous extracts obtained These were evaluated to know their effect on *C. falcatum* by poisoned food technique.

All the organic extracts significantly reduced mycelial growth of the pathogen over control however vermicompost significantly increased the mycelial growth of pathogen over control. The extracts of castor cake, poultry manure and pressmud were found totally inhibitory showing their fungicidal effect on the pathogen The extract of mustard cake significantly inhibited the radial growth of pathogen and next best in order of merit were farm yard manure and neem cake.

The fungus did not sporulate in the extract of mustard cake whereas it was lower in neem and FYM extracts as compared to the control. While in the extract of vermicompost, it was observed more.

Singh (1985) reported baggase, margoses and castor cake as effective soil amendments for reducing red rot incidence and increasing the population of useful soil microflora. Application of pressmud and bagasse significantly reduced red rot incidence (Saharan *et al.*, 1994). Patel (2000) reported that neem seed kernel extract significantly inhibited the growth of *C. falcatum in vitro*.

Anadani (1995) reported that unsterilized extracts of neem, castor and mustard cake had inhibitory effect on *Fusarium moniliformae*

causing wilt of sugarcane *in vitro*. Vala *et al.* (1997) reported application of castor cake and neem cake @ 25 t ha^{-1}, pressmud and FYM @ 50 t ha^{-1} to reduce wilt incidence and increased yield under South Gujarat conditions.

Champawat and Pathak (1988) reported reduction in cumin wilt (*F. oxysporum* f.sp. *cumini*) by application of castor and mustard cake

The effectiveness of neem cake, castor cake and pressmud on red rot reported in this study more or less tallied with earlier workers. But the effective organic matter viz., mustard cake, poultry manure and farm yard manure found in this study is new and very useful information. The stimulatory effect of vermicompost reported here is also a new information warning against the use of the same in the red rot prone areas. This needs detail investigation. The effective organic matter like castor cake, poultry manure, pressmud, mustard cake, farm yard manure and neem cake can be used as soil amendment for the management of sugarcane red rot.

5.6 Effect of root exudates of various plant species on spore germination of *C. falcatum*

The results showed that all the root exudates significantly inhibited the spore germination of the pathogen over control. Significant lower spore germination (11.33 %) was recorded in root exudates of brinjal over the rest. The other root exudates found better in reducing spore germination are of garlic, chickpea, methi, coriander, onion, mustard, cabbage, sorghum and sesamum. In root exudate of brinjal, maximum inhibition of spore germination (76.79 %) was observed and rest of the exudates were ranging from 40.35 to 69.39 per cent.

Significantly lower length of germ tube was recorded in the root exudates of methi and brinjal. The next best in order of merit were garlic, onion, cabbage, coriander, chickpea, mustard, sorghum and sesamum.

The root exudates are a kind of plant product and they are secondary plant metabolites. Singh *et al.* (1993) reported that the red rot incidence was reduced by growing sugarcane with linseed, mustard or onion as compared to only sugarcane, they also noticed reduction in red rot incidence by crop rotation of sugarcane with garlic, mustard, coriander onion of linseed. The recovery of *C. falcatum* was also higher from rhizosphere of pure sugarcane crop than from the rhizosphere of companion crop. They concluded that the root exudates of linseed, mustard, onion and coriander might have direct or indirect effect on host or pathogen providing protection against the red rot disease.

Lavroko (1962) reported infection of *Pellicularia* in cabbage seedlings was reduced when sown in combination with beet root, garlic and onions. Curl (1982) showed that CO_2, which released from growing root may inhibit many soil borne fungi. Asparagus root exudates contain some bio-chemicals having nematicidal effect (Rice, 1984).

Here, in this experiment, all the root exudates of various crop have shown inhibitory effect on *C. falcatum*. So these results are in line with the conclusions of Singh *et al.* (1993) and also similar to those reported by various workers. This is a very new information that is helpful in deciding crop rotation and intercropping cultural practice for management of red rot disease in sugarcane.

