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CHEMICAL CONTROL OF WHIP SMUT OF SUGARCANE CAUSED BY *SPORISORIUM SCITAMINEUM*

MUHAMMAD ASLAM RAJPUT[1,2], REHANA NAZ SYED[2], MUHAMMAD ALI KHANZADA[2], NASIR AHMED RAJPUT[3], FAHAD NAZIR KHOSO[2] AND ABDUL MUBEEN LODHI[2*]

[1] *National Sugar and Tropical Horticulture Research Institute, PARC, Thatta, Pakistan*
[2] *Faculty of Crop Protection, Sindh Agriculture University Tandojam, Pakistan*
[3] *Department of Plant Pathology, University of Agriculture Faisalabad, Pakistan*
**Corresponding author's mubeenlodhi@gmail.com*

Abstract

Whip smut of sugarcane is considered as the most important disease of sugarcane and occurrs in almost all sugarcane producing regions of the world, including Pakistan. In many cases, the use of the chemical fungicides becomes indispensable to combat destructive plant diseases, which otherwise cause heavy economical losses. Fungicides not only eradicate smut from the planting material, but also prevent re-infection when they are used as a pre-plant treatment of setts. During the present investigation, setts are inoculated with teliospores suspension of *Ustilago scitaminea* and treated with eleven different fungicides. Pre-inoculated setts are dipped for 30 minutes in hot fungicide solution, ambient fungicide solution. Hot and ambient water without fungicides serves as control. Most of the fungicide treatments significantly improved sett germination and check the smut development. For most of the quantitative and qualitative parameters, Bayleton, Bavistan and Tilt provide better results, as compared to the other fungicides. Based on the results we conclude that the effectiveness of fungicides increase more when applied as hot water fungicidal dip than ambient fungicidal dip.

Key words: *Ustilago scitaminea, Saccharum officinarum*, Hot water treatment, Bayletan, Bavistan, Tilt

Introduction

Globally 121 countries grow sugarcane and among them Australia, Argentina, Bangladesh, Brazil, China, Columbia, Cuba, India, Mexico, Myanmar, Pakistan, Philippines, South Africa, Thailand and USA contribute 86% of area and 87% of production. In Pakistan, it is the second major cash crop after cotton (Qureshi, 2004), contributing in value added agriculture and GDP upto 3.4% and 0.7%, respectively (Anon., 2009). It was grown on an area of 1,313 thousand hectares in Pakistan during 1917-18, with total cane production of 81.102 million tones and sugar production of 8.2 million tons (Anon., 2018). Despite the fact that Pakistan is the 4th largest sugarcane growing country of the world, it ranks 60th in terms of average yield i.e. 52.4 tons/ha. It is far below the world's average yield of 65 tons/ha as well as the prominent sugarcane growing countries, such as Egypt (105 tons/ha), Philippines (92.6 tons/ha), Thailand (92.6 tons/ha), China (77.1 tons/ha), Australia (75.5tons/ha) and India (70.6 tons/ha) (Alam, 2007). Although, domestic sugarcane production has steadily increased during the last four decades, but our average national cane yield is much lower than the production potential of 256 tons/ha in existing domestic varieties (Gill, 1995). The causes of low yields are **c**onventional production practices, non-availability of high yielding varieties, imbalanced use of fertilizers, water shortage, poor irrigation system, water logging and salinity, poor crop management, pest and diseases, poor ratoon crop management and poor agronomic status of soil. Sugarcane is a long duration crop; consequently several biotic and abiotic agents affect its productivity, including insect pests, viruses, bacteria, fungi, nematodes, invertebrates and weeds (Rasool *et al*., 2010; Zafar *et al*., 2010; Showler, 2016; Tukaew *et al*., 2016). In general, diseases and insect pests have potential to decrease its production by 19 and 20%, respectively (Singh, 1988; Ferreira & Comstock, 1989; Rott *et al*., 2000). In the field, sugarcane crop is subjected to attack of a large number of diseases including whip smut.

