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Enhancing chemical delivery efficiency through sett treatment device for management of red rot in sugarcane (*Saccharum officinarum*)

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ABSTRACT

The management of red rot in sugarcane (*Saccharum officinarum* L.) poses a significant challenge to growers due to its detrimental effects on yield and quality. The present study was carried out during 2021–22 and 2022–23 at Kalyanpur farm, Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar aimed to enhance the efficiency of chemical for managing red rot through sett treatment device (STD) in sugarcane (varieties CoSe 95422 and CoV 92102). Treatments, viz. T_1, Sett treatment in STD with Thiophanate Methyl (Roko 70 WP) at 1.3 g/L; T_2, T_1 + soil drenching with Thiophanate Methyl at 1.3 g/L on the 45th and 90th days; T_3, Sett treatment in STD with Carbendazim (50 WP) at 1.0 g/L; T_4, T_3 + soil drenching with Carbendazim at 1.0 g/L on the 45th and 90th days; T_5, Sett treatment with Carbendazim 50 WP at 1.0 g/L + Urea at 0.5 g/L, $ZnSO_4$ at 0.5 g/L + $FeSO_4$ at 0.5 g/L + Fipronil (5 SC) at 0.5 ml/L + Soil drenching by 30th and 45th days with Carbendazim 50 ml @1.0 g/L; T_6, Healthy setts resistant control; T_7, Infected setts + Grain inoculation (Untreated disease control) were applied to single-budded setts. Results demonstrated a significant reduction in disease incidence and settling mortality, along with improved quantitative and qualitative cane parameters compared to untreated controls. The combination of Carbendazim 50 WP, Urea, $ZnSO_4$, $FeSO_4$ and Fipronil, with additional soil drenching, yielded the highest germination rates (70.38% in CoSe 95422 and 65.30% in CoV 92102). CoSe 95422 exhibited superior performance in cane length (256.67 cm), girth (7.98 cm), yield (87.42 t/ha) and sucrose content (16.94%). Similarly, CoV 92102 achieved substantial gains, including a yield of 84.95 t/ha and sucrose content of 16.10%. Correlation analysis revealed strong positive associations between germination percentage, cane yield and quality parameters (brix, sucrose and purity), while disease incidence and settling mortality negatively impacted these metrics. The integration of fungicides, insecticides and micronutrients through mechanized delivery significantly enhanced sugarcane productivity and quality, emphasizing the role of micronutrients in addressing deficiencies in subtropical soils.

Keywords: Chemical delivery, Management, Red rot, Sett treatment device, Sugarcane

Sugarcane (*Saccharum officinarum* L.) is a crucial global crop, primarily used for sugar production and playing a significant role in carbon sequestration due to its high biomass production as a C_4 plant (Kumar *et al.* 2024). The biomass residue left post-harvest enhances soil organic carbon, improving soil fertility and structure (Kumar *et al.* 2023). India ranks as the second-largest sugarcane producer, with an annual output of 348.45 million tonnes (Wani *et al.* 2023). Sugarcane is cultivated on 55.83 lakh ha, producing 461.65 million tonnes, with a productivity of 82.7 t/ha (Co-operative Sugar 2023). In Bihar, it is grown on 2.11 lakh ha, with a production of 12.03 million tonnes and a productivity of 56.95 t/ha (Directorate of Economics and Statistics, New Delhi, 2021–22).

Sugarcane faces over 50 diseases in India, with red rot and wilt being particularly concerning (Viswanathan and Rao 2011). Around 20 diseases are reported in Bihar's mill cane areas, with red rot being the most destructive (Minnatullah *et al.* 2022). Notably, the commercial variety Co 0238 was decimated by a red rot epidemic in Bihar and Uttar Pradesh, severely impacting growers (Viswanathan *et al.* 2021). According to Minnatullah *et al.* (2007), the highest reduction in sett germinability (41.0%) was seen in variety BO70, followed by 37.0% in BO74, 25.0% in BO141, 18.2% in BO91 and 18.0% in BO142. Red rot

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causes significant reductions in brix (16.60–20.80%), pol (31.60–38.60%), and cane juice purity (18.00–22.10%) (Minnatullah and Kamat 2018). Severe outbreaks of red rot, often in association with wilt, have been reported in key varieties such as Co 0238, CoSe 95422, CoS 8436, CoSe 92423, Co 0233, CoH 160, and CoH 167 in Bihar (Minnatullah and Singh 2021).

