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RESEARCH ARTICLE

Mechanized Means of Sett Treatment: An Effective Way of Delivering Fungicides for the Management of Red Rot in Sugarcane

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Abstract Role of sett treatment for the management of primary source of red rot inoculum from setts and soil has been established earlier, but could not be recommended for large-scale application due to practical limitations. Hence, in the present investigation, a practically feasible mechanized means of sett treatment has been standardized and compared with conventional overnight soaking method. Both the methods of treatment were evaluated for selecting fungicidal dosage, duration of sett treatment, compatibility among the fungicides, their efficacy and phytotoxic effect on sugarcane growth. Results of tissue bioassay, green house and field experiments revealed that the efficacy of fungicides was found to be at par for both the methods of treatment. Among the fungicides tested, thiophanate methyl was found to be highly suitable under mechanized treatment, while azole fungicides were phytotoxic at elevated concentrations. However, combination of fungicides had added advantage than the individual use of fungicides. Besides, the mechanized treatment had certain advantages such as rapidity, economical as it requires less chemical, less cumbersome in handling material, capable of delivering more than one agrochemical and suitability for large-scale application under farmer's field condition.

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Introduction

Among the sugarcane diseases challenging crop production, red rot caused by *Colletotrichum falcatum* Went (Teleomorph: *Glomerella tucumanensis* (Speg.) Arx and Muller) is the major disease in the country (Viswanathan 2010). As sugarcane is propagated by vegetative means, different pathogens are transmitted to the new crop through seed canes. The pathogens causing red rot, smut and wilt diseases survive in the soil and infect planting material immediately after planting. Hence, sett treatment plays an important role in protecting the crop from sett and soilborne inoculum of fungal pathogens during their initial growth period of sugarcane. Our earlier studies with thiophanate methyl indicated that overnight soaking is effective for the management of soilborne inoculum of red rot (Malathi et al. 2004). However, overnight soaking is impractical on a large scale due to voluminous planting material, and hence, application methods like spray/soil drench and dipping the setts for short time were recommended. Considering the limitations of each method, modified fungicide treatments through low-pressure diffusion technique involving less fungicide consumption with short duration of treatment was evolved with a lab prototype and we got encouraging results. Patent of this mechanized treatment technology has been filed (3323/CHE/2011- Malathi and co workers) as "Rapid treatment for planting materials of sugarcane and other vegetatively propagated crops" and published in "The patent office Journal 21/06/2013." The efficacy has been investigated by different means for the management of red rot in sugarcane. In the present investigation, the technology on mechanized sett treatment of fungicides has been standardized and validated with selected systemic fungicides and compared it with conventional overnight soaking for their efficacy and applicability.

Materials and Methods

Pathogen, Cultivar and Fungicides Used

In the present study, red rot susceptible sugarcane cv CoC 671 and the virulent *C. falcatum* pathotype Cf671 were used. The pathogen was multiplied on sand maize medium, and the inoculum was applied at 30 g/pot in greenhouse studies and 100 g/10′ row in the field at the time of planting. Two new fungicides viz, trifloxystrobin-25 % + tebuconazole-50 % (Nativo 75WDG) and pyraclostrobin-5 % + metiram-55 % (Cabrio 60WDG) along with thiophanate methyl—TM (Roko 70WP) were used to compare their efficacy at different levels. The new fungicides were provided by M/S Bayer (Nativo), BASF (Cabrio), and Roko 70WP was purchased from the market. In the present study, the technical grades of Roko, Nativo and Cabrio were thiophanate methyl (TM), azole–strobin (AS) and strobin–metiram (SM).

In vitro Testing of Fungicides

Efficacy of the fungicides was tested against *C. falcatum* by poisoned food technique at 1, 5 and 10 ppm concentrations. Compatibility of the fungicides was tested among TM and AS/SM at 5 ppm level each, and the fungicidal efficacy was recorded as percent reduction of pathogen growth over control.

Mechanized Means of Sett Treatment

To treat sugarcane setts with fungicides, we have developed a new method i.e. vacuum infiltration by creating a negative pressure followed by absorption of the chemicals inside the setts. This method of sett treatment was performed with the prescribed pressure and duration (15–30 min) in the prototype (Fig. 1). The new method of fungicide treatment was compared with overnight soaking of the respective fungicides alone or with their combinations under greenhouse and field conditions.

