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REVIEW

Biological control of major sugarcane diseases using microbes –A review

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Sugarcane (*Saccharum officinarum* L.) is a major source of sugar and cultivated >110 countries worldwide, covering about 26.34 million hectares and yielding approximately 1,859.39 million tons for sugar and bio-energy production. Globally, India ranked second in the production of sugarcane after Brazil, accounting for about 25% of the world's production. Sugarcane crop faces significant threats from various diseases caused by fungi, bacteria, viruses, phytoplasmas and nematodes. Among the sugarcane diseases, red rot, wilt, smut, pokkahboeng, grassy shoot, mosaic, yellow leaf disease, leaf scald, ratoon stunting disease and sett rot are found to be of economic importance. Over reliance on chemical pesticides have lead to the development of resistant pathogen strains, necessitating higher doses and more toxic chemicals. To combat these issues, an eco-friendly approach particularly using microbes to minimize the use of chemical pesticides, promoting sustainable agriculture and environmental health.Biocontrol offers a viable alternative by providing natural disease suppression without contributing to resistance. The major sources of these antagonistic microbes are rhizospheric soil, phyllosphere and endophytes which are found potential to suppress sugarcane diseases. Effective fungal and bacterial antagonists have been identified and tested both in laboratory and field conditions. Key strategies followed by fungal antagonist like *Trichoderma* are antibiosis, competition for food and niche, mycoparasitism, and induced resistance, while bacterial antagonist such as *Pseudomonas* and *Bacillus* species suppress fungal, and bacterial pathogens via antibiotic production,competition and induced systemic resistance. Examples of successful biological control include use of *Trichoderma, Chaetomium, Pseudomonas, Bacillus* and *Paenibacillus* species for the management of majordiseases of sugarcane. Integration with other disease management practices like moist hot air treatment, consortia of microbes, resistant varieties and low doses of chemical and cultural practices is essential to improve bio-efficacy of biocontrol agents. In this review paper, major diseases of sugarcane andtheir biocontrol using microbes has been described. Overall, biological control represents a promising, sustainable solution for managing sugarcane diseases, supporting long-term productivity and environmental safety.

Keywords : Antagonist, biological control, sugarcane diseases, Microbes

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most important commercial crops after cotton in > 110 countries of the world. It contributes nearly 70% of world sugar and provides the base materials essential for many other industries. Globally, the sugarcane is probably the most ancient and one of the important crops cultivated in the tropical and subtropical countries for the production of sugar, ethanol and other products including molasses, falernum, cachaça, rum and bagasse. In some parts of the world people use sugarcane reeds to make mats, pens, thatch and screens (Anonymous, 2017-2018). Globally, sugarcane is cultivated across roughly 26 to 27 million hectares, yielding approximately 1.9 to 2.0 billion metric tons annually. Braziland India dominate the global market, jointly accounting for more than half of the worldwide sugarcane output, which is then processed into an estimated 185 to 189 million metric tons of sugar (United States Department of Agriculture Foreign Agricultural Service, 2025). India is the second largest sugarcane producing country with an annual output of roughly 450 - 500 million metric tons of

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sugarcane, heavily driven by high domestic consumption and biofuel policies. In India, Uttar Pradesh has the largest area under cane production (~50% of the cane area in the country) followed by Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Bihar, Haryana and Punjab (Anonymous, 2017- 2018).

Sugarcane crop is attacked by numerous foliar and root pathogens. Some of these diseases cause serious quantitative and qualitative losses which have negative effects on sugarcane production, as well as in the sugar industry. Diseases are the major constraint to sugarcane cultivation in general and various fungal and viral diseases affect sugarcane germplasm. More than 240 diseases have been reported from all over the world in sugarcane (Rott *et al.* 2000). However, about 56 diseases of sugarcane reported so far from different parts of the world have significant important in reduction of yield. Out of these, 40 diseases are caused by fungi and several of which can cause economic losses. About 10–15 % of the nation sugar produced is lost due to the diseases in India (Viswanathan and Rao, 2011; Kurian and Jehani, 2023; Singh *et al.* 2025). Red rot, smut, rust, wilt, leaf scald, yellow leaf disease (YLD), grassy shoot disease (GSD), ratoon stunting disease (RSD) (Singh *et al.* 2023) and mosaic are the important diseases of sugarcane (Viswanathan and Rao, 2011; Viswanathan 2012, Latha *et al.* 2026). The major sugarcane fungal diseases in different tropical and subtropical regions are: smut disease (*Ustilagoscitaminea*); rust disease (*Puccinia melanocephela*); red rot (*Glomerella-tucumanensis* [*Colletotrichum falcatum*]); eye spot disease (*Bipolaris sacchari*), pokkahboeng disease (*Fusarium moniliforme and F. fujikuroi*), pineapple disease (*Ceratocystis paradoxa*) and grassy shoot diseases (*Candidatus* Phytoplasma sacchari) which affect the production and quality of the sugarcane (Jernisha *et al.* 2024).The major diseases of sugarcane have been described including causal organism, mode of transmission and disease symptoms in (Table.1).

Biological control of major diseases of sugarcane using microbes

Of the various control measures in vogue, biological control particularly using microbes appears to be the best solution for long-term sustainability and effective management of soil-borne diseases (Fravel, 2005; Singh and Singh, 2021). Different biocontrol agents have been integrated with cultural practices, soil solarization, fungicides, and disease-resistant varieties for the management of various diseases in different crops (Gogoi *et al.* 2007; Singh and Singh, 2021; Singh *et al.* 2025). In bacterial antagonists, *Bacillus* and *Pseudomonas* species that are antagonistic are preferable to other biocontrol agents in several aspects, including their widespread presence in soils, high sporulation, extended shelf life, and improved plant nutrition (Hassan *et al.* 2015). Certain *Burkholderia* species have been shown to have characteristics that inhibit disease and encourage plant development (Mendes *et al.* 2007). Fungal biocontrol agents *Trichoderma* species have high antagonistic potential against various diseases in sugarcane. Plants that are subjected to *Trichoderma* spp. can develop systemic resistance, which is an improved defense state (Tiwari *et al.* 2021). A list of potential microbes used to control sugarcane diseases is given in (Table 2)**.** A brief descriptions of biological control using microbes for major sugarcane diseases is given below