Whip smut is one of the most important and destructive diseases of sugarcane in all cane growing countries of the world, including Pakistan (Khan *et al*., 2009). It becomes more serious under favorable conditions, like temperature of 25-30ºC and 65-70% humidity (Mansoor *et al*., 2016) in susceptible varieties and it can cause considerable losses of 12-75%. The losses are higher in ratoon crop as compared to the planted crop (Muthusamy, 1973; Chona, 1976; Bailey, 1977; Whittle, 1982; Rutherford *et al*., 2003; Nzioki & Jamoza, 2006). Under severe conditions, such as cultivation of highly susceptible varieties in areas of disease hot spot during suitable environmental conditions, total crop fails (Lee-Lovick, 1978).

Whip smut is caused by Basidiomycota species, *Sporisorium scitamineum* (Syd.) M. Piepenbr., M. Stoll & Oberw, formerly known as *Ustilago scitaminea* Syd. The whip smut disease usually perpetuates from one season to another through propagative material and/or pathogen propagules present in the soil, which serve as a source of primary infection. Although, apparently disease-free setts are used for planting new crop, but the causal pathogen may present asymptomatically within the setts (Agnihotri, 1983). Therefore, it is necessary to treat the setts before planting to eradicate the pathogen, especially in the areas where whip smut occurs frequently.

Globally different measures are applied for the avoiding and control of sugarcane smut (Sundar *et al*., 2012), such as hot water treatment, rouging out diseased plants, planting resistant or tolerant cultivars, and application of fungicides (Gupta, 1979; Agnihotri, 1983; Ferreira & Comstock, 1989; Fauconnier, 1993; Wada *et al.,* 1999; Rott *et al.,* 2000). Fungicides not only eradicate smut from the planting material, but also defend seed cane from infection of pathogen inoculum present in the planting soil (Firehun *et al.,* 2009). Little work has been reported on fungicides' application to healthy or diseased setts that have been planted in the field under severely smut-contaminated conditions. Therefore, the present study was conducted to determine the effect of hot water treatment, fungicides and their combination on disease development as well as their impact on plant germination, quantitative and qualitative parameters of sugarcane.

Materials and Methods

Inoculum collection: Fresh smut whips were collected from the different sugarcane field of Sindh. After shade drying, the teliospores alongwith plant somatic tissues were gently scraped and thoroughly sieved using 53 µm mesh. The sieved teliospores weighing out 25 g were sealed in cellophane bags and stored in the refrigerator at 4ºC for further use. The germination of the teliospores on plain agar plates was also determined, which was found to be 90 percent at the time of inoculation.

Preparation of smut teliospores suspension: The 25 g smut teliospores were mixed with distilled sterilized water (Nasr, 1977; Wada & Anaso, 2013) alongwith 0.01% Tween-20 (v/v) to obtain a homogeneous suspension of the teliospores. The concentration of spore suspension was adjusted to haemocytometer value of 5×10^6 teliospores/ ml (Wada & Anaso, 2016).

Sett inoculation: The variety used in this experiment was CP29-120, which was highly susceptible to smut when inoculated with inoculum concentration of $5x10^6$/ml for 20 minutes, during previous screening of varieties against smut in 2012-13 season. Three budded setts were artificially inoculated with smut by soaking 20 minutes in a fresh suspension (5×10^6 teliospores/ ml) of smut spores (Abera, 2001). To create favorable environmental conditions for disease development, the inoculated setts were incubated for whole the night in polythene bag, filled with a liter of water just after inoculation (Wada, 2003).

Treatment of inoculated setts: After 24 hours of inoculation, setts were treated with eleven different fungicides to check efficacy of different fungicides for the control of whip smut of sugarcane. Their specification is given in Table 1. Fungicides were applied to the inoculated setts @ 0.15%/L for 30 minutes by two different methods. In first method, fungicide suspensions were prepared in hot water (52ºC) (Fauconnier, 1993; Bharathi, 2009), while in second one suspensions were prepared at normal temperature water (ambient temperature). Hot water treatment (without fungicide) was done for 30 minutes at 52ºC and control (no hot water and no fungicide) without hot-water treatment.

Experiment design and location: The experiment was conducted at experimental field area of Sugarcane Section, ARI, Tandojam during 2013-14 season on CP29-120 variety. The trial was laid out in a randomized complete block design with three replications. Each treatment consisted of three rows of 5m (total 15m) at spacing of 1.0 m between the two rows. Each treatment consisted 40, 3-budded setts (total 120 buds) and the experiment was arranged as RCBD with three replications.