Sugarcane, a vegetatively propagated crop, is susceptible to soil-borne fungal diseases like red rot, wilt and smut, which infect planting materials soon after sowing. Effective seed treatment is crucial for protecting crops in the early stages. Manual treatment of large quantities of seed materials is impractical in commercial cultivation. Traditional methods like dipping or soil drenching are insufficient due to the cane's impervious rind. Malathi *et al.* (2017) introduced "mechanized sett treatment" for early red rot protection, while Zakaria *et al.* (2008) demonstrated vacuum infiltration to effectively distribute endophytes within sugarcane stalks. Red rot, caused by *Colletotrichum falcatum*, remains a significant threat, leading to yield losses if not controlled (Minnatullah *et al.* 2023). Recent strategies emphasize improving chemical delivery systems for effective disease management and healthy crop establishment.

MATERIALS AND METHODS

The present study was carried out during 2021–22 and 2022–23 at Kalyanpur farm, Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The sett treatment device (STD), developed by ICAR-Sugarcane Breeding Institute in collaboration with ICAR-Central Institute of Agricultural Engineering, is an innovative technology designed to treat sugarcane planting material effectively for disease management and healthy nursery production (Fig. 1). By applying negative pressure (vacuum) and subsequent absorption, this device ensures rapid and uniform delivery of agrochemicals, fungicides, microbes or nutrients into sugarcane setts, offering a more efficient alternative to conventional overnight soaking methods. The experiment involved treating disease-affected setts with fungicides and comparing them with healthy setts. Inoculum was prepared using a sorghum grain and sand mixture inoculated with *Colletotrichum falcatum* spore suspension, applied in furrows along with chopped diseased canes to create disease pressure. Various fungicide combinations were tested to assess their efficacy based on germination percentage, disease incidence and yield attributes. The study also examined nutrient supplementation, using micro-nutrients, urea, fungicides and insecticides to enhance disease control and cane yield. The results provided valuable insights into optimizing chemical delivery systems for disease management, particularly red rot. Mechanized sett treatment was found to be beneficial due to its speed, cost-efficiency and ability to distribute agro-inputs effectively, significantly reducing fungal pathogens and increasing yield (Malathi *et al.* 2021).

Inoculum preparation: A mixture of one kg of sorghum grain (partially broken grains without powdering) and sand in a 1:3 ratio was prepared. This mixture was combined with 100 ml of distilled water and distributed into 500 ml conical flasks. The medium was sterilized at 15 lb pressure for 2 h. After sterilization, each flask was inoculated with a spore suspension of *Colletotrichum falcatum* and kept for 15 days. On the 16th day, the entire inoculum was collected in a tray, thoroughly mixed, and then applied uniformly in the furrows at a rate of 100 g/m row before 7 days of planting. Additionally, chopped red rot diseased affected canes were incorporated into the furrows to induce red rot disease.

Fig. 1 Treatment of sugarcane setts through sett treatment device.

Sett treatment and planting: After 7 days of mixing the inoculum into the soil, diseased single bud setts were treated in the sett treatment device (STD) with the following fungicide treatments: T_1, Sett treatment in STD with Thiophanate Methyl (Roko 70 WP) at 1.3 g/L; T_2, T_1 + soil drenching with Thiophanate Methyl at 1.3 g/L on the 45th and 90th days; T_3, Sett treatment in STD with Carbendazim (50 WP) at 1.0 g/L; T_4, T_3 + soil drenching with Carbendazim at 1.0 g/L on the 45th and 90th days; T_5, Sett treatment with Carbendazim 50 WP at 1.0 g/L + Urea at 0.5 g/l, $ZnSO_4$ at 0.5 g/L + $FeSO_4$ at 0.5 g/L + Fipronil (5 SC) at 0.5 ml/L + Soil drenching by 30th and 45th days with Carbendazim 50 ml @1.0g/L; T_6, Healthy setts resistant control; T_7, Infected setts + Grain inoculation (Untreated disease control). The vacuum level applied during the STD process was 200 mm of Hg, with the following duration, Vacuum buildup, 5 min; Retention, 15 min; Air release, 10 min.