Red Rot

Biological control red rot disease of sugarcane was observed to be biologically controlled through *Trichoderma harzianum* and *T. viride*. *T. harzianum* and *Pseudomonas* spp. possess the ability to protect the crop from soil borne inoculum of red rot and the efficacy is because of the chitinase enzyme produced by them. For red rot, bioagents, *viz.* species of *Chaetomium*, *Trichoderma*, and bacterial antagonists individually and in combination of bacterial antagonists were found to be effective in protecting the crop. *T. harzianum* strain Th 37 @ 20 kg/ha on the stubbles at the ratoon initiation stage increased the availability of nitrogen (N), phosphorus (P) and potassium (K) by 27, 65 and 44per cent, respectively and reduced red rot significantly in combination of salicylic acid.*Pseudomonas* spp. induce systemic resistance against C*. falcatum* causing red rot in sugarcane. Iftikhar *et al.* (2023) reported the efficiency of *T. harzianum* and *T. viride* isolated from sugarcane rhizosphere and emphasized on the use of biological control agents as an alternative to chemical pesticides. The bacterial strains significantly reduced red rot pathogen colonization in the stalk tissues and disease progress. Sett treatment followed by soil application of bacterial strains (*P. putida* and *P. fluorescens*) has also reduced the red rot disease development in the crop in pathogen-sick soil. Setts treatment with bacterial strains to pathogen infected setts resulted in higher germination of setts as compared to the untreated setts. The many PR-proteins were linked to the resistance against red rot that was produced by *Pseudomonas* (Viswanathan and Samiyappan, 2006). *Acinetobacter*, and *Klebsiella pneumonia* have antagonistic effects on sugarcane red rot (Bhardwaj *et al.*2017).

Ochrobactrum intermedium TRD14, *Acinetobacter* sp. PK9, *Bacillus* sp. (RSC29 and KR91), and *Escherichia* sp. (VRE34) have been reported to exhibit inhibitory effects on the pathogen *C. falcatum*, concurrently facilitating plant growth in sugarcane. These efficacious strains are utilized as significant bioinoculants for the integrated management of red rot disease in sugarcane (Patel *et al.* 2019). Sett treatment followed by soil application of bacterial strains (*P. putida* and *P. fluorescens)* has also reduced the red rot disease development in the crop in pathogen-sick soil. The fluorescent pseudo-monads (FPs) (also known as plant growth-promoting rhizobacteria (PGPR)) have received prominent attention due to their abundance in the plant rhizosphere. Rhizobacteria and their metabolites are found be quite effective in management of red rot disease in sugarcane (Loper and Gross, 2007; de Vasconcellos- Cardoso, 2009; Vanitha, 2009). Several microbial species have been identified, which showed effective against red rot pathogen as listed (Table1). Most of the studies, however, were based on assay whose, field validation is necessary for calculating its bio-efficacy against red rot disease in sugarcane under field conditions. It is an ecologically friendly method and of great potential in effective control of red rot disease.

Integrated disease management (IDM) practices, like the use of resistant variety, healthy seed from crops raised from heat-treated seed cane, sett treatment with systemic fungicides, rouging of diseased plants, and foliar spray of copper oxychloride and dithiocarbamate fungicides against foliar diseases may be adopted for higher germination and cane yield. *T. viride* (bio-agent) in combination with MHAT and fungicidal treatment (carbendazim) (IDM practice) over a normal package of practice (non-IDM practice) of cane cultivation on red rot incidence, yield, and quality parameters of sugarcane in a moderately red rot susceptible variety was high in IDM treated plot (Singh *et al.* 2008). Sameera *et al.* (2025) reported that sett treatment with carbendazim 50 WP @ 0.1% + soil drenching with *T. harzianum* @ 0.6% + three foliar applications with fungicide azoxystrobin 11% + tebuconazole 18.3% @ 0.1% was found effective to control red rot disease of sugarcane. Antagonistic activity of strains was influenced by addition of thiophanate methyl which resulted in enhanced suppression of fungal growth. Fungicide at lower concentration improved the antagonistic potential of species which may be due to weakening of pathogen by fungicide (Malathi, 2002). Soaking the setts in *T. harzianum* and then in farmyard manure can reduce the red rot infection. Combined inoculation of *Trichoderma* spp. (*T. asperullum*, *T. atroviride*, *T. harzianum* and *T. auroviride*) along with bacterial antagonist *Paenibacillus alvei* also effectively managed red rot in sugarcane (Yadav *et al.* 2008; Singh *et al.* 2008, Elamathi *et al.* 2016).

Wilt

Under *in vitro* and in planta assay, dual culture assay showed that *T. harzianum* strain TRSR-4 inhibited 90.60% growth of *F. sacchari* than untreated control. The sugarcane susceptible var. Co-7717 setts were treated with *T. Harzianum* strain TRSR-4 (Conc. $2x10^6$) for 10 min. After 48 h the pots were soil inoculated with *F. sachhari* ($1.5x\ 10^6$). In planta assay under polyhouse conditions showed 51.67% decrease in wilt than untreated control. Application of *T. harzianum*, *T. viride* and *T. longibrachiatum* in the sick soil was also found effective in the management of sugarcane wilt (Solanki *et al.*2001).The wilt incidence in the susceptible variety CoLk 97169 was considerably reduced and yield was enhanced in soil application of *Trichoderma* (20 kg TMC/ha) followed by sett dipping in Trichoderma spore suspension (10^6spores/ml) before planting (Lal *et al*. 2019). Bhatti and Chohan (1990) found that the strains of *Streptomyces* and *Bacillus* to be highly antagonistic to *Cephalosporium sacchari* (Presently *Fusarium sacchari*) and indicated the possibilities of suppressing it in soil through their use. *Trichoderma* multiply on different substrates and corn Cobbs is good byproduct. *Trichoderma* multiply on it and mix in the soil and reduced wilt incidence under pot conditions (Fatima *et al.* 2024).Sabalpara *et al.* (2009) reported that the antagonism by different *Trichoderma* isolates to sugarcane wilt pathogen was examined by the use of Taijibaiyo dual culture method on PDA medium. For the purpose of controlling sugarcane wilt pathogen and to obtained efficient isolates, seven isolates of *Trichoderma* were tested. The results indicate that all the tested isolates were effective but among them TCN-8, TCN-11 and TCN-12 showed severe antagonism.A total of twenty *Bacillus* isolates from the rhizoplane of commercially grown sugarcane varieties were isolated. Among them, *Bacillus inaquosorum* strain SRB2 and *B. vallismortis* strain SRB20, reduced the seedling mortality by >70% by sett bacterization in *F. sacchari* inoculated pots under greenhouse conditions (Chetan *et al.* 2024).