The effectiveness of garlic, coriander, onion and mustard reported here is tallied with the results of Singh *et al.* (1993). But the effectiveness of brinjal, chickpea, methi, cabbage, sorghum and sesamum proved from this study is a new and useful information

From this study it can be suggested that brinjal, garlic, chickpea, coriander, methi, onion, mustard, cabbage, sorghum and sesamum can be grown as companion crop or can be used in crop rotation for the management of sugarcane red rot.

5.7 Chemical control

5.7.1 Bio-efficacy of various fungicides against *C. falcatum in vitro*

In the present investigations, fourteen fungicides with three levels of concentrations were screened *in vitro* by poisoned food technique for their effect on *C. falcatum*.

The systemic and non-sytemic both the group of fungicides at all the three levels of concentrations significantly checked the radial growth of pathogen over control.

Among the systemic group, cent per cent inhibition of mycelial growth of fungus over control was observed with Cyproconazole (San) at 100, 250 and 500 ppm; Hexaconazole (Contaf) at 250 and 500 ppm; Propiconazole (Tilt) at 250 and 500 ppm; Matalaxil · Mancozeb (Ridomil-MZ), Triadémefon (Bayleton), Thophanate methyl (Topsin-M), Carbendazim (Bavistin), Benomyl (Benlate) at 500, 1000 and 1500 ppm while, the next best in order of merit were Fridémorph (Calixin) at 1000 ppm, Hexaconazole (Contaf)

and Propiconazole (Tilt) at 100 ppm, Tridemorph (Calixin) at 500 ppm and 250 ppm also inhibited the mycelial growth of the pathogen

Carbendazim (Bavistin) is a chitin inhibitor and according to Garg and Mehrotra (1975), it is known to reduce activities of polygalacturonase and cellulolytic enzymes and inhibits the mycelial growth of *Fusarium solani* Many workers reported same trend that carbendazim is most effective against *Colletotrichum* sp including *C. falcatum* (Patel, 1978; Saifulla and Ranganathan, 1978; Khirbat *et al.*, 1984; Rahman *et al.*, 1994; Goswami *et al.*, 1996 and Patel, 2000). The fungicidal activity of Propiconazole ((Rahman *et al.*, 1994; Goswami *et al.*, 1996) and Thiophanate methyl (Agnihotri, 1996) against *Colletotrichum* sp. including *C. falcatum* have been reported Their views are also in agreement with this results. Patel (2000) reported Triademefon having fungicidal effect on *C. falcatum* at 500 and 1000 ppm which is also in close conformity with the findings

Among the non-systemic fungicides, all the fungicides viz., Ziram, Chlorthalin, Mancozeb, MEMC showed cent per cent inhibition of *C. falcatum in vitro* showing fungicidal effect at all the tested concentrations.

The fungitoxic effect of Ziram (Narain and Panigrahi, 1971), Mancozeb (Saifulla and Ranganathan, 1978; Goswami *et al.*, 1996), heavy metal toxicant like Ceresan and Aretan (Agnihotri, 1996), MEMC (Patel, 2000) have been reported against *Colletotrichum* sp. by earlier workers, their views are also in agreement with our findings.

The fungicidal activity of Benzimidazoles (Carbendazim and Benomyl), Triazoles (Propiconazole, Cyproconazole and Hexaconazole) and the other group of fungicides and among the

non-systemic fungicides the fungicidal effect of all the tested fungicides in this experiment were found promising and can be used as sett dip treatment for the eradication of pathogen from the sett

5.7.2 Bio-efficacy of fungicides against red rot in pot culture

Different fungicides found effective during *in vitro* screening and were further tested to know their eradicant effect on the pathogen as sett dip treatment in pot culture Naturally infected setts of highly susceptible variety CoC 671 were used in this trial

All the treatments proved significantly superior over the rest giving more germination except Triadimefon Significantly higher germination was observed with MEMC (Emisan), Carbendazim (Bavistin) and Benomyl (Benlate) (59.98 %), over the rest and check. The next best treatments in order of merit were Copper oxychloride (Blitox), Thiophanate methyl (Topsin-M), Hexaconazole (Contaf), Propiconazole (Tilt) and Cyproconazole (San). All the treatments except Triadimefon (Bayleton) induced germination ranging from 68.48 to 193.01 per cent as compared to the check infected. Highest germination (79.01 %) was recorded when healthy setts were planted without giving sett treatment. The per cent germination in the setts planted from healthy setts increased over infected setts were 285.98 per cent.