Observations: Germination percentage of cane were recorded on 30th day after planting (DAP), disease incidence was observed at pre-emergence and post-emergence stages at monthly intervals. Disease development indicators included death of settlings (settling mortality), yellowing and drying of leaves, midrib lesions in the whorl and production of dead hearts (red rot) observations on various cane parameters like brix, sucrose, purity, cane weight, cane height, cane girth, number of millable canes/plot and cane yield were recorded also correlation studies of various parameters of different treatment related to effect of mechanized delivery of agrochemicals on varieties were studied.

The number of sprouted buds in each plot was determined using the formula:

$$\text{Germination (\%)} = \frac{\text{Number of buds sprouted/plot}}{\text{Total number of buds planted in the plot}} \times 100$$

The percentage of disease incidence was calculated in each plot using the following formula:

$$\text{Disease incidence (\%)} = \frac{\text{Number of affected settlings}}{\text{Total number of settlings assessed}} \times 100$$

The percentage of settling mortality was determined for each plot using the formula:

$$\text{Settling mortality (\%)} = \frac{\text{Number of settlings died}}{\text{Total number of settlings}} \times 100$$

The purity coefficient was calculated by the given formula:

$$\text{Purity coefficient} = \frac{\text{Sucrose per cent}}{\text{Corrected brix}} \times 100$$

The cane yield in t/ha was find out with the help of given formula:

$$\text{Cane yield (t/ha)} = 10/\text{plot area (m}^2) \times \text{cane yield (kg/plot)}$$

RESULTS AND DISCUSSION

By adopting the different treatments on the basis of observation, all the tested treatments reduced the red rot incidence, settling mortality and increased the quantitative as well as qualitative attributes of the cane significantly over untreated disease control. Among the treatment, sett treatment with Carbendazim 50 WP @1.0 g/L + Urea @0.5 g/L + $ZnSO_4$ @0.5 g/L + $FeSO_4$ @0.5 g/L + Fipronil (5 SC) @0.5 ml/L + Soil drenching by 30th and 45th days with Carbendazim 50 WP @1.0 g/L showed the highest germination (70.38%) and (65.30%) in both the varieties i.e. CoSe 95422 and CoV 92102 respectively (Table 1 and 2). In this treatment, reduction in disease incidence and mortality was also noticed least in both the varieties. The highest cane length (256.67 cm), cane girth (7.98 cm), cane weight (1.52 kg), millable cane (106.97), cane yield (87.42 tonnes/ha), brix (20.10%), sucrose (16.94%) and purity (88.94%) were obtained in the variety CoSe 95422. Whereas, the highest cane length (253.50 cm), cane girth (7.16 cm), cane height (1.46 kg), millable cane (103.87), cane yield (84.95 t/ha) brix (19.37%), sucrose (16.10%) and purity (87.70%) were obtained in CoV 92102. Similar results were found by Minnatullah *et al.* (2007) and Minnatullah and Kamat (2018). Treatment of single node setts with sett treatment device using mixture of fungicides, insecticides and nutrients enhanced all the cane parameters as compared to control, these findings were similar to Malathi *et al.* (2021). Mangrio *et al.* (2020) confirmed that the soil interaction effect of soil application of Zn (15 kg/ha) and foliar application of Boron (10%) was significantly increased the brix, yield and nutrients composition of the

Table 1 Effect of various treatments through sett treatment device over single bud on sugarcane varieties against red rot with respect to quantitative attributes (2021–22 and 2022–23)