Data collection

Disease data: Data on sett germination were recorded after 45 days of planting. Smut incidence was recorded at fortnightly intervals till harvesting. The smut clumps and whips noticed were roughed out after each observation and destroyed to avoid secondary infestation. Cumulative incidence of smut in each replicate was calculated on the basis of total setts germinated. Total number of whips in each treatment was also calculated. The germination% and incidence of the disease was computed using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of buds germinated}}{\text{Total number of buds}} \times 100$$

$$\text{Incidence (\%)} = \frac{\text{Number of infected stools}}{\text{Total number of stools}} \times 100$$

Quantitative and qualitative observations: Data on growth parameters such as Tillers/plant, Girth (mm), Plant height (cm), Millable cane/ h, Yield tons/ha was recorded as described above. For qualitative parameters, i.e. Brix, Pol, Purity, Fiber and CCS% (Commercial Cane Sugar), five canes were selected randomly from each replication (Meade & Chen, 1977) after harvesting. These canes were crushed with the help of Cutter grinder (Fabricator) (Model No. SCF-L4, Smith Crafts Fabricator, Gujranwala, Pakistan). Five hundred grams of crushed cane were pressed in a hydraulic press (Model No. SCF-HP-06, Smith Crafts Fabricator, Gujranwala, Pakistan); the yielded sugar juice was collected in 500 ml glass beaker and fiber cake was removed to calculate fiber contents (%) in cane.

Table.1. List of fungicides used for chemical control of whip smut of sugarcane caused by *S. scitamineum*.

Trade name	Active ingredient	Chemical group
Topsin-M	70% Thiophanate-methyl	Thiophanate-methyl
Score	Difenoconazole 250 EC	Difenoconazole
Bayletan	50% triademifon	Demethylation Inhibitor
Antracol	70% Propineb	Dithiocarbomate
Bavistan-DF	50% Carbendazim	Benzimidazole
Hexacare	Hexaconazole 5% EC	Hexaconazole
Tilt	Propiconazole (25%)	Triazole
Revus	Mandipropomide 250 SC	Mandelamides
Dithane M-45	80% Mancozeb	Dithiocarbamate
Tegula	Tebuconazole 12.5% EW	Triazole
Rally	Myclobutanil 40 WSP	Triazole

Fibre percentage: Hundred grams of residues remaining after extracting juice was placed in a pre-weighted Petri dish and oven dried for 24 hours at 70ºC. The fiber percentage in cane was calculated by applying the following formulae (Chen & Chou, 1993):

$$\text{Moisture percentage in bagasse} = \frac{\text{Loss in weight}}{\text{Weight of sample}} \times 100$$

$$\text{Juice percentage bagasse} = \frac{\text{Moisture \% in bagasse}}{\text{1-juice brix}} \times 100$$

Fibre percentage in bagasse = 100 – Juice percentage in bagasse

$$\text{Fibre percentage in cane} = \frac{\text{Bagasse \% cane} \times \text{Fibre percentage in bagasse}}{} \times 100$$

Brix percentage of sugarcane: For the determination of brix level (concentration of total soluble solids) in extracted cane juice, a drop of juice was placed on the prism of Refractometer (PR-101, ATAGO Co. Ltd, Japan) with the help of pipette. Before and after each sample, the prism was carefully cleaned with distilled water and tissue paper.

Pol percentage of sugarcane: The extracted juice sample was treated with Horns Lead sub Acetate method. For obtaining good juice clarity, 4 g of Lead sub Acetate was thoroughly mixed in 100 ml of juice with the help of glass rod. After an hour, the juice was gently poured on the funnel containing Wattman filter paper No.1 and placed on 100 ml beaker. The filtrate was then used for determination of pol reading by Polarimeter (Model: AA-5 Series. Optical Activity, London). In this process, Polarimeter tube (200 mm) was first washed with distilled water and then thoroughly rinsed with the sample to remove any juice left by the previous sample for effective pol reading. Then the tube was filled with the juice and placed in the Polarimeter to record the pol reading and the pol percentage was estimated by following the Schmitz's table (Anon., 1977). The corrected pol reading and brix percentage values were calculated by using the following formula:

Sucrose (%) = Polarimeter reading x 0.752 for 200 mm (Tube factor)

Purity percentage of sugarcane: To have an idea regarding the effects of smut infection of the quality of cane sample, purity of the cane juice was calculated by the following equation:

$$\text{Purity percentage} = \frac{\text{Pol in juice}}{\text{Brix in juice}} \times 100$$

Commercial cane sugar (CCS): CCS of the extracted juice samples was calculated on the bases of corrected pol and brix values with the help of following formula (Meade & Chen, 1977):

$$\text{CCS (\%)} = 3P/2\ [1-(F+5)/100]-B/2[1-(F+3)/100]$$

whereas, P: pol percentage of the juice; B: brix percentage of the juice and F: fibre percentage in the cane

Results

Effects of hot water treatment and fungicides on germination: All fungicides either used in ambient or hot water significantly increased the setts germination as compared to hot water alone and control (no fungicide or hot water). It also appears that hot water fungicidal treatments of setts were slightly more effective than the ambient water treatment of respective fungicides. The hot water fungicidal treatment of Tilt and Bayletan provides highest germination of 79.44% and78.33%, followed by Bavistan and Antracol (76.67 and 73.33 %). Among all tested fungicides, Rally and Topsin-M were the least effective, although they performed better than control and hot water alone (Table 2).

Effects of hot water treatment and fungicides on smut incidence: Significantly maximum incidence of whip smut was observed in untreated (38.05%), followed by hot water alone (14.16%), Rally (4.71%) and Topsin-M (3.30%). All other treatment results very low disease incidence ranging from 0.74 to 2.81%. Hence, all the fungicides in hot or ambient water remarkably reduced disease development as compared to the control or hot water alone. Hot water treatment of setts without any fungicide also brought some reduction in disease development, but not as much as from fungicidal treatments. The effectiveness of fungicides was slightly enhanced when used in hot water as compared to the ambient water. Bayleton, Bavistan and Tilt appeared as the highly effective fungicides as they completely eliminated the disease development and thereof the smut pathogen (Table 2).

Effects of hot water treatment and fungicides on Quantitative parameters: Generally, fungicidal treatment of inoculated setts brought reduction in the production of tillers. Maximum number of tillers/plant was observed in control, i.e. 9.66, followed by HWT (8.55), Topsin-M (7.78) and Revus (7.44). The other fungicides showed almost similar trend in production of tillers (Table 3). The application of all fungicides profoundly increased the cane girth as compared to non-fungicidal treatments. The highly effective fungicides were Tilt, Bayletan and Bavistan, which significantly increased the cane girth of 25.33-25.63 mm (Table 3). All fungicidal applications, whether in hot or ambient water greatly enhanced plant height. The increase in plant height was recorded as 21-31% in fungicide treated setts. Among tested fungicides, Tilt, Bavistan and Bayleton produced significantly maximum plant height as compared to other fungicides. Minimum plant height of 192.53 and 208.3 cm was recorded in plants grown from untreated and HWT setts (Table 3). Application of all fungicides tremendously increased the number of millable canes. Although, the effectiveness greatly varied in some fungicides, such as Tilt, Bayleton and Bavistan remained highly effective and brought 94% increase in the number of millable canes. On the other hand, Rally appeared as the least effective fungicide, which increased 63% in millable as compared to control. The HWT appeared slightly more effective than control (Table 3). The application of fungicides almost doubled the cane yield either used in hot or ambient water. Maximum yield of about 93 tons ha^{-1} was obtained in Tilt, Bayletan and Bavistan treatments. The lowest cane yield was recorded in Rally (78. 38 tons ha^{-1}) and Topsin-M (79.67 tons ha^{-1}), although these were much higher than those recorded in untreated and hot water alone, i.e., 41.13 and 47.58 tons ha^{-1}, respectively (Table 3).

Table 2. Effects of different treatments on disease development.