Tissue Bioassay

Efficacy of different sett treatment methods on absorption and translocation of fungicides inside the sugarcane stalk tissue was determined by tissue bioassay with tissue samples from cut ends, buds, rind, nodal and internodal tissue of sugarcane setts. For which, two-budded setts were subjected to fungicide treatment by overnight soaking (~18 h) and mechanized treatment for 15 min. The treated setts were split open, and tissue samples were collected using sterile scalpel and placed over the seeded agar medium of *C. falcatum*. Absorption of the fungicides in the tissue was determined based on the production of inhibition zone around the tissue in the plates.

Fig. 1 Lab prototype of mechanized unit developed to demonstrate the technology for validation

Mechanized Sett Treatment with Different Types of Sugarcane Planting Material

The practical feasibility of the treatment device for different sugarcane planting materials such as bud chips, single-, double- and triple-budded setts was tested with thiophanate methyl and compared with overnight soaking. The treated materials of both the methods were evaluated for their efficacy against soilborne inoculum of *C. falcatum* as mentioned before. The efficacy of the treatment was assessed in terms of plant survival.

Standardization of Mechanized Sett Treatment with Fungicide

For mechanized treatment, fungicidal dosage was tested from 100 to 1000 ppm concentrations of three fungicides viz., thiophanate methyl, azole–strobin and strobin–metiram, and the effective dose for mechanized treatment was selected based on the efficacy and non-deleterious effect of the fungicides. In the second experiment, the selected doses were compared with overnight soaking at 1000 ppm concentration for all the fungicides. In addition, fungicidal combinations at 500 ppm each were used among these three fungicides and compared mechanized means of treatment with overnight soaking.

Field Trials

After standardizing fungicidal dose and their combinations, the effective treatments under greenhouse were further validated under field conditions by artificial inoculation of *C. falcatum* inoculum multiplied on sorghum grains. The plot size was four 10′ rows, and for each row, 15 two-budded setts were planted. The setts were treated with fungicides and their combinations by conventional overnight soaking and mechanized means of sett treatment. At the time of planting, pathogen inoculum was applied as mentioned above. The treatments were replicated four times in a randomized block design. Observations were recorded on germination and plant survival at periodical intervals, and finally the number of millable stalks and yield/plot were recorded at the time of harvest.

Statistical Analysis

The data on percent germination and plant survival in various greenhouse and field experiments were subjected to angular transformation, analyzed using SPSS program and subjected to analysis of variance (ANOVA), and the treatment means were compared by Duncan's multiple range test (DMRT). For yield attributes, the data were not subjected to angular transformation.

Results

Inhibitory Effect of Fungicides Against *C. falcatum*

Results of in vitro study revealed that thiophanate methyl was found to be highly effective in inhibiting the pathogen growth at 10 ppm as compared to azole–strobin and strobin–metiram fungicides, and synergistic effect of fungicides was found by producing complete inhibition at lower concentration of 5 ppm each (Fig. 2).

Uptake of Fungicides by Different Sett Treatment Methods

Efficacy of mechanized treatment was found to be equal to overnight soaking for fungicide uptake in different tissues like buds, rind, cut ends and internal tissues (Fig. 3).

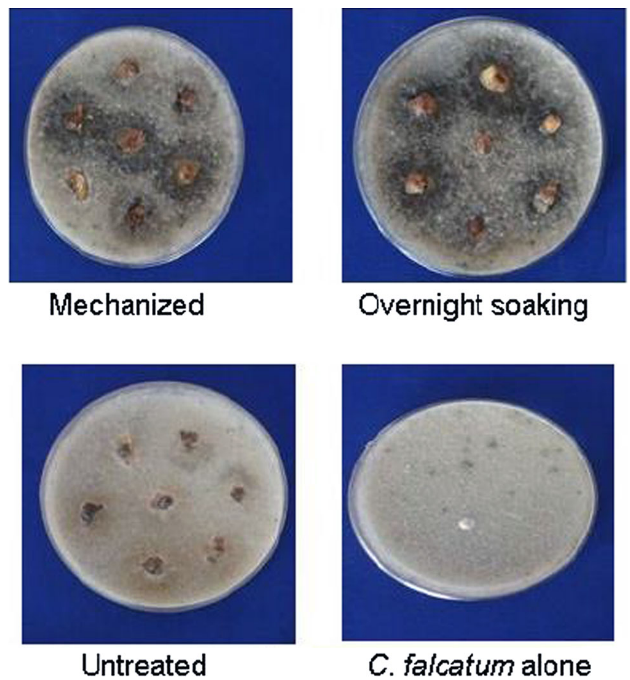

Fig. 3 Comparison of thiophanate methyl uptake by sugarcane setts in mechanized treatment with overnight soaking