Smut

Fungal bioagents, like *Trichoderma*, *Aspergilus flavus*, *A. niger*, *Penicillium* spp. etc., have been found antagonistic to *S. scitamineum* by various workers (Vaishnav *et al.* 1992; Miranda *et al.* 1996; Martinez *et al.* 1998). Sinha and Singh (1983) reported that culture filtrate of *Fusarium* sp. completely inhibited the germination of teleiospores of *S. scitamineum*. Culture filtrate (5%) of *T. viride* inhibited mycelial growth and teliospore germination of *S. Scitamine - um*causing smut disease of sugarcane (Lal *et al.* 2009). *Pseudomonas guariconensis* strain ST4 grown on potato dextrose agar (PDA) agar medium, showed strong inhibitory activity on the sexual mating of *S. scitamineum* sporida, without killing the haploid cells MAT-1 or MAT-2.Further analysis showed that only glucose can support strain ST4 to produce antagonistic chemicals, but not sucrose, maltose, and fructose. Addition of 2% glucose to the bacterial inoculum significantly increased the strain ST4 biocontrol efficiency against sugarcane smut disease by 77% than the inoculum without glucose under greenhouse conditions (Liu *et al.* 2017). An attempt was made to explore the potential of endophytic bacteria as a biocontrol agent for the management of smut disease. Out of 119 endophytic bacteria isolated from internode, bud and root,eight exhibited strong antagonistic potential with [30% mycelia growth inhibition of *S. scitamineum* under in vitro conditions. These eight antagonists for their biocontrol potential in two independent glass house experiments were identified four endophytic bacterial strains viz., ESS 9, ESR 3, ESR 7 and ESR 21 as consistent performers (Jayakumar *et al*. 2019). In field trial, the least incidence of smut was recorded in ESR 7-B (14.8%) and ESR 21-B (16.6%) treated plants, i.e., more than 50% reduction in smut incidence over control. These two endophytes also showed potential in improving germination, number of millable canes, yield and juice quality parameters, viz. brix and sucrose. The endophyte *B. pumilus* ESR 21- B and *B. axarquiensis* ESR 7-B treated plants recorded the highest yield of 85.2 and 82.4 kg/plot, respectively, when compared to just 52.2 kg/plot in smut pathogen-inoculated control and 68.3 kg/plot in healthy control.

In Ethiopia, untreated NCo-334 variety of sugarcane demonstrated greater smut intensity followed by untreated Mex 54-245 at Wonji in plant cane. However, ratoon crops prevailed similar trends of infection except that Mex 54-245 treated with Apron, Triadimefon + Native *T. harzianum* (NT) and NT were unable to protect smut (Tegene*et al.* 2024). The seed cane treatment with Opera and Opera + NT could be used for sugarcane smut management. The better protection of the seed cane treatments against smut and the better economic return, irrespective of the varieties, were the main reasons to consider Opera and Opera + NT as candidates for future smut management.

Pokkah Boeing

Pseudomonas fluorescens was used in a seed based bioformulation that not only helped the plant grow but also reduced the prevalence of *F.*

verticillioides, which causes disease in maize (Singh and Nautiyal, 2012). *Bacillus subtilis* is a biocontrol agent that is successful in preventing *F. verticillioides* from proliferation. In sugarcane plants, the application of Bacillus decreased the prevalence of diseases by 45-49% (Hassan *et al.* 2012). The *B. amyloliquefaciens* are potential antagonistic in the control of Pokkah Boeng in the sugarcane (Manjula *et al.* 2017). Several scientists reported that *T. viride* and *T. harzianum* were the most efficient for preventing the infection of Pokkah Boeng disease (Joshi and Misra, 2013). The pathogens *F. fujikuroi* and *F. proliferatum* can both have their maximum mycelial growth inhibited by the *T. harzianum* strain (Tiwari *et al.* 2021).Soil application with bioagents enriched farm yard manure (FYM) in different plots was done before sowing and result showed that all the bioagents suppressed the colony growth of *F. moniliforme*. The suppression of the growth of the pathogen is significantly higher with *T. viride* and *T. harzianum* which were at par among themselves. The minimum inhibition was observed in *T. hamatum, A. niger* and *A. flavus*. Moreover, soil application with *Trichoderma*-enriched FYM gives an additive effect in reducing the incidence of pokkahboeng disease of sugarcane in comparison to those of bioagents alone (Chaudhary *et al.* 2019).The crude biosurfactant rhamnolipid from *Pseudomonas aeruginosa* DS9 effectively inhibited the growth of the plant pathogen *F. sacchari*, with the highest concentration (2.0 g/L) significantly reducing fungal growth by more than 50%, showing a stronger effect than the cell-free culture supernatant or whole culture treatment (Li *et al.*2022). Additionally, several bacteria such as *Nguyenibacter vanlangensis*, *Acidomonas methanolica*, *Asaia bogorensis*, *Tanticharoenia aidae*, *Burkholderia gladioli* and *Bacillus altitudinis* isolated from sugarcane showed strong antagonistic activity against *F. moniliforme*. These bacteria not only controlled diseases, but also promoted plant growth by producing growth-promoting substances such as IAA, siderophores, ammonia, and by solubilizing zinc or phosphate (Pitiwittayakul *et al.* 2021). A combination of phosphite (Phi) and *Trichoderma* Taz-016 effectively controlled *Fusarium* in sugarcane, with 4000 μg/mL Phi and *Trichoderma* Taz-016, resulting in improved plant height, stem length, and leaf dry weight (Solis-Palacios *et al.* 2021). A sett treatments with *P. fluorescens* (Psf02) resulted the lowest disease incidence at 0.92%, followed by the consortium of *Trichoderma* Th14 and *P. fluorescens* Psf02 at 1.51%, and Th14 alone at 5.53% under field conditions (Anshu *et al.* 2022).

Root rot and seedling rots

Incorporating beneficial antagonistic fungi like *Trichoderma* spp. into the soil or potting mix is highly effective at suppressing *Pythium* growth and promoting healthy root development. Geetha *et al.* (2002) who conducted experiment to examine the efficacy of *Pseudomonas fluorescens* in controlling rot in sugarcane caused by *Pythium* sp. The F1 seeds (fluff) of the crosses between CO 671/Si 91104, Si 96118/Si 96115 and S1 980001/Si 96118, and CO 671 GC were used. Treatments included an untreated control, *P. fluorescens* mixed in with a pot mixture in the ratio 1:50 and pot mixture treated with 0.2% copper chloride. Results showed that *P. fluorescens* controlled Pythium rot and also induced the growth of sugarcane seedlings.

Pineapple disease and sett rot

Trichoderma harzianum and bavistin treated sugarcane setts showed significantly higher germination (20.34 to 26.17% higher) over control. Trichoderma harzianum and Bavistin treated sugarcane setts showed respectively 40.72 and 62.69% higher yield of cane compared to control. Hence, *Tharzianum* may be used as bio agent and alternative to Bavistin 50WP (a standard sett treating fungicide of sugarcane) in controlling pineapple disease of sugarcane (Talukder *et al.* 2008). The pathogen (10^7 spores/ml) and T. koningii were applied through spraying on cane setts. A total of 6 treatments, including the negative and positive controls were evaluated. *T. koningii* at 72 hours pre-inoculation inhibited *C. paradoxa* mycelia growth significantly by 86.04% in-vitro, while its prophylactic application brought about rapid and significantly high germination percentages of 75.00 and 80.00 for TK 105 and TK 107 respectively. Percentage germination failure was significantly lowest (20.00) with prophylactic application of TK 107. The highest

Table 1: Major diseases of sugarcane, their causal organism, mode of spread and appearance of symptoms.

