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Effect of Thiophanate Methyl on Red Rot Disease (*Colletotrichum falcatum*) and Yield Attributes of Sugarcane

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Abstract
Sugarcane (*Saccharum officinarum* L.) is an important cash crop grown in tropical and sub tropical regions of India but the productivity of sugarcane is low as compare to other cane growing countries of the world due to several biotic and abiotic factors. Among the biotic factors, red rot of sugarcane is serious fungal disease affecting sugarcane stalks, the most economical part of the sugarcane. In India, red rot disease has been menace for sugarcane cultivation and many elite varieties were removed from cultivation due to their susceptibility to the disease. Application of fungicide thiophanate methyl against red rot can be the efficient approach for disease suppression and improving growth of the sugarcane plant so it becomes imperative to know the field performance of thiophanate methyl against red rot and quantitative parameters of sugarcane. Thiophanate methyl @ 0.25 % was applied effectively as sett treatments. Disease management was ascertained by inoculation challenged with test pathogen *Colletotrichum falcatum*. Red rot infection was considerably suppressed in all treated plot where grade of infection was also reduced. The protection offered might be due to antifungal properties of chemical on pathogen. Fungicide thiophanate methyl was also found better to increase germination percentage (4.99 % to 5.91 %), tillers count (2.38 % to 8.09 %), number of millable cane (4.20 % to 14.76 %), single cane weight (1.25 % to 6.67 %), cane length (1.11 % to 5.30 %), cane diameter (0.85 % to 1.61 %) and cane yield (7.92 % to 14.24 %).

Keywords: Sugarcane, red rot, quantitative parameters, cane yield, cane diameter

1. Introduction
Among the diseases, red rot caused by fungus *Colletotrichum falcatum* Went is one of the most dreaded disease of sugarcane and losses due to red rot may range from 10-50 % depending upon the cultivars, environment and pathogen strain (Ghazanfar and Kamran, 2016) [8]. The perfect stage of the fungus was identified as *Physalospora tucumanesis* Speg. (Carvajal and Edgerton, 1944) [4] and finally known as *Glomerella tucumanesis* Speg. (Arx and Muller, 1954) [2]. The disease was first discovered in Java (now Indonesia) by Went (1893). He called the fungus *Colletotrichum falcatum* and disease as het root snot meaning red smut disease. In India, the disease was first noticed in 1895 in Godavari delta of Andra Pradesh, thereafter it was observed in almost all the states (Yadav, 2006) [27]. This disease has several epidemics to its credit and virtually during 1938-1940, it wiped out sugarcane cultivation in Northern Uttar Pradesh and Bihar (Duttamajumder and Misra, 2004) [7].
Sugarcane is also one of the crops which consume large quantity of water and moisture plays a major role in the development on many diseases in the crop plants (Kalaimani and Jeyaraj, 2012) [10]. Rainy season and 25^0 to 30^0 C temperatures favor the development of disease (Khan *et al.*, 2011) [11]. It causes reduction in cane weight, yield and quality of sugarcane cultivars in Indian sub-continent (Satyavir, 2003, Duttamajumder, 2008, Singh *et al.*, 2008) [19, 5, 22]. It can reduce weight by up to 29 % and loss in sugar recovery by 31 % (Hussnain and Afghan, 2006) [9]. Red rot pathogen hydrolyzed the stored sucrose by producing the enzyme invertage which breaks the sucrose molecule into its components namely glucose and fructose. As a result the quantity of molasses increases (Sehtiya *et al.*, 1993) [21]. It is aptly called the cancer of sugarcane (Khan *et al.*, 2011) [11]. As this has become major constraint in the profitable cultivation of sugarcane (Mohan and Sangeeta, 2009) [17].
The endless struggle between varieties and the complexity of disease have led to the
Development of correspondingly a variety of approaches for control. Fungicides are often a vital part of disease management as they control many diseases satisfactorily (McGrath, 2004) [16]. The role of fungicides in modernizing and changing the condition of agriculture is quite significant (Subhani *et al.*, 2008) [24]. Role of sett treatment for the management of primary source of red rot from setts have been

established earlier (Malathi *et al.*, 2016) [14] and use of fungicides to control the red rot is normally restricted to the sett treatment. Keeping in view the seriousness of disease, present investigations were conducted to study the field performance of thiophanate methyl on red rot disease and quantitative parameters of sugarcane cultivars.