Fungicide	Treatments	Germination	Smut incidence	No. of whips/h
Topsin-M	Ambient	59.17 g*	3.30 cd	11630.00 d
	Hot water	62.78 g	2.21 def	8370.40 e
Score	Ambient	69.44 def	1.20 fg	3777.80 hi
	Hot water	72.22 cde	0.76 fg	1925.90 jk
Bayletan	Ambient	75.28 abc	0.74 fg	1925.90 jk
	Hot water	78.33 a	0.00 g	0.00 l
Antracol	Ambient	68.61 ef	1.22 fg	4740.80 gh
	Hot water	73.33 cd	0.76 fg	2222.20 ij
Bavistan-DF	Ambient	75.28 abc	0.77 fg	2518.50 ij
	Hot water	76.67 ab	0.00 g	0.00 l
Hexacare	Ambient	68.89 ef	1.21 fg	5037.10 gh
	Hot water	71.39 cdef	1.17 fg	3703.70 hij
Tilt	Ambient	76.67 ab	1.79 def	370.37 kl
	Hot water	79.44 a	0.00 g	0.00 l
Revus	Ambient	60.28 g	2.81 de	8666.70 e
	Hot water	68.89 ef	2.03 def	6888.90 ef
Dithane M-45	Ambient	68.89 ef	1.21 fg	5111.10 fgh
	Hot water	68.89 def	1.21 fg	4370.40 gh
Tegula	Ambient	67.78 f	1.65 ef	5777.80 fg
	Hot water	69.17 def	1.21 fg	4740.80 gh
Rally	Ambient	58.89 g	4.71 c	15333.00 c
	Hot water	61.67 g	3.16 cde	12222.00 d
Hot water		48.89 h	14.16 b	31704.00 b
Control		43.06 i	38.05 a	38296.00 a
LSD		4.2619	1.5608	1810.9
CV		3.83	26.71	14.75

*Values in the same column with different superscripts are significantly different at $p<0.05$

Effects of hot water treatment and fungicides on Qualitative parameters: The application of fungicides greatly influenced on the qualitative parameters of sugarcane including brix, pol, purity, fibre and commercial cane sugar (CCS). All Fungicidal treatments showed significantly more brix, pol, purity and CSS as compared to control and HWT. The fibre contents were significantly lowered in fungicides treated canes and higher in untreated and canes treated with hot water alone. Within the different treatments, the best quality parameters were yielded in plants treated with Tilt, Bayleton and Bavistan.

Maximum brix percentage (22.6%) was recorded in the fungicide Tilt-HW treatment, followed by Bavistan-HW and Byletan-HW (22.53 and 22.5%). Minimum brix was observed in Rally and Topsin-M, either used with ambient water or hot water. The brix was significantly reduced in control and hot water alone treatment (18.27 and 18.77%) (Table 4). Maximum pol percentage was also recorded in Tilt used with hot water (18.32%), followed by Bavistan and Byletan with hot water (18.29 and 18.25%), respectively. The minimum pol percentage was observed in control (14.02%), followed by HWT (14.52) (Table 4). Maximum purity was obtained in Tilt and Bavistan with hot water (81.20 and 81.18%), followed by Bayletan with hot water, Tilt and Bavistan with ambient water. Minimum purity was observed in control (76.78%) followed by HWT (77.4%), respectively (Table. 4). Maximum fibre contents were recorded in control and Rally with ambient water (14.61 and 14.29%), followed by HWT (14.25%) as well as Rally and Topsin-M with hot water (14.22 and 14.14%). Minimum fibre contents were noted in Tilt with hot water (13.24%), followed by Byletan, Bavistan and Hexacare, respectively (Table. 4). Maximum CCS was obtained in Tilt with hot water (13.02%), followed by Bavistan and Bayletan (12.99 and 12.96%) when applied in hot water. While minimum CCS was recorded in control (9.39%), followed by HWT (9.83%) (Table 4).

Table 3. Effects of fungicides and hot water treatment on quantitative parameters.