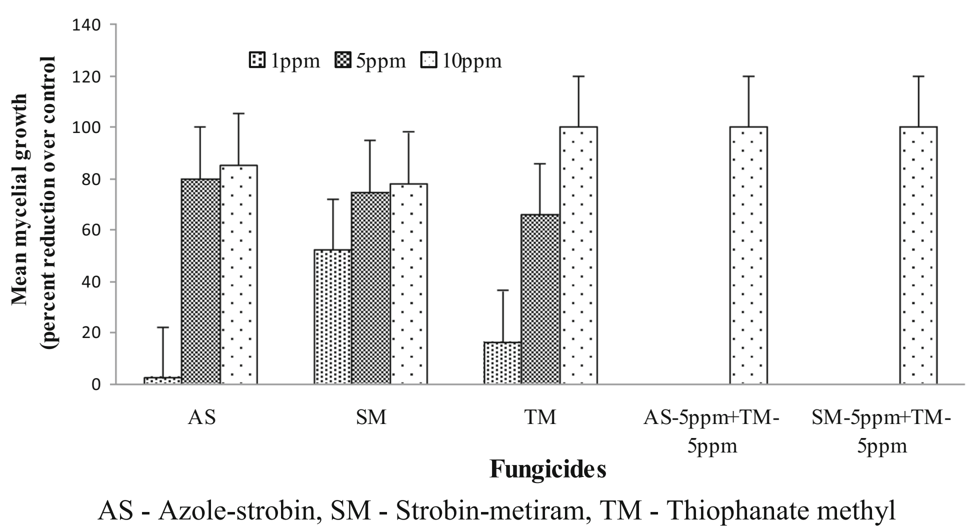

Fig. 2 Inhibition of different systemic fungicides against *Colletotrichum falcatum* in vitro. *AS* Azole–strobin, *SM* Strobin–metiram, *TM* Thiophanate methyl

Among the tissues, uptake was found to be maximum in buds as they were not at all affected in medium layered with spore suspension of the pathogen.

Efficacy of Method of Sett Treatment for on Different Planting Materials

Our results revealed that till 90 days after planting, both the methods of treatment were found to be at par in their efficacy irrespective of planting material used (Fig. 4). The disease incidence was significantly reduced in all the materials, and the survival was above 80 % in case of both the methods of sett treatment. In untreated control, red rot disease incidence was high in bud chips (90 %) followed by setts with 1 or 2 buds with incidence of 60–80 % and only 50 % in 3-budded setts. However, both the methods of fungicide sett treatment protected the setts in treated pots.

Selection of Fungicides Dosage and Comparison of Sett Treatment Methods

Results of the greenhouse studies indicated that increasing the fungicidal dosage from 100 to 1000 ppm was found to be significantly effective under mechanized treatment for 15–30 min, and the dosage was found to vary depending on the fungicide (Table 1). For thiophanate methyl, the higher dose of 1000 ppm was found to be most effective, while at this concentration, azole–strobin affected germination, reduced the growth and caused phytotoxicity at early phases. However, the disease incidence was restricted significantly like thiophanate methyl, while the other fungicide strobin–metiram showed moderate effect at elevated doses.

Based on results from the dosage studies, 500 and 1000 ppm concentrations were selected for all the three fungicides for mechanized treatment and compared with overnight soaking at 1000 ppm concentration. Results of the study indicated that all the fungicides at 1000 ppm were equally effective in both the methods although azole–strobin affected the early phases of growth at 1000 ppm by mechanized treatment (Table 2). Similarly, the fungicidal combinations of thiophanate methyl with azole–strobin at 500 ppm each were found to be equally effective by both the methods of treatment. Hence, 1000 ppm of thiophanate methyl

Table 1 Selection of fungicidal dosage for sett treatment in sugarcane against *Colletotrichum falcatum* by mechanized sett treatment