2. Materials and methods

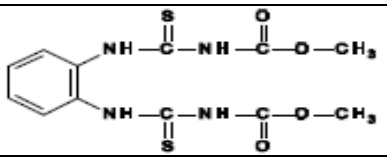
2.1. Experimental plan

Field experiments were conducted during *spring* season (2014-15 and 2015-16) at Sugarcane Research Centre, Kashipur (*tarai* region of Uttarakhand). The experiment was laid out in randomized block design with three replications at 90 cm row to row spacing having 5.0 x 5.4 m^2 plot size. All the cultural operations were followed right from land preparation till harvesting. Red rot inoculum in the form of infected crop debries was also added into the experimental field over a period of time.

2.2. Fungicide Thiophanate Methyl

One of the most important specific site inhibiting and systemic fungicide groups introduced in the 1960s was benzimidazole fungicides and thiophanate methyl belongs to this group. It is a broad spectrum fungicide with protective and curative action. Under natural condition, thiophanate methyl are converted to common active product i.e. methyl benzimidazole-2-ylcarbamate. This may be the reason why thiophanate methyl exhibit disease control effects similar to benzimidazole. Matheron (2001) [15] also reported that thiophanate methyl inhibit the DNA synthesis/nuclear division of pathogen. Important information regarding fungicide Thiophanate methyl was also presented in Table 1.

Table 1: Information regarding fungicide thiophante methyl

Common Name	Chemical Name	Chemical Formula	Chemical Structure	Molecular Weight
Thiophanate-methyl	Dimethyl 4,4'-(*o*-phenylene) bis (3-thioallophanate)	$C_{12}H_{14}N_4O_4S_2$		342.4

2.3. Sugarcane cultivars used

Total five cultivars viz., CoPant 5224, CoS 767, CoS 97264, CoS 8436, CoPant 99214 were planted on 27th March, 2014 and 19th March, 2015. These cultivars are very popular in *tarai* region of Uttarakhand. So the main aim of selection of these cultivars was to manage the red rot disease in the best suitable and adaptive cultivars of sugarcane through sett treatment and to study its effect on quantitative parameters. Some important information regarding sugarcane cultivars is presented in Table 2.

Table 2: Important information regarding sugarcane cultivars

Cultivars	Parentage	Year of release	Maturity type
CoPant 5224	CoPant 84212 (Poly cross)	2013	Mid late
CoS 767	Co 419 x Co 312	1979	Mid late
CoS 97264	Co 1158 x CoS 510	1999	Mid late
CoS 8436	MS 68/47 x Co 1148	1987	Early
CoPant 99214	CoS 767 x CoS 510	2007	Mid late

2.4. Method of inoculation

10 sugarcane stalks of each cultivar were inoculated by standard plug and nodal method with the suspension containing healthy sporulated culture of *C. falcatum* (10^6 conidia per ml) collected from naturally infected sugarcane plant, during last week of august under favourable condition (28^0 to 30^0 C temperature and 90 % relative humidity).

2.4.1. Plug method

From the very beginning of systematic red rot research in India, plug method was tried for artificial production of red rot disease (Butler and Khan, 1913) [3]. Later this method became the main method of testing disease resistance against red rot pathogen (Duttamajumder, 1997) [6]. In this method, bored hole is punched in the middle of 3rd internode from the bottom with cork borer/metal inoculator of 0.5 cm diameter and the plug of cane tissues with rind removed. A small quantity (0.5 ml) of spore suspension is dropped into bored hole, the hole replugged with removed cane tissues and sealed with plastic clay to avoid aerial contamination.