Fungicide	Treatments	Tillers/plant	Girth (mm)	Plant height (cm)	Millable cane/ ha^{-1} (000)	Yield tons ha^{-1}
Topsin	Ambient	7.78 bc*	23.90 defgh	233.77 def	102.67 gh	79.67 gh
	Hot water	6.89 cdef	24.03 defgh	239.97 bcde	106.33 g	82.51 g
Score	Ambient	6.67 cdef	24.33 cdef	233.63 ef	112.00 ef	86.91 ef
	Hot water	6.55 cdef	24.50 cde	239.90 bcde	116.33 abc	90.27 abc
Bayletan	Ambient	6.33 def	25.43 a	244.17 abc	116.33 abc	90.27 abc
	Hot water	6.55 cdef	25.53 a	247.10 ab	120.00 a	93.12 a
Antracol	Ambient	6.22 def	24.07 cdefgh	236.93 cdef	112.67 cdef	87.43 cdef
	Hot water	6.11 def	24.20 cdefgh	240.17 bcde	116.00 bcd	90.02 bcd
Bavistan-DF	Ambient	6.44 cdef	25.33 ab	244.23 abc	115.67 bcde	89.76 bcde
	Hot water	6.33 def	25.47 a	247.43 ab	120.00 a	93.12 a
Hexacare	Ambient	6.11 def	23.97 defgh	233.57 ef	112.33 def	87.17 def
	Hot water	6.22 def	24.13 cdefgh	240.43 bcde	114.33 cdef	88.72 cdef
Tilt	Ambient	6.44 cdef	25.50 a	248.03 ab	118.33 ab	91.83 ab
	Hot water	6.22 def	25.63 a	251.50 a	120.00 a	93.12 a
Revus	Ambient	7.44 bcd	23.67 gh	230.40 f	106.00 g	82.26 g
	Hot water	6.90 cde	23.87 efgh	233.57 ef	115.67 bcde	89.76 bcde
Dithane M-45	Ambient	6.22 def	24.53 cd	234.07 def	112.00 ef	86.91 ef
	Hot water	5.55 f	24.70 bc	236.33 cdef	113.33 cdef	87.95 cdef
Tegula	Ambient	5.67 ef	24.30 cdefg	239.43 bcdef	111.00 f	86.14 f
	Hot water	5.55 f	24.40 cde	242.90 abcd	112.67 cdef	87.43 cdef
Rally	Ambient	7.11 cd	23.57 h	232.87 ef	97.00 i	75.27 i
	Hot water	6.78 cdef	23.70 fgh	235.83 cdef	101.00 h	78.38 h
Hot water		8.55 ab	22.40 i	208.30 g	71.33 j	47.58 j
Control		9.66 a	21.93 i	192.53 h	61.67 k	41.13 k
LSD		1.4074	0.6594	9.2152	3.8159	2.9103
CV		12.81	1.65	2.37	2.14	2.12

*Values in the same column with different superscripts are significantly different at $p<0.05$

Discussion

In the absence of resistant varieties as well as non-availability of effective non-chemical measures, the use of the chemical fungicides becomes indispensable to combat destructive plant diseases, which otherwise cause's heavy economical losses. Therefore, searching of effective fungicides is an ongoing process because with the passage of time either resistance will be developed in targeted pathogen and/or emergence of new pathotypes will take place in organisms. Throughout the world, the areas which are considered as the hot spot for the whip smut disease, the application of fungicides for setts treatment is a common practice. During the present investigation, eleven fungicides were tested for their effects on disease development as well as on various qualitative and quantitative parameters of sugarcane. Most of the fungicide treatments brought significant increment in sett germination and greatly checked the smut development. For most of the evaluating parameters, Bayleton, Bavistan and Tilt performed better than other fungicides. The performance of these fungicides in inhibiting the pathogen infection in artificially inoculated planting material was much better than hot water treatment alone. However, their efficacy was marginally increased when they applied as a hot fungicidal dip than ambient. The sett germination was reduced remarkably in control and ineffective treatments. Generally, successful infection of *Sporisorium scitamineum* considerably retarded the germination either by disturbing hormonal function or by killing the growing buds (Agnihotri, 1983). In contrast to germination, profuse but abnormal tillering was noted in ineffective treatments. Abundant tillering in sugarcane is also considered as the result of pathogen infection (Agnihotri, 1983). The highly effective fungicidal treatments, by inhibiting the pathogen activities brought significant enhancement in other quantitative parameters as well as increased plant height upto 31% and miallable canes 94%, which ultimately double the yield.

Table.4. Effects of fungicides and hot water treatment on qualitative parameters.