Fungicidal concentration (ppm)	Germination (%)	Plant survival (%)		
		30 DAP	60 DAP	90 DAP
AS – 100	66.7[abcd]	54.2[bcde]	37.5 [cd]	33.3[bc]
AS – 250	94.4[ab]	77.8[abc]	50.0[abcd]	44.4[abc]
AS – 500	88.9[ab]	88.9[ab]	72.2[abc]	66.7[ab]
AS – 1000	75.0[abc]	75.0[abc]	75.0[ab]	75.0[a]
SM – 100	61.1[bcd]	50.03[cde]	38.9[bcd]	33.3[bc]
SM– 250	100.0[ab]	88.9[ab]	61.1[abc]	44.5[abc]
SM – 500	75.0[abc]	62.5[abcd]	45.8[abcd]	41.7[abc]
SM – 1000	88.9[ab]	88.9[ab]	77.8[a]	66.7[ab]
TM – 100	44.5 [cd]	22.2[e]	16.7[d]	16.7[c]
TM – 250	72.2[abcd]	72.2[abc]	44.4[abcd]	33.3[bc]
TM – 500	91.7[ab]	83.3[abc]	75.0[abc]	58.4[ab]
TM – 1000	94.4[a]	94.4[a]	77.8[a]	72.2[ab]
Inoculated control	38.9[d]	33.3[de]	22.2[d]	11.1[c]
Uninoculated control	72.2[abcd]	77.8[abc]	77.8[a]	77.8[a]

Superscript letters are based on the data analysed using SPSS programme and subjected to analysis of variance (ANOVA) and the treatment means were compared by Duncan's multiple range test (DMRT)

TM, thiophanate methyl; AS, azole–strobin; SM, strobin–metiram; DAP, days after planting

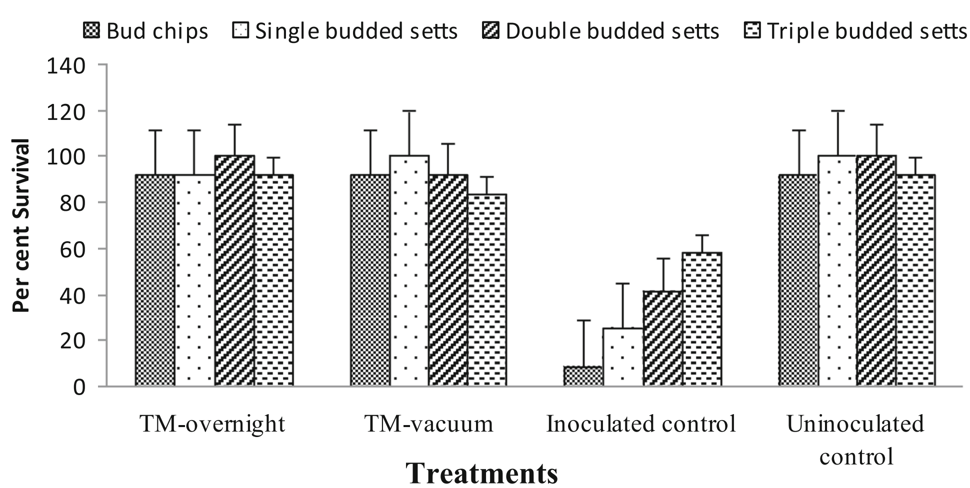

Fig. 4 Efficacy of sett treatment methods—comparison of different planting materials for the uptake of thiophanate methyl (TM) and red rot development in sugarcane (cv CoC 671)

Table 2 Comparative efficacy of fungicides and their combinations by different sett treatment methods against red rot in sugarcane cv CoC 671

Treatments	Germination (%)	Plant survival (%)		
		30 DAP	60 DAP	90 DAP
AS – 500 - Mech	94.4[a]	83.3[a]	77.8[a]	61.1[bc]
AS – 1000 - Mech	77.8[a]	83.3[a]	77.8[a]	77.8[bc]
AS – 1000 - ON	88.9[a]	88.9[a]	83.3[a]	83.3[ab]
SM – 500 - Mech	88.9[a]	88.9[a]	66.7[a]	55.6[c]
SM – 1000 - Mech	88.9[a]	83.3[a]	77.8[a]	72.2[abc]
SM – 1000 - ON	83.3[a]	88.9[a]	77.8[a]	77.8[abc]
TM – 500 - Mech	94.4[a]	94.4[a]	77.8[a]	61.1[bc]
TM – 1000 - Mech	100.0[a]	94.4[a]	88.9[a]	77.8[abc]
TM – 1000 - ON	88.9[a]	88.9[a]	77.8[a]	77.8[abc]
TM + AS – 500 ppm each - ON	88.9[a]	88.9[a]	88.9[a]	83.3[ab]
TM + AS – 500 ppm each - Mech	94.4[a]	94.4[a]	94.4[a]	88.9[a]
TM + SM – 500 ppm each - ON	88.9[a]	83.3[a]	83.3[a]	77.8[abc]
TM + SM – 500 ppm each - Mech	83.3[a]	83.8[a]	77.8[a]	77.8[abc]
Inoculated control	33.3[b]	27.8[b]	16.7[b]	16.7[d]
Uninoculated control	83.3[a]	88.9[a]	88.9[a]	88.9[a]