2.4.2. Nodal method

Node being the focal point of entry of the red rot pathogen into the cane, this region was also targeted by workers for this purpose. In this method, inoculum was placed between leaf and leaf sheath. Nodal region of immature top of the cane tightly covered by green leaf sheaths took infection when exposed to the red rot inoculum. Inoculation is carried out by dropping 1 ml of spore suspension in the axil of 4 and 5 node from the top between leaf sheath and stalk at two opposite buds after slightly pulling out of leaf sheaths.

2.5. Disease rating scale

The inoculated cane will be split longitudinally after 60 days of inoculation. Then red rot reaction is evaluated based on the condition of tops (leaves), progress of red rot lesion along with length of cane, width of lesion and amount of white spot present (Table 3). The values of these spots/symptoms were added and their mean values were calculated.

Table 3: Red rot rating based on 0-9 rating scale (Srinivasan and Bhat, 1961)

Symptoms	Numerical scale	Severity of symptoms
Condition of tops	0	Green
	1	Yellow or drying
Nodal transgression	0	No lesion spread, lesion restricted to the inoculated node
	1	Lesion transgression of one node above the inoculated node
	2	Lesion transgression of two nodes above the inoculated node
	3	Lesion transgression of more than two node above the inoculated node
Lesion width	0	No lesion spread
	1	Lesion spread to about 25 % of width of the stalk
	2	Lesion spread to about half the width of the cane
	3	Lesion spread to about more than half of the width of the cane
White spots	0	No white spots
	1	Sparse presence of white spots
	2	Moderate to profuse presence of white spots

Red rot disease were graded by using 0-9 disease rating scale (Table 4).

Table 4: Categorization of red rot reaction (Srinivasan and Bhat, 1961)

Score on 0-9 scale	Reaction category
0-2.0	Resistant
2.1-4.0	Moderately Resistant
4.1-6.0	Moderately Susceptible
6.1-8.0	Susceptible
> 8.0	Highly Susceptible

2.6. Quantitative parameters

Quantitative parameters include germination percentage, tillers count, number of millable cane, single cane weight, cane length, cane diameter and cane yield. Germination percentage was counted at 45 days after planting while tillers were counted at 120 days after planting. Number of millable cane, single cane weight, cane length, cane diameter and cane yield were recorded at the time of harvesting. The data on different quantitative parameters were recorded both on treated as well as control plots of sugarcane cultivars.

3. Results and Discussion

3.1 Red rot resistance

Dipping of sugarcane setts in fungicidal solution of thiophanate methyl could express the protection even by artificial inoculation of potent *C. falcatum*. In treated plots, level of protection was higher than control. Results revealed that control plots of cultivars viz., CoPant 5224, CoS 767, CoS 97264 and CoPant 99214 showed moderately resistant reaction while CoS 8436 developed susceptible reaction against red rot disease. In case of treated plots, development of red rot disease was also checked in the cane. Pathogen *C. falcatum* hardly moved beyond 2-3 nodes and white spots were absent in case of sugarcane cultivars viz., CoPant 5224, CoS 767, CoS 97264 and CoPant 99214. This clearly indicated that fungicide had boosted the protection level (Table 5).

Agnihotri (1990) [1] reported fungicidal effect of Topsin M (thiophanate methyl) against *C. falcatum in vitro* as well as on protective effect against debris-borne infection. Rao and Sathyanarayana (1995) [18] reported that fungicides like Benomyl, Vitavax, Topsin M (thiophanate methyl) etc. have been found effective against red rot disease in field conditions. Satyavir *et al.*, 2002 [20] also reported that thiophanate methyl with trade name Topsin-M are specific against the red rot pathogen *C. falcatum*. Khan *et al.*, 2009 [12] also studied the red rot resistance and reported that thiophanate methyl showed superior effect over other treatments in protecting cane against red rot disease.