Sr. No.	Disease	Causal Organism	Mode of spread of diseases	Appearance of symptoms	References
Fungal diseases					
1.	Red rot	*Colletotrichum falcatum* Went (Perfect stage:*Glomerella tucumanensis* (Speg.) Arx and Muller)	Sett borne	Affected stalks exhibit purplish discoloration of rind and usually spindle leaves followed by other leaves gradually dry up. On splitting the canes length -wise, the internal tissues display red discoloration interrupted by white patches (Fig.1a & b) . The tissue emits smell of vinegar.	Duttamajumder, 2008
2.	Seedling rot/ root rot	*Pythium* spp.(often *P.graminicola* Subramaniam or *P.arrhenomanes* Drechsler)	Sett/ soil borne	Fungus infects the young root tips and shoots, leading to damping -off, dark brown lesions, root decay, stunted growth, and seedling collapse.	Lee and Hoy, 1992
3.	Pokkahboeng	*Fusarium fujikuroi* Nirenberg species complex (FSSC)	Air borne	The characteristics symptoms of Pokkah Boeng disease are the appearance of chlorotic patches towards the base of the young leaves, distortion of stalk with external and internal cut like lesions and rotting of apical part of stalk(Fig. 1c & d).	Huang and Li, 2016
4.	Whip Smut	*Sporisorium scitamineum* (Syd.) M. Piepenbr., M. Stoll & Oberw	Sett borne	Affected plants have slender and thin stalks. The leaves are stiff with acute angle. Emergence of a black whip like structure from central core of meristematic tissue. Whip when young is covered by a thin, white papery membrane. On maturity it ruptures and millions of tiny black teliospores liberated and disseminated by wind(Fig. 1 e).	Bhuiyan *et al.* 2021
5.	Wilt	*Fusarium sacchari* (Butler & Khan) Gams	Sett and soil borne	Appears mainly during monsoon and post - monsoon period. The leaves show yellowing followed by drying from upward. Late in season, crown withers and plant may die. The split open cane manifests dull red colour of internodes and due to drying of tissues the internode becomes hollow. Pith becomes fibrous (Fig. 1 f & g).	Viswanathan *et at.* 2012; Goswami *et al.* 2020
6.	Pineapple disease/ Sett rot	*Ceratocystis paradoxa* (Dade) Moreau. *Thielaviopsis paradoxa* s.lat	Soil borne	Poor germination or wilting of young shoots, characterized by an overripe pineapple smell and internal reddening, browning, or blackening of setts (seed pieces) that eventually turn into black, spore -filled cavities, leading to stunted growth, leaf withering, and eventual plant death.	Comstock *et al.* 1984; Borges *et al.* 2019
7.	Brown rust	*Puccinia melanocephala* Sydow	Air borne	Appears as small, elongated reddish -brown or dark brown spots on both leaf surfaces, which can stunt plant growth	Huang *et al.* 2018

8.	Eye spot disease.	*Bipolaris sacchari* (Butler) Shoem	Air borne	The disease symptoms appear on leaves of sugarcane as le sions that begin as small reddish spots. The spots become elliptical with the long axis parallel to the main veins. The margin is red to brown. The centre of the spot becomes grey or tan. The spots may run together and form long streaks. Sugarcane seedlings may be killed by blight 12-14 days after sowing from a top rot in severe infections.	Huang and Li, 2016
Bacterial diseases					
9.	Ratoon stunting disease (RSD)	*Leifsonia xyli* subsp. *xyli* (Lxx)	Sett borne	Up & down stunted growth, reduced tillering, thin s talks with shortened internodes. During dry conditions, the plants shows distress symptoms such as wilting, scorching of the tips and edges of the leaves. On scrapping the nodes, fibrovascular bundles of the stalk display orange -red to pink dots in several varieties(Fig. 1 h &i).	Huang *et al.* 2018
10.	Leaf scald	*Xanthomonas albilineans*	Sett borne	The disease, in nature, occurs in two distinct phases. *Acute phase* : Affected clumps suddenly show wilt symptoms and die without displaying any of the diagn ostic symptoms. *Chronic phase:* Appears in plants growing under stress conditions, like drought, low temperature, poor soil fertility or in waterlogged condition(Fig. 1j & k).	Ricuad*et al.* 2012
11.	Sugarcane grassy shoot disease	*Candidatus* Phytoplasma sacchari	Sett borne and insect vector *Deltocephalus vulgaris*,	Sugarcane grassy shoot symptoms include profuse, thin tillering (bunchy, grass - like growth), narrow, pale yellow to white leaves (chlorosis), stunted growth (reduced height), and premature sp routing of auxiliary buds, creating a bushy, broom-like appearance and hindering millable cane formation (Fig.1l)	Rao *et al.* 2012
12.	White leaf	*Candidatus* Phytoplasma cynodontis	Set borne and insect vector *Deltocephalus vulgaris*,	Severe chlorosis of entire leaf blades, reduced growth, and occasional stalk death, white line that runs vertically down the middle of the leaf blades., eventually covering the entire leaf length.	Rao *et al.* 2012
Viral diseases					
13.	Mosaic disease	Sugarcane mosaic virus	Sett borne & and insect vector	Mottling of the leaf displays light -green and yellowish patches contrasting with the normal dark-green healthy tissues. Prominent symptoms appear on the basal portion of younger leaves. In severe cases, the cane becomes stunted.	Huang *et al.* 2018
14.	Yellow leaf disease	Sugarcane yellow leaf virus	Sett borne & and insect vector (Aphids, *Melanaphis sacchari* and *Rhopalosiphum maidis*,	Yellowing of leaf tips or midribs on the underside of the leaf that progressively spreads alo ng the veins. As the disease advances, it causes leaf necrosis (browning/drying), stunted growth, and reduced crop yields.	Huang *et al.* 2018
15.	Leaf fleck	*Sugarcane bacilliform virus* (SCBV)	Insect vector (Pink mealy bug (*Saccharicoccus Sacchari*	Major s ymptoms of the disease include appearance of flecks or specks throughout leaf lamina. Gradually, the chlorotic flecks increase in size, turn yellow and reddish. In extremely	Krishna *et al.* 2023