Treatment	CoSe 95422						CoV 92102					
	Germination (%)	Increase over control (%)	Disease incidence (%)	Reduction over control (%)	Settling mortality (%)	Reduction over control (%)	Germination (%)	Increase over control (%)	Disease incidence (%)	Reduction over control (%)	Settling mortality (%)	Reduction over control (%)
T_1	55.7	29.67	5.7	75.3	7.12	62.44	51.47	28.54	6.89	71.48	8.16	58.74
T_2	62.97	37.79	4.37	81.1	6.14	67.62	58.42	37.04	4.8	80.13	6.69	66.17
T_3	52.12	24.84	6.12	73.52	7.97	57.96	48.33	23.89	7.98	66.97	8.93	54.85
T_4	57.73	32.14	4.86	78.98	6.57	65.34	53.17	30.82	5.69	76.44	7.83	60.41
T_5	70.38	44.34	3.32	85.64	4.76	74.89	65.3	43.67	3.97	83.56	5.32	73.1
T_6	45.17	14.83	7.98	65.48	9.68	48.95	43	14.46	10.28	57.45	10.87	45.04
T_7	39.17	0	23.12	0	18.96	0	36.78	0	24.16	0	19.78	0
SEM (±)	1.53		0.42		0.4		1.69		0.51		0.54	
CD (P=0.05)	4.78		1.31		1.25		5.26		1.71		1.68	
CV	4.86		9.18		7.94		5.74		10.43		9.7	

Treatment	CoSe 95422						CoV 92102					
	Average cane length (cm)	Average cane girth (cm)	Average cane weight (kg)	No. of millable cane/plot	Cane yield (tonnes/ha)	Increase in yield over control (%)	Average cane length (cm)	Average cane girth (cm)	Average cane weight (kg)	No. of millable cane/plot	Cane yield (tonnes/ha)	Increase in yield over control (%)
T_1	248.89	7.16	1.24	98.42	77.98	26.57	245.11	6.2	1.12	97.18	76.17	26.32
T_2	254.36	7.86	1.42	104.89	84.26	32.04	251.61	7.1	1.28	102.11	82.87	32.27
T_3	244.1	6.93	1.18	94.67	73.39	21.97	241.26	5.93	1.08	92.92	71.52	21.53
T_4	250.16	7.68	1.36	101.42	81.37	29.63	248.17	6.71	1.2	101.21	80.13	29.96
T_5	256.67	7.98	1.52	106.97	87.42	34.5	253.5	7.16	1.46	103.87	84.95	33.93
T_6	230.63	6.23	1.02	88.14	67.87	15.63	229.72	5.1	1	87.16	65.16	13.87
T_7	203.65	5.73	0.86	79.76	57.26	0	201.81	4.08	0.72	79.12	56.12	0
SEM (±)	10.35	0.28	0.05	4.19	3.29		9.78	0.26	0.04	4.02	3.2	
CD (P=0.05)	32.23	0.89	0.14	13.05	10.25		30.48	0.8	0.14	12.53	9.96	
CV	7.43	6.98	6.58	7.52	7.53		7.1	7.33	6.94	7.35	7.5	

Treatment details are given under Materials and Methods.

cane. As it is a well-defined fact that in subtropical belt lower organic carbon content and free $CaCO_3$ percentage leads to micronutrient deficiency. Sugarcane is a highest biomass accumulator crop (550 kg ha/day) (Meena *et al.* 2023) and as here sugarcane productivity is a major concern, so application of micronutrient especially Zn and Fe was important. Majeed *et al.* (2022) observed that, the fertilizer application with $ZnSO_4$ @30 kg/ha along with recommended dose of N, P and K resulted in 30% more economic return in comparison to control. Also showed the higher yield of 19.08% in first plant and 22.03% in ratoon crop in comparison to control. It is observed that these treatments enhanced the sucrose content upto 5.91% in first plant and 8.64% in ratoon crops over the control.

Correlation studies for variety CoSe 95422: The correlation matrix for sugarcane variety CoSe 95422 revealed significant relationships between various growth and quality parameters under treatments involving the mechanized delivery of agrochemicals. Germination percentage showed a strong positive correlation with cane yield (0.9729), brix (0.9474), sucrose (0.881511) and purity (0.92281), suggesting that higher germination rates lead to improved yield and quality. However, germination percentage also showed a negative correlation with disease incidence (-0.79727) and settling mortality (-0.8589), meaning better germination is associated with fewer diseases and lower mortality. On the other hand, disease incidence is negatively correlated with cane yield, brix, sucrose and purity, indicating that increased disease incidence resulted in lower yield and quality. Settling mortality, similarly, is negatively correlated with cane yield (-0.93532), brix (-0.96158), sucrose (-0.99767) and purity (-0.98344), highlighting that higher mortality leads to poorer yield and quality. Overall, higher germination rates, along with effective disease management, resulted in improved sugarcane performance across various yield and quality parameters (Supplementary Table 1).