Fungicide	Treatments	Brix %	Pol %	Purity %	Fiber %	CCS %
Topsin	Ambient	20.07 ij*	15.83 ij	78.86 ij	14.14 cd	10.88 ij
	Hot water	20.17 hi	15.93 hi	78.97 hi	14.11 d	10.96 hi
Score	Ambient	22.30 de	18.06 de	80.98 cde	13.35 hijk	12.79 de
	Hot water	22.40 bcd	18.16 bcd	81.07 abd	13.33 ijk	12.87 bcd
Bayletan	Ambient	22.43 abcd	18.19 abcd	81.09 abc	13.39 ghij	12.89 abcd
	Hot water	22.50 ab	18.26 ab	81.15 ab	13.28 jk	12.96 ab
Antracol	Ambient	22.23 ef	17.99 ef	80.92 def	13.47 fgh	12.72 ef
	Hot water	22.33 cde	18.09 cde	81.01 bce	13.38 ghij	12.81 cde
Bavistan-DF	Ambient	22.47 abc	18.23 abc	81.12 abc	13.33 ijk	12.93 abc
	Hot water	22.53 ab	18.29 ab	81.18 a	13.29 jk	12.99 ab
Hexacare	Ambient	22.20 ef	17.96 ef	80.89 ef	13.44 fghi	12.70 ef
	Hot water	22.30 de	18.06 de	80.98 cde	13.29 jk	12.80 cde
Tilt	Ambient	22.47 abc	18.23 abc	81.12 abc	13.33 ijk	12.93 abc
	Hot water	22.57 a	18.33 a	81.21 a	13.24 k	13.02 a
Revus	Ambient	20.10 hij	15.86 hij	78.90 hij	14.18 bcd	10.90 hij
	Hot water	20.23 h	15.99 h	79.04 h	14.12 d	11.02 h
Dithane M-45	Ambient	22.1 f	17.86 f	80.81 f	13.53 f	12.60 f
	Hot water	22.2 ef	17.96 ef	80.89 ef	13.48 fg	12.69 ef
Tegula	Ambient	21.6 g	17.36 g	80.36 g	13.83 e	12.15 g
	Hot water	21.63 g	17.39 g	80.39 g	13.81 e	12.18 g
Rally	Ambient	19.97 j	15.73 j	78.76 j	14.29 b	10.78 j
	Hot water	20.10 hij	15.86 hij	78.90 hij	14.22 bcd	10.90 hij
Hot water		18.77 k	14.53 k	77.40 k	14.25 bc	9.83 k
Control		18.27 l	14.03 l	76.78 l	14.61 a	9.39 l
LSD		0.1485	0.1485	0.1436	0.1252	0.1328
CV		0.42	0.53	0.11	0.56	0.67

*Values in the same column with different superscripts are significantly different at $p<0.05$

Accordingly, the effective fungicides also increased the quality criterion, such as brix, pol, purity, CCS contents and decreased the fibre. For instance, fungicide application in hot water was more effective than their ambient water application or equal in both cases. Reduction in sugarcane quantitative and qualitative parameters as the indicator of potent smut infection has already been recognized (Valladares & Gonzáles, 1986; Rott & Comstock, 2002). On susceptible cultivars, *S. scitamineum* infection remarkably lowered the yield as well as juice quality parameters, such as pol, brix, purity and CCS contents (Kumar *et al.,* 1989; Barnabas *et al.*, 2012). There are several reports regarding impact of fungicide treatment on smut development and yield of sugarcane (Comstock *et al*., 1983; Sharififar & Kazemi, 1999; Satyanarayana *et al.,* 2001; Bharathi, 2009). Our findings are in accordance with those reported by (Abera *et al*., 2009), which found that Tilt, followed by Bayfidan, Bayleton and Vincit were highly effective against whip smut. Similarly, Sundravadana *et al*., (2011) obtained effective control of this disease by using Triademifon (Bayleton) and Propiconazole (Tilt).

On the basis of the present study, it is concluded that whip smut is an aggressive and destructive disease of sugarcane and may cause substantial economic losses if proper control measures are not applied. Pre-sowing treatments of planting materials with suitable fungicides inhibit or eradicate the pathogen present within the sett tissues and subsequently, enhance the sett germination, plant growth and yield. Hence, sett dip with Tilt, Bavistan and Bayletan (0.15%) can be recommended for an effective management of sett transmitted sugarcane smut disease.

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