Nematodes					
16.	Root-knot nematode	*Meloidogyne javanica, M. incognita*	Soil borne	Damage roots, leading to stunting, yellowing, poor roo t systems, and significant yield loss, often manifesting as "stubble decline" in ratoon crops.	Bhuiyan *et al.* 2019
17.	Lesion nematode	*Pratylenchus zea*	Soil borne	Common symptoms include yellowing, chlorosis in patches, pale leaves and general stunting o f the plant. Nematodes invade the cortical parenchyma of roots, causing browning and collapse of adjacent cells. Affected roots exhibit red, purple, or brown lesions that eventually turn black and necrotic dark, round or elongated lesions.	Jayakumar *et al.* 2025

(Source: Latha *et al.* 2026)

value recorded for seedling establishment (98.00%), lowest disease incidences and severities (0.00%) from the 4th to 6th months after planting were all recorded for TK 107 prophylactic application. *T. koningii* at 107 is therefore recommended as prophylactic agent against pineapple disease of sugarcane (Ajayi *et al.* 2016).*Bacillus subtilis* QST-713 and *B. pumilus* QST-2808 inhibited mycelial growth of *Thielaviopsis paradoxa*, causing pineapple disease and also helped in growth promotion in sugarcane. However, they did not control the pineapple disease of sugarcane and did not promote sugarcane growth in the growth chamber or in the field (Brandi *et al.* 2018). Biocontrol agents *viz.*, *T.asperellum* (TNAU), *B.subtilis* (TNAU), *Chaetomium globosum* (Cg6) with fungicide check propiconozole 0.1% were used to manage sett rot disease. Among the treatment, highest millable cane (91,080/ha) and yield (91.39 tonnes / ha) and sugar yield (10.63 tonnes/ha) were recorded in single bud treated with *T. asperellum* (TNAU) @ 4 g l^{-1} + soil application @ 2.5 kg ha^{-1}) followed by single bud treated with *B. subtilis* (TNAU)@ 10 g l^{-1} + soil application @ 2.5 kg ha^{-1}) (Yamunarani *et al.* 2023) .

Leaf scald

The albicidin detoxifying bacterium *Pantoea dispersa* (syn. *Erwinia herbicola*) SB1403 provides very effective biocontrol against leaf scald disease in highly susceptible sugarcane cultivars (Zhang and Birch, 1997). Blanco *et al.* (2005) reported that *Gluconacetobacterdia zotrophicus,* a nitrogen-fixing endos-ymbiont of sugarcane antagonizes with *X. albilineans* by impeding the production of the bacterial gum. *Lactococcus lactis* subsp. *lactis* showed antimicrobial activity against *X. albilineans* and is thus a biological alternative for the control of leaf scald disease in sugarcane (Serna-Cock *et al.* 2013a). *Weissella confuse* is a potential biocontrol agent to control of leaf scald disease of sugarcane (Serna-Cock *et al.* 2013b).

Ratoon stunting disease

As an alternative, biocontrol can be employed to mitigate the negative impacts of ratoon stunting disease. Endophytic bacteria like *Gluconaceto-bacterdiazotrophicus* can compete for colonization sites with the pathogen, stimulate resistance mechanisms in the host, and produce bacteriocins (Arencibia *et al.* 2006; Blanco *et al.* 2010; Oliveira *et al.* 2018).Treatment with *Herbaspirillum rubrisubalbicans* alone showed a low incidence of *L. xyli* subsp. *xyli* and good agronomic yields, indicating a potentially detrimental effect of the pathogen's colonization in the xylem of the sugarcane variety Co 421 (Carneiro *et al.* 2021). A diverse range of endophytic fungal and bacterial communities were found in the stalks of sugarcane varieties resistant to this disease.

Phytoplasma diseases

Phytoplasma diseases are very difficult to control directly by using microbes. However, it can be

Table 2 : Biocontrol agentsused for the management of major diseases of sugarcane

Sr.	Disease	Bioagents	References
Fungal diseases			
1.	Red rot	*Trichoderma harzianum*	Singh, 1994; Singh *et al.* 2008; Elamathi *et al.* 2016;Iftikhar *et al.* 2023, Sanika *et al.* 2025
		T. viride	Singh *et al.* 2008;Iftikhar et al. 2023; Riaz *et al.* 2025
		T. asperellum	Yamunarani *et al.* 2023
		T. longibrachiatum STr-83 and STr-108)	Joshi *et al.* 2018
		Trichoderma spp.	Vandana *et al.* 2024
		Chaetomium sp.	Singh, 1994
		Chaetomium globosum(Cg6)	Yamunarani *et al.* 2023
		Beauveria bassiana	Sanivada and Challa, 2014
		Plant growth promoting rhizobacteria	Viswanathan and Samiyappan, 2001; 2007
		Acinetobacter PK9	Patel *et al.* 2019
		Bacillus sp.NH-217, *B. subtilis* NH-100, *Bacillus* sp. SC 29	Hassan *et al.* 2015
		Bacillus subtilis	Yamunarani *et al.* 2023
		Bacillus velezensis	Xie *et al.* 2024
		Klebsiella pneumonia VRE36	Patel *et al.* 2019
		Ochrobactrum intermedium TRD14	Patel *et al.* 2019
		Paenibacillus alvei	Elamathi *et al.*2016
		Pseudomonas flourescens	Sanika *et al.* 2025
		Pseudomonas aeruginosa DS9	Goswami *et al.* 2015
		Fluroscent*Pseudomonads*	Malathi *et al.* 2008
2.	Wilt	*Trichoderma* isolates	Viswanathan, 2012
		Trichoderma spp.	Fatima *et al.* 2024
		Pseudomonas aeruginosa	Goswami *et al.* 2014
		P. chlororaphis subsp. *aurantiaca* and *P. aeruginosa*	Chetan *et al.* 2024
3.	Seedling rot	*Trichoderma* formulation	Malathi *et al.* 2001
		T. viride	Padmanaban and Alexander, 1990
		Trichoderma asperellum, Bacillus subtilis, Chaetomium globosum	Yamunarani *et al.* 2023
4.	Whip Smut	*Streptomyces griseorubiginosus*	Liu *et al.* 2017
		Pseudomonas guariconensis	
		Trichoderma viride	Lal *et al.* 2009
		Bacillus pumilus ESR 21 and *B. axarquiensis* ESR7	Velusamy *et al.* 2019
		Burkholderia gladioli	Cui *et al.* 2020
		Trichoderma viridae	El-Dawy *et al.* 2023
		Trichoderma viride, *T. asperellum*, and *T. harzianum*	Tegene *et al.* 2024
		Trichoderma spp.	Joshi and Goswami, 2024
		Bacillus velezensis	Pan *et al.* 2025