Correlation studies for variety CoV 92102: For sugarcane variety CoV 92102, the correlation matrix similarly highlights the impact of germination percentage on yield and quality. Higher germination is positively correlated with cane yield (0.965059), brix (0.95602), sucrose (0.899012) and purity (0.944278), suggesting that better germination leads to better yield and quality parameters. Germination percentage also showed negative correlations with disease incidence (-0.8454) and settling mortality (-0.88359), emphasizing the importance of healthy germination in reducing disease and mortality. Disease incidence in CoV 92102 also negatively affects cane yield, brix, sucrose and purity, reflecting the detrimental impact of diseases on both yield and quality. Settling mortality is again negatively correlated with cane yield (-0.93375), brix (-0.95193), sucrose (-0.99328) and purity (-0.96053), showing that higher mortality correlates with lower yield and poorer quality. Additionally, brix and sucrose were strongly positively correlated (0.975062 and 0.997204, respectively), confirming their close relationship in determining sugarcane quality. These correlations underscore the significant role of germination and disease management in optimizing sugarcane yield and quality in this variety (Supplementary Table 2).

The field experiment on sugarcane varieties CoSe 95422 and CoV 92102 demonstrated the effectiveness of sett treatment with a combination of Carbendazim 50 WP, Urea, $ZnSO_4$, $FeSO_4$ and Fipronil in improving both growth and disease management. The combination of carbendazim 50 WP with urea, $ZnSO_4$, $FeSO_4$ and fipronil, followed by soil drenching, proved most effective

Table 2 Effect of various treatments through sett treatment device over single bud on sugarcane varieties against red rot with respect to qualitative attributes (2021–22 and 2022–23)

Treatment	CoSe 95422						CoV 92102					
	Brix (%)	Increase in Brix over control	Sucrose (%)	Increase in sucrose over control	Purity (%)	Increase in purity over control	Brix (%)	Increase in Brix over control	Sucrose (%)	Increase in sucrose over control	Purity (%)	Increase in purity over control
T_1	18.36	27.78	15.18	37.87	85.23	15.11	17.81	27.56	14.86	38.69	83.89	16.26
T_2	19.86	33.23	16.10	41.42	88.12	17.90	19.02	32.17	15.96	42.91	87.40	19.62
T_3	17.63	24.79	15.00	37.13	83.74	13.60	16.43	21.48	14.21	35.89	81.14	13.42
T_4	19.08	30.50	15.76	40.16	86.73	16.58	18.26	29.35	15.30	40.45	85.18	17.53
T_5	20.10	34.03	16.94	44.33	88.94	18.65	19.37	33.40	16.10	43.41	87.70	19.90
T_6	16.22	18.25	14.10	33.12	80.96	10.63	15.40	16.23	13.10	30.45	77.18	8.98
T_7	13.26	0.00	9.43	0.00	72.35	0.00	12.90	0.00	9.11	0.00	70.25	0.00
SEM(±)	0.41		0.33		1.81		0.40		0.34		1.70	
CD (*P*=0.05)	1.29		1.02		5.64		1.24		1.05		5.29	
CV	3.99		3.87		3.74		4.04		4.13		3.60	

Treatment details are given under Materials and Methods.

regimen, enhancing cane length, girth, weight, millable cane count and overall yield for both varieties. These results underline the importance of tailored treatment strategies for optimizing sugarcane germination and disease management. Incorporating micronutrients like zinc and iron into treatment not only addresses nutrient deficiencies but also boosts productivity. The use of STDs offers a promising method for disease management and enhancing sugarcane growth. The correlation analysis between sugarcane varieties CoV 92102 and CoSe 95422 reveals that optimal germination rates and reduced disease incidence are crucial for maximizing cane yield and quality. Notably, while longer seedlings tend to show lower yield and quality and higher disease incidence, balancing seedling growth and disease management is essential. Further research is required to refine these strategies and deepen understanding of the factors influencing sugarcane performance.

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