Yasuda *et al.*, 1973 [28] reported that metabolites of thiophanate methyl were identified as methyl benzimidazole 2-ylcarbamate (MBC) and methyl 5-hydroxy 2-benzimidazole carbamate (HMBC) showed the antifungal activities in plants. Matheron (2001) [15] also reported that thiophanate methyl inhibit the DNA synthesis or nuclear division of pathogen. The systemic fungicide thiophanate methyl showed very good result in the management of red rot of sugarcane (Malathi *et al.*, 2004) [13]. Vonk and Sijpesteijn, (2006) [25] concluded that methyl benzimidazole 2-ylcarbamate is responsible for fungitoxic effect. Fungal metabolic activity can increase the rate of conversion of thiophanate methyl into methyl benzimidazole 2-ylcarbamate. Subhani *et al.*, 2008 [24] also reported the inhibition of mycelial growth of *C. falcatum* through fungicides.

3.2. Field response of Thiophanate methyl on quantitative parameters of sugarcane

Germination percentage, tillers count, number of millable cane, single cane weight, cane length, cane diameter and cane yield are considered as an important quantitative parameters which finally affect the cane yield. In literature, very little information is available regarding effect of fungicide thiophanate methyl in quantitative parameters of sugarcane. It is evident from data (Table 6 and Table 7) that fungicide thiophanate methyl established itself as potent factor which effect the quantitative parameters of sugarcane cultivars..

3.2.1. Effect in germination percentage

The inherent growth potential of sugarcane cultivars is determined by the germination capacity of its seed cane. The data revealed that the average germination in control plots was 36.48 % to 43.57 % (Table 6). The maximum germination was (43.57 % and 45.93 %) noticed in case of control as well as treated plots of CoS 97264. The lowest germination (36.48 % and 38.80 %) was recorded in control and treated plots of CoS 8436 and showed 4.99 % increase in germination over control. Sugarcane cultivars viz., CoPant 5224, CoS 767 and CoPant 99214 showed 5.18 %, 5.71 % and 5.91 % respectively increase in germination over control.

3.2.2. Effect in tillers count

Tillering potential of any cultivar determines the ultimate crop stand and it makes up. The data revealed that (Table 6) cultivar CoS 97264 produced significantly higher tillers count (138.28 and 142.55 thousand per ha in case of control and treated plots respectively). All the treated plots showed higher tillers count as compare to control plots. There was 2.38 % to 8.09 % increase in tiller counts over control. The minimum

number of tillers were recorded in case on sugarcane cultivars CoS 8436 (122.76 and 125.68 thousand per hac in control and treated plot respectively).

Table 6: Germination (%), tillers count (000/ha), number of millable cane (000/ha), single cane weight (g) as influenced by fungicide thiophanate methyl

Culti Vars	Germination (%)			Tillers count (000/ha)			Number of millable cane (000/ha)			Single cane weight (g)		
	Control	Treated	% increase	Control	Treated	% increase	Control	Treated	% increase	Control	Treated	% increase
CoPant 5224	42.25	44.44	5.18	124.29	130.17	4.73	110.62	119.71	8.22	813.33	831.66	2.25
CoS 767	40.27	42.57	5.71	124.33	134.39	8.09	111.43	122.57	9.99	700.00	733.33	4.76
CoS 97264	43.57	45.93	5.42	138.28	142.55	3.09	118.63	136.14	14.76	793.33	830.00	4.62
CoS 8436	36.48	38.30	4.99	122.76	125.68	2.38	96.58	100.64	4.20	800.00	810.00	1.25
CoPant 99214	40.13	42.50	5.91	117.73	123.64	5.02	110.64	115.67	4.55	750.00	800.00	6.67
CD (P= 0.05)	2.87	2.40	-	10.11	11.97	-	8.29	9.85	-	54.75	75.86	-

Note: Pooled data of two cropping season (2014-15 and 2015-16)

3.2.3. Effect in number of millable canes

Number of millable cane is one of the most important yield contributing factors and different cultivars responds differently. There was increase in number of millable cane in treated plots as compare to control plots. Cultivar CoS 97264 recorded the highest number of millable cane (118.63 and 136.14 thousand per ha) in case of control as well as treated plots while cultivar CoS 8436 exhibited minimum value of this parameter (96.58 thousand per ha in control plots and 100.64 thousand per ha in treated plots). All the treated sugarcane cultivars increased the number of millable cane over control by 4.20 % to 14.76 %. Fungicide thiophanate methyl gave the better results for the production of more number of millable canes.