Superscript letters are based on the data analysed using SPSS programme and subjected to analysis of variance (ANOVA) and the treatment means were compared by Duncan's multiple range test (DMRT)

TM, thiophanate methyl; AS, azole–strobin; SM, strobin–metiram; DAP, days after planting; Mech, mechanized treatment; ON, overnight soaking

for individual application and 500 ppm for combination of fungicides were selected for field studies for confirmation.

Fungicide Sett Treatment Methods Against Red Rot Under Field Conditions

Results from field trial indicated that irrespective of sett treatment method, combination of fungicides viz., thiophanate methyl and azole–strobin at 500 ppm each was found to be highly effective in maintaining plant survival and improving yield attributes. However, statistically it was at par with thiophanate methyl at 1000 ppm and uninoculated control. It was interesting to note that invariably all the treatments have 100 % more plant survival and yield as compared to inoculated control (Table 3).

For an acre, 30,000 two-budded setts require 3500 liters of water for complete soaking which needs bigger container and the chemical requirement is about 4600 g which costs Rs 5670 (1US$ = 65 INR). The time requirement is at least 18–24 h. While in mechanized sett treatment device of 300 l or two connective units of 150 l capacity, 30,000 two-budded setts require only 420 g chemical in 300 l of water costing Rs. 490 only. By repeating ten times, within five hours all the setts can be treated. Furthermore, for single-bud setts/bud chips, it can be made easily for number of time in a smaller unit with several advantages viz., any agrochemical in small quantity, combination of many inputs at a time, less cumbersome and effective delivery within short time.

Table 3 Field efficacy of sett treatment methods with fungicides and their combinations against red rot and plant growth in sugarcane

Treatments	Germination (%)	Plant Survival (%)		Number of stalks/10′ row	Yield (Kg/plot)
		60 DAP	120 DAP		
TM – 1000 ppm - ON	17.2[a] (57.3)	15.9[a] (53.0)	14.1[a] (47.0)	17.6[ab]	83.5[b]
TM – 1000 ppm - Mech	15.3[a] (51.0)	14.6[a] (48.7)	13.9[a] (46.3)	16.4[b]	82.8[b]
TM + AS – 500 ppm each - ON	17.1[a] (57.0)	16.2[a] (54.0)	15.3[a] (51.0)	19.5[ab]	98.4[ab]
TM + AS – 500 ppm each - Mech	16.8[a] (56.0)	16.8[a] (56.0)	16.8[a] (56.0)	19.1[ab]	95.8[ab]
Inoculated control	8.9[b] (29.7)	7.1[b] (23.7)	7.1[b] (23.7)	9.0[d]	31.7[c]
Uninoculated control	14.6[a] (48.7)	15.7[a] (52.3)	15.0[a] (50.0)	16.0[bc]	81.9[b]

Superscript letters are based on the data analysed using SPSS programme and subjected to analysis of variance (ANOVA) and the treatment means were compared by Duncan's multiple range test (DMRT)

Numbers in parenthesis represents percent value

TM, thiophanate methyl; AS, azole–strobin, SM, strobin–metiram; DAP, days after planting; Mech, mechanized treatment; ON, overnight soaking

Discussion

Sugarcane is a major industrial crop of the country grown in about 4.2 million hectares in both tropical and subtropical regions. It is subjected to a number of biotic and abiotic stresses during its growth. Effective management of a stress is associated with cropping system and practicability of a management practice. For most of the management practices/kits, seed treatment plays a major role for easy, effective, economical and rapid method of delivering agrochemicals/microbes. As sugarcane is propagated by vegetative means, it facilitates introduction of different pathogens to the field and development of disease epidemics in the field. However, sett treatment operation becomes impractical under larger scale basis, and hence, application through other methods like spray/soil drench and in some cases dipping the setts in fungicide solution for short time are recommended. Considering limitations in each method, an effective delivery system having long-term effect with preventive/protective principle in the integrated management system is required under field conditions. All these factors were considered to develop an improved method or device of sett treatment in sugarcane which was specifically tested for red rot management with fungicides. However, this technique can be adopted for other agrochemicals used for sugarcane cultivation and even for other vegetatively propagated materials.