All the fungicides significantly reduced red rot incidence over the infected check. The disease incidence per cent on cane basis was found significantly lower in the treatment of Carbendazim (26.63 %) which was at par with MEMC (28.75 %). Next best treatments in order of merit were Thiophanate methyl (Topsin-M), Benomyl (Benlet), Triadimefon (Bayleton), Cyproconazole (San), Propiconazole (Tilt)

and Hexaconazole (Contaf) However, the disease incidence was significantly higher in all the fungicidal treatments as compared to the check healthy. The per cent disease control (P D. C.) over the infected check was highest in the treatment of Carbendazim (Bavistin - 70.02 %) followed by MEMC (Emisan - 67.64 %) and Thiophanate methyl (Topsin-M - 58.50 %) There was less than 50 per cent disease control over check in the rest of the treatments.

Looking to the effect of fungicidal treatments on germination and per cent disease control, Carbendazim (Bavistin) and MEMC (Emisan) found better than the rest fungicides.

Chand *et al.* (1974) reported sett dip treatment to two eye-buded naturally infected setts with Benlet and Vitavax increasing germination by 50 per cent and controlled *C. falcatum*. Pre-plant treatment to healthy setts with Agallol (0.5 %) for 15 minutes and planted in sick soil gave excellent control of sugarcane red rot (Lewin et al., 1970). Waraitch (1983) observed good control of red rot and higher germination through sett treatment with Bavistin (0.5 %) for 1 hr to three eye-buded naturally infected sugarcane setts and Benlate was also reported effective. Saharan and Satyavir (1988) reported that one hour treatment of Bavistin (0.25 %) to the three eye-budded setts of Cv. Col. 29 was effective f for reducing red rot. Fungicidal treatment to healthy setts of highly susceptible Cv. CoC 671 with MEMC (Emisan @ 2 g l^{-1}) and Carbendazim (Bavistin @ 2 g l^{-1}) and planting in red rot - wilt complex sick soil gave significant results (Anon., 1999a).

There are a large number of factors of variation in fungicidal effectiveness viz., length of sett, treatment time, type of infection

(natural soil infection, natural sett infection), types of chemical (systemic or contact) and its concentration However, the present results are more or less tallied with those reported earlier

The efficacy of Carbendazim (Bavistin @ 0.1 %) and MEMC (Emisan @ 0.2 %) as sett dip treatment for 30 minutes to naturally infected two eye-buded setts of highly susceptible Cv. CoC 671 observed here to increase germination as well as dicrease red rot incidence.

5.7.3 Efficacy of fungicides against red rot with respect to treatment time and length of setts

The fungicides viz., Carbendazim (Bavistin @ 1 g l^{-1}) and MEMC (Emisan @ 2 g l^{-1}) found most effective during *in vitro* and pot culture screening were selected to know their eradicant effect on red rot with respect to time of treatment (10 and 20 minutes) and length of setts (1, 2 and 3 eye-buded setts).

The results showed that Bavistin (1.0 g l^{-1}) was effective as there was no fungal growth when singal eye-buded setts were treated for 10 or 20 minutes while for the treatment of two eye-buded setts, only 20 minutes dipping was effective. From the three eye-buded setts, the pathogen could not be eradicated in 10 or 20 minutes treatment as the growth of the pathogen was observed in these setts after 10 days of isolation. Emisan was effective in all the treatments except two eye-buded setts and three eye-buded setts dipped for 10 minutes.

It is obvious from the results that as the time of sett dip treatment increases, the efficacy of both the fungicides (Carbendazim and MEMC) increases. Waraitch (1983) reported efficacy of Bavistin

increased as the time of sett dip treatment increased. Saharan and Satyavir (1988) reported similar results. Dipping the setts in Agallol (0.5 %) for 15 minutes effectively controlled *C. falcatum* (Lewin *et al.*, 1976). MEMC is good contact fungicide and also act as fumigant (Nene and Thapliyal, 1993). This fact may be responsible for increasing the efficacy of MEMC with increasing time. The present results are more or less in line with earlier reports.