5.	Pokkahboeng	*Trichoderma harzianum*	Vishwanathan *et al.* 2014; Chauhan *et al.* 2018; Olowe *et al.* 2022
		T. aureoviride	Tiwari *et al.* 2021;
		T. viride	Joshi, 1999; Olowe *et al.* 2022
		Bacillus amyloliquefaciens	Manjula *et al.* 2017, 2023
		B. subtilis	Hirozawa*et al.* 2024
		Paenibacillus polymyxa	Ran *et al.* 2023
		P. fluorescens	Ayala-Torres *et al.* 2023; Manjula *et al.* 2023
		P. aeruginosa	Li *et al.* 2022
6.	Pineapple disease	*Trichoderma harzianum*	Talukdar *et al* .2008; Rahman *et al.* 2009; Ajayi *et al.* 2016
		T. koeningii, Gliocladium virens, T.viride, T.hirsuta, Aspergillus awamori, A. niger, T. harzianum, T. glaucum, Trichothecium and *Penicillium citrinum*	Mahalingam *et al.* 2011; Ajayi *et al.* 2016
Bacterial diseases			
7.	Leaf scald	*Pantoea dispersa*	Zhang and Birch, 1996
		Gluconacetobacterdiazotrophicus	Blanco *et al.* 2005
		Lactococcus lactis subsp. *lactis*	Serna-Cock *et al.,* 2013a
		Weissella confuse	Serna-Cock *et al.,* 2013b
8.	Ratoon stunting disease	*G.diazotrophicus*	Arencibia *et al.* 2006; Blanco *et al.* 2010; Oliveira *et al.* 2018
		Herbaspirillum rubrisubalbicans	Carneiro *et al.*2021
9.	Sugarcane white leaf disease	*Beauveria bassiana* (*Control* of vector)	Wangkeeree *et al. 2024*
Viral diseases			
10.	Sugarcane yellow leaf disease	*Verticillium lecanii* (Control of vector)	Hall, 1987
Nematodes			
11.	Root-knot nematode	*Pasteuria penetrans*	Bhuiyan *et al.* 2018
		Bacillus subtilis + B. licheniformis	Mazzuchelli *et al.* 2020; Dinardo - Miranda *et al.* 2022
12.	Lesion nematode	*Bacillus subtilis*	Mazzuchelli *et al.* 2020
		Purpureocillium lilacinum	Jayakumar *et al.* 2025

controlled by managing insect vector (*Deltocephalus vulgaris, Cofana unimaculata, Matsumura tettixhiroglyphicus, Yamatotetti-xflavovittatus*, and *Maiestas portico)* in sugarcane. Sugarcane grassy shoot disease caused by *Candidatus* Phytoplasma sacchari of group 16SrXI and Several sap-sucking insects such as were identified as vectors. Sugarcane white leaf (SCWL) phytoplasma is minor disease of sugarcane belongs to group 16SrXI or rice yellow dwarf phytoplasma group (Marcone, 2011; Nithya *et al*. 2023). Notably, the fifth passage of *Beauveria bassiana* SUTTU01-treated leafhoppers showed the lowest phytoplasma titer, leading to a reduced transmission rate and fewer infected plants. This is the first report demonstrating the influence of *B. bassiana* on the leafhopper's vector capacity (Wangkeeree *et al*. 2024). These findings provide a foundation for future research on effective fungal strains capable of reducing the phytoplasma transmission rate by their leafhopper vector.

Viral diseases

There is a knowledge gap on biological control as a way to mitigate the spread of vector borne diseases in crops, specifically whether biological control of insect vectors could maintain virus and phytoplasma damage below the economic threshold. The effects of biological control on virus spread through vector are not easy to predict. Sugarcane mosaic disease caused by the *Sugarcane Mosaic Virus* (SCMV), a + ssRNA virus belongs to genus *Potyvirus*, spread is primarily due to the virus being perpetuated through vegetative cuttings, making it a considerable threat to the sugarcane industry. Insect vectors such as sugarcane aphid (*Melanaphis sacchari*) and the corn leaf aphid (*Rhopalosiphum maidis*) are potential vectors to transmit SCMV. No such chemical viricides are available for SCMV, and once plants are infected with this virus, it is too late to take action.

Sugarcane yellow leaf disease caused by *Sugarcane Yellow Leaf Virus*, a +ssRNA virus is transmitted by planting of infected setts and secondary spread by phloem feeding aphid (*Melanaphis sacchari*) in a persistantcirculative manner. Biological control of aphid vectors can potentially reduce the widespread occurrence and spread of yellow leaf disease in sugarcane. Applying the grey fungus *Verticillium lecanii* led to a 45% reduction in aphid populations (Hall, 1987).

Nematode diseases *Bottom of Form*

Recent past, the work on biological control of nematode diseases in sugarcane has been reported. The efficacy of *Pasteuria penetrans* bacteria against second stage juvenile of root-knot nematode (*Meloidogyne javanica*) was conducted under field and glass-house condition. This study showed that regardless of harvest time, the severity of root galling and the number of nematode eggs produced per plant decreased as the bacterial endospore concentration increased. These findings suggest that maintaining high endospore concentrations in the root zone can significantly reduce populations of the root-knot nematode, a particularly important pest of sugarcane (Bhuiyan *et al*. 2018).In another experiment *Bacillus subtilis* used to find its efficacy to control the nematode in an area naturally infested with root-knot nematodes (*Meloidogyne* spp.) and root-lesion nematodes (*Pratylenchus* spp.). Biological control using *Bacillus subtilis* effectively managed nematodes across all three sugarcane production cycles. Applying the bacteria in the planting groove was found to be more effective for nematode control than post-emergence application (Mazzuchelli *et al*. 2020). Talc based formulation of fungal antagonists such as *T. viride, T. asperellum*, *Purpureocillium lilacinum*, *T. harzianum, Pochonia chlamydosporia, T. reesei* and *Clonostachysf rosea* as well as bacterial antagonist such as *B. firmus, B. subtilis* and *Lysinibacillus fusiformis* applying at 2.5 kg/ha reduced the soil population density of lesion nematode *(Pratylenchus zeae).* However,among these antagonists evaluated, *P. Lilacinum* and *B. subtilis* applied separately performed the best and reduced nematode populations and increased germination, tillers count, sugar percentage, cane yield and sugar yield (Jayakumar *et al.* 2025). Further they reported that in second year, a combination of *P. lilacinum* @ 2.5 kg/ha with Fluensulphone 2% GR @ 10 kg/ha reduced lesion nematode populations by 81.23% and achieved a maximum cane yield. A combined application two bacterial antagonists *i.e.B. subtilis* + *B. licheniformis* in the line furrow of sugarcane @ 0.16 kg ha^{-1} and 0.20 kg ha^{-1}increased 5 per cent higher yield than the control (Dinardo-Miranda *et al.* 2022).