During the past decades, a wide range of fungicides have been evaluated under in vitro (Imtiag et al. 2007; Subhani et al. 2008) and in vivo (Chand et al. 1974; Lewin et al. 1976; Agnihorti 1990) conditions for the effective management of red rot along with resistant varieties. Usually, the fungicides are applied as sett treatment (Rao and Satyanarayana 1995) and rarely as spray on sugarcane clumps in the field (Pliansinchai 1999) to protect from the soilborne/secondary inoculum. Sett treatment for limited duration or spray on stalks in clumps resulted failure of disease control even at earlier stage. Partial chemical control of disease under field conditions might be due to impervious nature of the rind, limited uptake of fungicide under limited duration of treatment and inability of the fungicide to reach the site of infection in the tissue (Agnihorti 1983; Rao and Sathyanarayana 1995). However, our earlier studies showed that the fungicides applied before infection reduced red rot incidence and improved both germination of setts and plant survival. We proved that soaking of sugarcane setts in a 0.1 % suspension of fungicides overnight before planting was found to be more effective in controlling debris-borne infection than soaking for 1-h period at elevated doses (Malathi et al. 2004). Also increased efficacy was demonstrated by combining the fungicide with biocontrol agents (Malathi et al. 2002).

Recent studies with new systemic fungicides also confirmed the effect of overnight sett treatment (Malathi et al. unpublished). However, none of the fungicides could be used in the sugarcane field due to practical difficulties in handling voluminous planting material. Hence, present investigation has been taken up to validate practically oriented method of delivering effective fungicides for the management of sugarcane red rot. Results of all the greenhouse and field studies of the present investigation confirmed that both mechanized and conventional treatments resulted more or less similar effect although certain fungicides like azole–strobin showed detrimental effect of phytotoxicity at elevated doses. However, use of fungicidal combinations found to be significantly effective in protecting sugarcane from red rot without any side effects. Besides fungicides, efficacy of mechanized sett treatment in delivering inducers and beneficial microbes has also been validated for red rot management (Results were not shown).

Earlier Zakria et al. (2008) from Japan tried vacuum infiltration technique for the effective delivery of endophytes in the internodal tissue of sugarcane stalks and proved its effectiveness. We used different kinds of sugarcane planting material viz., bud chips and 1-, 2- or 3-budded setts for treatment with fungicides and proved that the new method is effective irrespective of planting materials to manage red rot and improve plant growth.

Besides fungicides, use of biotic and abiotic inducers, insecticides and biocontrol agents against insect pests (Leslie 2002) and diseases (Talukder et al. 2007; Jayakumar et al. 2007), biofertilizers/endophytes/growth hormones/other agrochemicals for growth and development by sett treatment is a regular practice or recommendation for sugarcane production. Hence, mechanized means of treating sugarcane planting material will increase sugarcane productivity in greater way. Furthermore, the mechanized treatment is being validated with different fungicides for the management of other fungal diseases such as smut and wilt in sugarcane and to deliver other inputs viz., insecticides, inducers, nutrients, beneficial microbes etc. for biotic and abiotic stress management and to improve sugarcane productivity.

Conclusion

Most of the fungal diseases are transmitted through the planting materials in sugarcane, and they serve as primary source for the pathogen inoculum in the field. This facilities buildup of the diseases in the early crop phase, and this leads to development of disease to an epidemic level depending on the variety and prevailing climatic conditions. Clean seed program is essential for effective fungal disease management. Although we had effective fungicides for sugarcane, efficient delivery system was not available. Our present studies revealed that the new method of sett treatment "mechanized sett treatment for fungicides" ensures protection of the crop from primary source of *C. falcatum* inoculum in early phases under field conditions. The new method of fungicide treatment would greatly reduce red rot and other fungal diseases in the disease-endemic regions in the country.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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