The efficacy of fungicides to eradicate the pathogen from different types of setts studied here is a new information. The eradicant effect of Carbendazim (Bavistin @ 0.1 %) and MEMC (Emisan @ 0.2 %) on one eye-buded setts at 10 or 20 minutes dip; two eye-buded setts at 20 minutes only was found as eradicant as there is no fungal growth This is also a new information.

5.8 Integrated management of red rot in pot culture

With the aim of finding out effective, economical and eco-friendly method of red rot management, a pot culture experiment was carried out.

The germination was significantly higher in all the treatments except *Lantana camera*. Among these, MEMC and Carbendazim (88.53 %) were proved significantly superior and at par with *Prosopis juliflora* (81.39 %), *T. harzianum* and *Datura stramoneum* (74.25 %).

Maximum increase in germination over check inoculated was recorded in MEMC and Carbendazim followed by *P. juliflora*. *D. stramoneum*, *T. harzianum* and *L. camera*.

The germination of all the treatments was also statistically at par with check (healthy) except *L. camera*.

The red rot incidence recorded significantly lower in MEMC which was at par with Carbendazim. The next best treatments in order of merit were *T. harzianum* and *P. juliflora*. The treatments of *D. stramoneum* and *L. camera* were at par with check inoculated. It was also observed that a significant higher red rot incidence was observed in all the treatments as compared to check healthy. The per cent disease control over check inoculated was highest in MEMC followed by Carbendazim and *T. harzianum*.

The results obtained in this experiment are tallied with the views of Natrajan *et al* (1997) and Shukla and Sinha (1998). They reviewed various methods for integrated management of red rot and suggested the use of antagonist viz., *T. harzianum*. The extract of *P. juliflora* significantly increased germination and decreased disease incidence but the remaining botanicals failed to reduce the disease incidence.

SUMMARY AND CONCLUSIONS

VI SUMMARY AND CONCLUSION

Sugarcane is the most important cash crop grown extensively under South Gujarat conditions. The red rot has become the most important disease of sugarcane during recent years with a severe threat to successful and profitable cultivation of the crop in South Gujarat area Most popular varieties CoC 671 and Co 86032 succumbed to this disease, causing heavy losses in yield and sugar recovery. The present investigations were carried out to pin point exact cause, symptomatology, occurrence and spread of the disease in this area, losses caused by the disease and to develop effective, economical and eco-friendly methods for disease management.

Microscopic examination and tissue isolation from nodal and internodal tissues of the infected sugarcane plant yielded pure culture of *Colletotrichum* sp. The typical symptoms of the disease were observed at all the stages of crop growth. At early stage, sett rot and settling blight were observed while at later stage during rainy season the symptoms observed on third and/or forth leaf of the infected canes, showed yellowing, drooping, rolling, withering of leaf and finally drying of the crown. The leaves showing the symptoms of red elongated lesions on midrib and reddish brown speaks on leaf lamina with reddish patches on leaf sheath particularly on Cv. CoC 91061 On splitting the infected canes, reddening of internal tissues with white spots were observed which emitted a strong alcoholic smell

On the basis of morphological and cultural characters, *Colletotrichum* sp. was identified as *Colletotrichum falcatum* Went This was also confirmed through identification by I. T. C. C. I. A. R. I.

New Delhi (ITCC No. 3923-99). The pathogenicity was tested by soil, sett, soil-cum-sett, cotton swab and plug method of inoculation, produced typical red rot symptoms similar to those observed under natural conditions and described in the literature, confirming pathogenic nature of the fungus, meanwhile the reoccurrence, primary source of infection and spread of the disease through infected setts.

The survey for occurrence and spread of red rot disease in South Gujarat during the year 1999-2000, revealed that 1.19 per cent area in plant crop and 2.18 per cent area under ratoon crops was found to be affected by red rot. The incidence was more in ratoon crops as compared to plant crops. In another survey carried out in Sayan, Bardoli and Chalthan sugar factory areas regarding the red rot incidence in different commonly grown varieties, the varieties viz., Co 86002, Co 8208, Mc 707, CoSi 95071, CoC 91061, Co 8338, CoN 91132, Co 86010, etc. were found free from red rot infection while CoC 671 and CoC 86032 found to be infected The area under these two varieties was about 21 per cent of total sugarcane cultivated area. It is concluded from this survey that due to replacement of susceptible varieties with tolerant and resistant varieties, the incidence was reduced, otherwise only CoC 671 was cultivated in about 70 to 80 per cent area which led to epiphytotics of red rot under South Gujarat conditions earlier years.