Mechanism of biocontrol Antibiosis

Biocontrol agents secrete broad-spectrum antimicrobial metabolites and enzymes that degrade the cell walls of fungal pathogens, effectively inhibiting their growth and spore germination. Rhizobacteria produced different secondary metabolites like siderophore, hydrolytic enzyme, and antibiotics which suppressed the pathogen growth and maintain good plant growth (El- Tarabily and Sivasithamparam, 2006; Matthijs *et al.* 2007). In the rhizosphere, *Trichoderma* species effectively compete with *Fusarium* and other soil borne pathogen for nutrients. Numerous enzymes that break down cell walls are produced by *Trichoderma* spp. These enzymes include massoia lactone, viridine, gliovirin, harzianic acid, alamethics, tricholine, peptaibols, and 6-penthyl-alphapyrone. These enzymes cause structural integrity to be disrupted and cell lysis to result from the breakdown of Fusarium and other fungi's cell walls. *Trichoderma* species produce secondary metabolites having antifungal qualities. Heptilide acid and other bioactive substances are among them. Such antibiotic compounds are secreted, and they prevent *Fusarium* and other infections from growing (Sharma, 2011). By producing both specific and nonspecific antibiotics such trichodemin, trichodermol, harzianun, and harzianolide, trichoderma are proven to eliminate plant pathogens (Bhattacharjee and Dey, 2014). When mycelium of *Pythium graminicolum* from dual plates was examined, neither coiling nor lysis was observed. *T. viride* had completely suppressed the growth of *P. graminicolum* within 4 days. *T. viride* produced toxic metabolites *in vitro* which inhibited the growth of *P. graminicolum* (Padmanaban and Alexander, 1990).Bacterial cells grown on chitin-containing medium showed enhanced antifungal activity against *C. falcatum*, causing red rot disease in sugarcane (Viswanathan and Samiyappan, 2007. *Bacillus* species produce different secondary metabolites, including various antibiotic compounds. Antibiotics produced by *Bacillus* species are deleterious to fungal and bacterial pathogens. Antifungal compounds include Fengycin, bacillopeptin, ituin A and C, bacillomycin and subtilin and mycosubtilin [Kumar *et al.* 2014; Roongsawang *et.al* 2002; Varma *et al.* 2017).

Mycoparasitism

A complex mechanism known as mycoparasitism or hyperparasitism allows an antagonistic fungus (mycoparasite) to parasitize on another fungus (host) directly coil around the hyphae of pathogenic fungi, penetrating them to extract nutrients and causing the pathogen to disintegrate and ultimately result in the death of pathogen cells (Ghorbanpour *et al.* 2018). *Trichoderma* species parasitize a variety of mycoparasites, especially soil borne pathogens. *Trichoderma* species have high mycoparasite ability to lyse and attack plant pathogenic fungi like *Alternaria alternata*, *Botrytis cinerea*, *Rhizoctonia solani*, *Sclerotinia sclerotiorum, Pythium* spp., and *Fusarium* spp. (Druzhinina *et al.* 2011). *Trichoderma* necrotrophs have a mycoparasitic effect on fungi, which involves chemotaxis and prey sensing, attachment to the host, and physical attack through vigorous branching and coiling around the hyphae of the host. The act of mycoparasitism consists of three fundamental phases *i. e*.i. identification of host by formation of oligochitins which is considered as a sensor molecule (Viterbo and Horwitz, 2010). ii. Production of papillae or appressoria-like structures and iii. Formation of coils around the pathogen hyphae and begins to degrade it by producing cell wall-degrading enzymes (CWDE), such as cellulases and hemicellulases, chitinases, proteases, xylanase, pectinase, lipase, amylase, arabinase, protease, 1,3-glucanases, and lytic enzymes (chitinolytic enzymes â-N-acetyl gluco saminidase, endochitinase, and chitobiosidase). These enzymes degrade the pathogen cell walls, which are composed of chitin and glucan polysaccharides. Fungal parasitism and inhibiting spore germination of other plant pathogenic fungi, which are produced by *T. harzianum*, *T. atroviride,* and *T. asperellum* (Saravanakumar *et al.* 2017). Chemical attack and degradation of the pathogen's cell wall by hydrolytic enzymes and

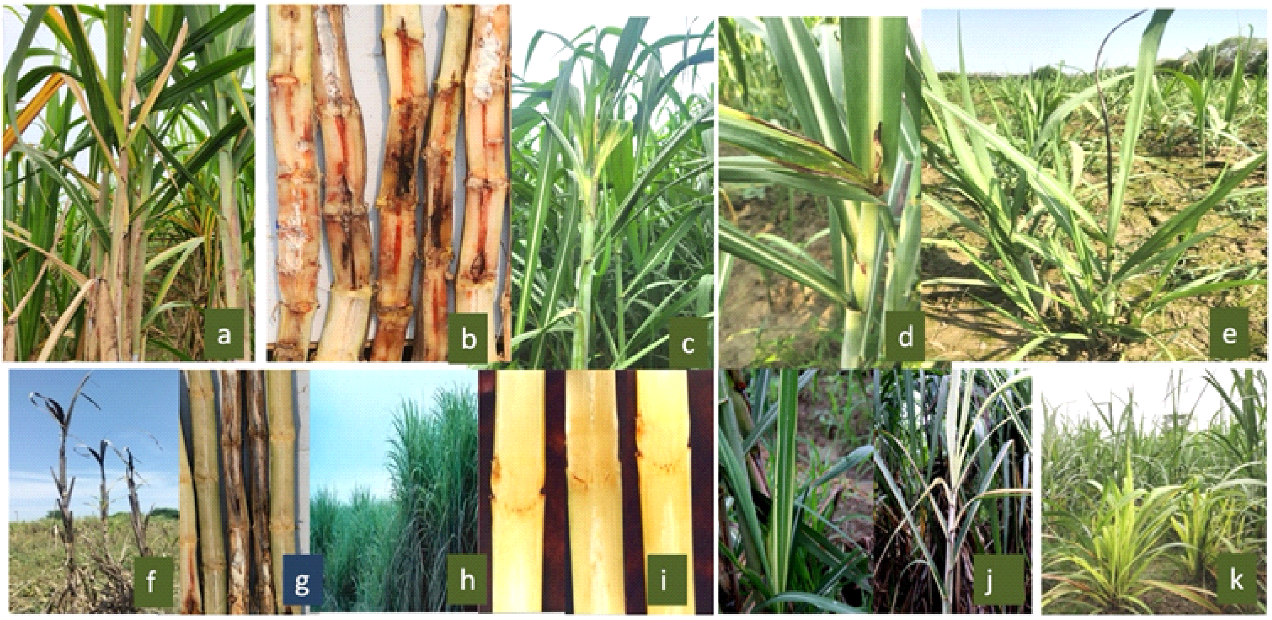

Fig. 1. Symptoms of different diseases of sugarcane. Red rot symptoms, a- yellowing of leaves & b- internal symptom like reddish with white patches; Pokkahboeng, c- twisting and yellowing of leaves & d- top rot of the plant; e- whip like blackish structure of smut disease; Wilt, f- yellowing of leaves and drying of plant & g- cavity formation in the stem; Ratoon stunting disease, h- dwarfing of plant &i- pinkish dots appear at nodes; Leaf scald , j- white strip along with midrib of the leaf & k- whole plant showing symptom; Grassy shoot disease showing yellowing and grassy appearance

antifungal compounds produced by *Trichoderma* is the final stage of the mycoparasitic interaction, ultimately causing host death.