3.2.4. Effect in single cane weight

Control plots of sugarcane cultivars viz., CoPant 5224, CoS 767, CoS 97264, CoS 8436 and CoPant 99214 recorded 813.33 g, 700.00 g, 793.33 g, 800.00 g and 750.00 g of single cane weight respectively while treated plots of sugarcane cultivars viz., CoPant 5224, CoS 767, CoS 97264, CoS 8436 and CoPant 99214 produced 831.66 g, 733.33 g, 830.00 g, 810.00 g, and 800.00 g respectively. All the treated plots of sugarcane cultivars increased the single cane weight over control by 1.25 to 6.67 %.

3.2.5. Effect in cane length

The data given in the Table 7 revealed that there was a significant variation in cane length among the different cultivars. Higher values of the cane length were noticed in sugarcane cultivar CoPant 5224 (257.00 cm in control plots and 265.33 cm in treated pots) while lower value of this parameter were recorded by cultivar CoS 767 (201.00 cm in control and 204.67 cm in treated plots). Cultivar CoPant 99214 showed maximum increase (5.30 %) in cane length. All the treated plots of sugarcane cultivars enhanced the cane length over control by 1.11 % to 5.30 %.

Table 7: Cane length (cm), cane diameter (mm), cane yield (q/ha) as influenced by fungicide thiophanate Methyl

Cultivars	Cane length (cm)			Cane diameter (mm)			Cane yield (q/ha)		
	Control	Treated	% increase	Control	Treated	% increase	Control	Treated	% increase
CoPant 5224	257.00	265.33	3.24	23.70	24.00	1.27	788.36	865.00	9.72
CoS 767	201.00	204.67	1.83	21.50	21.73	1.07	613.66	670.74	9.30
CoS 97264	224.00	230.00	2.68	22.90	23.17	1.18	735.32	840.00	14.24
CoS 8436	210.00	212.33	1.11	23.50	23.70	0.85	630.32	680.27	7.92
CoPant 99214	220.00	231.67	5.30	23.00	23.37	1.61	800.57	877.06	9.55
CD (P= 0.05)	9.81	7.39	-	1.24	0.547	-	70.23	89.46	-

Note: Pooled data of two cropping season (2014-15 and 2015-16)

3.2.6. Effect in cane diameter

Cane diameter is also considered as important parameter, which finally effect the cane yield. Results revealed that cultivars CoPant 5224 succeeded in producing more cane diameter (23.70 mm in control plots and 24.00 mm in treated plot) and showed 1.27 % increase in cane diameter over control. Minimum value of this parameter were reported from cultivar CoS 767 (21.50 mm in control plot and 21.73 mm in treated plot) which showed 1.07 % increase over control. CoPant 99214 showed 1.61 % whereas CoS 8436 recorded 0.85 % increase over control.

3.2.7. Effect in cane yield

It is considered one of the most important yield contributing factors as it is evident from data (Table 7). Sugarcane cultivars viz., CoPant 5224, CoS 767, CoS 97264, CoS 8436 and CoPant 99214 produced 788.36 q/ha, 613.66 q/ha, 735.32 q/ha, 630.32 q/ha and 800.57 q/ha respectively of average yield in control plots. The treated plots of sugarcane cultivars viz., CoPant 5224, CoS 767, CoS 97264, CoS 8436 and CoPant 99214 gave 865.00 q/ha, 670.74 q/ha, 840.00 q/ha, 680.27 q/ha and 877.06 q/ha respectively with the use of fungicide. Khan *et al.*, 2009 [12] also reported that fungicide thiophanate methyl improved the cane yield over control.

4. Conclusion

Present finding clearly revealed that sett treatment with thiophanate methyl lowered down the red rot disease reaction. The fungicide thiophanate methyl was also found effective in improving germination percentage, tiller counts, number of millable cane, single cane weight, cane length, cane diameter and cane yield of different sugarcane cultivars. Reduction in red rot disease and improvement in quantitative parameters encourage taking this fungicide at particular dose might be appear as solution for effective management of disease

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