During assessment of losses, a drastic reduction in quantitative and qualitative parameters were observed. The reduction in cane length, cane girth, number of internodes and cane weight recorded ranging from 2.15 to 15.31, 1.36 to 16.91, 2.40 to 19.04 and 5.00 to 80.60 per cent, respectively in different varieties tested. The reduction in brix, pol, purity, extraction and C C S recorded ranging from 6.78

to 40.10, 7.80 to 51.47, 1.13 to 29.00, 6.10 to 64.17, 9.45 to 65.90 per cent, respectively in different sugarcane varieties tested. Maximum losses of both qualitative and quantitative parameters were recorded in highly susceptible varieties viz., CoC 671, Co 86032 and Co 91121 followed by susceptible varieties viz., Co 85019, CoN 95132, CoN 97134 while minimum losses were recorded in resistant varieties viz., Co 86249 and Co 6806 and moderately susceptible varieties viz., 86 A 146, Co 87263, CoN 91132 and CoC 92020. Thus, it can be concluded from this result that the losses due to red rot are inversely proportional with the level of resistance.

Twenty five ruling and new varieties were screened for resistance against red rot disease *in vivo*. Of these, Co 6806, Co 86249 and CoSi 98071 were found resistant, 86 A 146, Co 87263, CoC 92020, CoN 91132, CoLk 8001 and CoN 85134 were moderately resistant, Co 7805, Co 85001, Co 86002, Co 6415, Co 91014, Co 8338 and CoSi 98061 found moderately susceptible, Co 91121, Co 87002, Co 85019 and CoN 97132 were susceptible; Co 86032, CoC 671, Co 7318, CoN 97134 and Co 91121 showed highly susceptible reaction against the disease.

The cultural filtrates of seven fungal and two bacterial antagonists were tested to know their inhibitory effect on *C. falcatum in vitro*. All the fungal antagonists tested at three levels of concentration were significantly superior over control. Among these, *Aspergillus flavus* (@ 25 % conc.) proved significantly superior over the rest. *A. niger* (@ 25 % and 15 % conc.), *Trichoderma harzianum* (@ 25 % conc.), *Gliocladium virens* (@ 25 % and 15 % conc.), *Chaetomium globosum* (@ 25 % and 15 % conc.) were proved better in

checking the mycelial growth of the pathogen. Among the bacterial antagonists, the filtrates of *Pseudomonas fluorescens* (cultured in King's B medium) inhibited maximum growth of the pathogen It is obvious from the results that as the concentration of cultural filtrates increases, the radial growth of the pathogen decreases. The pathogen did not sporulate in the treatments of *A. flavus* and *A. niger* (@ 25 % conc.) while in other treatments, there was moderate inhibition of sporulation. In case of bacterial antagonists, the sporulation was totally inhibited in *P. fluorescens* (cultured in King's B medium) while in other treatments, there was moderate sporulation. The fungal and bacterial antagonists tested here are found potential antagonists and mechanism behind the antagonism might be due to production of non-volatile antibiotics.

Nine different antagonists including seven fungal and two bacterial were evaluated in pot as sett dip treatment. The setts of highly susceptible variety CoC 671 were first artificially inoculated and then dipped in the respective suspension of antagonists. Looking to their effect on germination and disease control, *Trichoderma harzianum*, *T. viride* and *Chaetomium globosum* were found superior antagonists as compared to the rest of fungal antagonists. The remaining antagonists were also found as good biological agent except the bacterial antagonists.