Competition for food

Beneficial microbes rapidly colonize the rhizosphere(root zone) and sugarcane setts, depriving harmful pathogens (such as *Colletotrichum falcatum* which causes red rot) of essential nutrients and physical space to grow. Most of the biocontrol agents including *Trichoderma*, *Pseudomonas* and *Bacillus* species are usually considered as a strong competitor against soil borne plant pathogens. They exhibits higher capacity to mobilize and quickly absorb the nutrients needed for the growth of the pathogen fungi, leading to nutritional deficit and preventing the growth and reproduction of the pathogen (Halifu*et al.* 2020). The main advantage of these biocontrol agents for plant growth is the development of roots. This theory is confirmed by recent studies (Vinale *et al.* 2013) that have shown *Trichoderma* spp. produces or controls plant hormones like auxin, harzianic acid, and harzionalide, which are responsible for promoting root development. According it was found that plants inoculated with *T. harzianum* on the 28th day developed significantly greater roots. The content of Cu, P, Fe, Zn, Mn, and Na increased in the inoculated root and at the same time, it was found that the concentration of Mn, Zn, and P had increased by 70%, 25%, and 30%, respectively, in the plant's shoot (Yedidia *et al.* 2001). A high root surface area caused by *Trichoderma* spp. inoculation permits the root to explore a larger area of soil (Contreras-Cornejo *et al.* 2016). This makes it possible for plants to absorb more macronutrients and micronutrients from the soil, which is advantageous for them when fighting for minerals with other organisms or when there is a lack of minerals.

Induced resistance

According to the definition, induced systemic resistance (ISR) is the systemic protection provided to plants after exposure to an inducing substance in a specific plant component (Kloepper *et al.* 1992). Various microbes induce systemic resistance (ISR) against diseases of sugarcane including red rot. Among the potential bacterial antagonists associated with the plant roots, *Pseudomonas* spp. induces systemic resistance against *C. falcatum*. The bacterial strains significantly reduced red rot pathogen colonization in the stalk tissues and disease progress. The bacterial strains significantly reduced red rot pathogen colonization in the stalk tissues and disease progress was checked (Viswanathan and Samiyappan, 1999). Sett treatment followed by soil application of bacterial strains has also reduced the red rot disease development in the crop in pathogen-sick soil. The efficient bacterial strains KKMI of *P. putida* Trevisan and YPT4 of *P. fluorescens* induced systemic resistance in sugarcane cultivar CoC 671, susceptible to red rot disease. The sett treatment while planting and soil application twice in the field with the strains of *P. fluorescens* such as EP1, Pfl, and CHAO and *P. putida* strain KKMI strongly suppressed the red rot development and the efficacy of PGPR strains against red rot pathogen, enhanced cane and sugar yields suggest that these bacterial strains could be exploited for management of red rot in sugarcane (Senthil *et al.* 2003). Red rot of sugarcane can be managed by the application of *T. harzianum*, since it acts directly on *C. falcatum* and induces systemic resistance in plants developed from treated setts (Yadav *et al.* 2008).

Sett treatment or foliar spray with *Trichoderma harzianum* Rifai and *Chetomium* sp. improved germination and was effective against red rot disease development in the *T. harzianum* T5 caused a higher level of lysis of the pathogen mycelium, and the inhibitory effect was more pronounced when the lytic enzymes were produced using chitin or the cell wall of the pathogen as carbon source (Viswanathan *et al.* 2003). Lytic enzymes of bacterial strains AFG2, AFG4, VPT4, and FP7 and *T. harzianum* T5 inhibited conidial germination and mycelial growth of *C. falcatum* (Singh, 1994). *T. harzianum* strain Th 37 @ 20kgha-1 on the stubbles at the ratoon initiation stage increased the availability of nitrogen (N), phosphorus (P), and potassium (K) by 27%, 65%, and 44%, respectively, and reduced red rot significantly in the combination of salicylic acid (Singh *et al.* 2010). Antagonistic entomo pathogenic fungal strains ARSEF-6646, ARSEF-6647, ARSEF-6648, ARSEF-6650 and ARSEF-2417 of *Beauveria bassiana* (Bals.-Criv.) Vuill producing chitinolytic enzymes and causing a higher level of lysis of the pathogen mycelium and suppressing the *C. falcatum*, red rot pathogen of sugarcane, and the inhibitory effect was more pronounced when the lytic enzymes were produced using chitin as carbon source (Sanivada and Challa, 2014).

CONCLUSION

Sugarcane is a commercial crop and it suffers with various diseases like red rot, wilt, smut, pokkahboeng, sett rot, grassy shoot, mosaic, yellow leaf disease, leaf scald, and ratoon stunting diseasewhich have significant importance in reduction of cane yield and sugar recovery. Management of these diseases through biocontrol using microbes such as *Trichoderma, Bacillus,* and *Pseudomonas* are found very effective under field conditions. To improve the bio-efficacy of antagonistic microbes, other control measures like low diseases fungicides, moist hot air treatment, resistant varieties, cultural practices and consortia of microbes can be used. Besides biocontrol agents, other methods of disease control like selection of disease free planting materials, field sanitation and removal of weeds from fields, sett treatment either fungicides or hot water treatment, use of resistant variety and judicious spraying of fungicides are also found effective to reduce the diseases. However, due to lack of awareness on seed cane health and ignoring quarantine regulations result in introduction of diseases, their epidemics and varietal degeneration in the country. Hence, strict quarantine norms are required if seed cane originated from unknown source or destination to prevent introduction of new diseases. Growing disease resistant varieties is the main stay in disease management in sugarcane. It is expected that the new challenges posed by the sugarcane fungal diseases can be overcome by adopting these new approache sand that will sustainsugarcane productivity in sugarcane. Disease surveillance programmes in the country need further strengthening including the use of remote sensing technique. This would leadtocreationofdiseasemapsforvarious diseases in sugarcane and this would facilitate developingpossibleforewarningsystemsand proper varietal deployment in a region in the future.

DECLARATION

Conflict of Interest. Authors declares no conflict of interest.

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