The phyto-extracts of commonly available 17 plant species were evaluated *in vitro* by poisoned food technique against *C. falcatum*. Phyto-extract of gando baval had strong inhibitory effect on *C. falcatum* followed by datura, lantana, kuvadio, mango turmeric, turmeric, pashugandha, Polylthia, ajmo neem seed extract, garlic, ginger, ajilo,

onion and fudina. while the extract of Allamanda was found stimulatory to the growth of the fungus The extracts of gando baval, datura, lantana, ginger. onion, ajmo and ajilo found to inhibit sporulation while a moderate inhibition of sporulation was observed in neem seed extract, kuvadio, turmeric. Polylthia, fudina, garlic, mango turmeric and Allamanda. The sporulation was not affected by the extract of pashugandha whereas it was stimulated in the extract of vachhnag.

The extracts of different organic materials which are commonly applied in soil were tested to know their effect on *C. falcatum* by poisoned food technique *in vitro*. The extracts of castor cake, poultry manure and pressmud were observed to be fungicidal to the pathogen whereas the extracts of mustard cake, farm yard manure and neem cake inhibited the fungal growth in varying degrees. However, the extract of vermi compost found to induce the fungal growth. The sporulation was not observed in mustard cake while it was inhibited moderately in farm yard manure and neem cake extracts. The extract of vermi compost found to induce the sporulation.

The root exudates of different crop species were obtained and these were evaluated for their effect on spore germination of *C. falcatum*. All the root exudates of different plant species found significantly superior over the control in checking spore germination Among these, the root exudates of brinjal proved the most effective in reducing spore germination. The next best treatments in order of merit were garlic, chickpea, methi, coriander, onion, mustard, cabbage, sorghum and sesamum. The root exudates of different plant species also found to reduce the length of germ tube significantly as compared to

control, root exudates of methi and brinjal were significantly superior over the rest.

Fourteen fungicides belonging to systemic and non-systemic group with three levels of concentration were evaluated *in vitro* by poisoned food technique. In systemic group, the fungicides viz., Cyproconazole, Metallaxyl + Mancozeb, Triadimefon, Thiophanate methyl, Carbendazim and Benomyl at all the concentrations inhibited cent per cent mycelial growth of the pathogen except Triademorph at all the concentrations and Hexaconazole and Propiconazole at 100 ppm concentration. Among the non-systemic group, Ziram, Chlorothalonil, Mancozeb, MEMC and Copper oxychloride inhibited cent per cent fungal growth.

Almost all the fungicides found to be effective in inhibiting the mycelial growth of *C. falcatum in vitro*. Among them, nine fungicides were selected for pot culture experiment as sett dip treatment. It is concluded from this experiment that Carbendazim (Bavistin @ 0.1 %) and MEMC (Emisan @ 0.2 %) are good fungicides as they increased germination and reduced disease incidence considerably.

The fungicides viz., Bavistin (0.1 %) and Emisan (0.2 %) found effective in pot culture experiment were further tested as sett dip treatment at two different levels of time and three different length of setts to know their eradicant effect.

It can be concluded from this experiment that Carbendazim (0.1 %) was effective for eradication of *C. falcatum* when one eye-budded naturally infected setts were dipped for 10 and 20 minutes and also two eye-budded infected setts dipped for 20 minutes. It could

not be eradicated from three eye-budded setts treated for 10 and 20 minutes. MEMC (0.2 %) was effective at all the levels of time and different length of setts except two eye-budded and three eye-budded setts dipped for 10 minutes.

With a view to find out most effective, economical and eco-friendly way to manage the disease the experiment on integrated management was planned in pot. Artificially infected setts of Cv. CoC 671 were treated with two fungicides, three phyto-extracts and one antagonist. Among these, the fungicides viz., Carbendazim and MEMC found significantly superior over the rest. The phyto-extract of gando baval emerged as good botanical fungicide. The bio-agent *Trichoderma harzianum* was also found good. However, the chemical fungicides found superior over the biological and botanical fungicides, it can be safely concluded from this experiment that healthy setts should be planted to increase germination as well as to control the disease. The setts which carry external invisible infection may be treated with the extracts of gando baval @ 5 per cent W/V or *T. harzianum* @ 10^8 c.f.u./ml of suspension. If two eye-budded setts of susceptible variety taken from a red rot prone area, it must be treated with MEMC (0.2 %) or Carbendazim (0.1 %) for 10 minutes before planting.

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* Original not seen

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