Ethiop. J. Agric. Sci. 20:35-46 (2010)

Importance and Status of Sugarcane Smut (*Ustilago scitaminea*) in the Ethiopian Sugar Estates

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Abstract

Sugarcane smut (*Ustilago scitaminea*) is considered as the most prevalent and serious disease in sugarcane producing countries of the world. To determine incidence of sugarcane smut, a total of 144 fields were surveyed at Wonji-Shoa, Metahara and Finchaa on plantcane, first and last ratoon crops from August 2008 to July 2009. Smut incidence varied significantly among the survey months within and across sites, among the varieties across sites and among crop types within and across sites. Among the sites, the highest incidence of the disease was recorded at Wonji-Shoa (3.78%) followed by Finchaa (3.61%) and Metahara (1.05%). Moreover, high number of affected stools was recorded during the months of June and July at Finchaa and from April to June at Wonji-Shoa. While at Metahara high number of smut-affected stools was recorded in April and May. Among the varieties, Co 421, mixed varieties (MV) and NCo 334 at Wonji-Shoa; NCo 334, NCo 376 and Mex 54/245 at Metahara and in NCo 334 and N 14 at Finchaa showed high incidence (> 10%) of smut. Low incidence (< 3%) of smut was observed on B58156 and B52298 at Wonji-Shoa; B52298, B41227, Co 678, Co 680 and MV at Metahara and B52298 and D 42/58 at Finchaa. The result also indicated that smut incidence increased as ratooning increases in all the plantations. Besides, long year data trend analysis on cane yield loss due to smut in the plantations revealed that there was a decreasing trend in the loss both at Wonji-Shoa and Metahara. However, the decreasing trend at Wonji-Shoa was not significant (R^2 = 0.49) as compared to Metahara (R^2 = 0.88). Nonetheless, the loss due to the disease showed a significant (R^2 = 0.91) increasing trend at Finchaa. Thus, the plantations need to strengthen smut management with special emphasis on use of disease-free planting material, resistant varieties and rouging efficiency. Sugarcane smut management control strategy should also treat each crop type and plantation differently.

Introduction

Sugarcane is an important commercial crop in Ethiopia covering about 30,000 ha of irrigated lands commercially with average cane and sugar yield of 145 tons per ha and 300,000 tons per year, respectively (ESDA, 2010). The International Sugar Organization (ISO, 2003) estimates that Ethiopia still needs to produce more than 80,000 metric tons of sugar per year to satisfy the current demand of consumption. To bridge the gap between supply and demand as well as to exploit the international market, Ethiopia is establishing additional new sugar factories with large tract of sugarcane plantation besides expanding the existing ones. Currently, the existing three sugar estates have created job opportunity for 30,329 people (ESDA, 2010).

Despite importance of sugarcane in the country, diseases, weeds and insect pests are among the major constraints of sugarcane production. About 18 sugarcane diseases are recorded in the three sugar estates (Abera et al., 2009; Firehun et al., 2009). In Ethiopia, sugarcane smut (*Ustilago scitaminea* Syd.) was first recorded immediately after commercial sugarcane plantation was established at Wonji-Shoa in 1954 (Abera and Tesfaye, 2001). Sugarcane smut is a cosmopolitan disease, which at one time or another has proved to be significant in nearly all sugarcane growing countries (Ferreria and Comstock, 1989).

Consequently, the plantations are undertaking different smut management practices such as continued monitoring and rouging of smut affected stools, hot water treatment (at 50 ^{o}C for 2 hours for initial seedcane nursery) of seed setts, chemical treatment of setts, use of resistant varieties, and avoidance of ratooning of affected fields (Abera et al., 2009; Firehun et al., 2009). According to Firehun et al. (2009), on average more than two million affected stools are rouged per year with an operation cost of about ten million Ethiopian Birr. In addition, Co 419, Co 421, NCo 310, NCo 376 and M165/38 sugarcane varieties have been put out of production in some of the estates due to their high susceptibility to the disease.

Though the plantations have been undertaking these smut management practices, the number of smut affected stools is increasing from time to time especially in some of the plantations whilst cost of smut management increases over time (FSF, 2007; WSSF, 2007). However, reports indicated that strict use of appropriate smut management practices could contain the disease satisfactorily and change its economic significance over time (Watson, 2007). In this regard, though different management strategies have been followed against the disease since long, assessment of their impact on the economic importance and status of the disease over time were not undertaken in the sugarcane plantations of Ethiopia. However, knowing the importance and status of a disease in a given site has an importance to change, modify and or omit the different control strategies being implemented. Thus, periodic assessment on the impact of smut management practices employed and determination of what changes had occurred in the distribution and incidence of the disease in the plantations is vital for devising sound smut management strategies.

This study was therefore designed to determine the current economic significance of sugarcane smut in Wonji-Shoa, Metahara and Finchaa sugar estates, and compare the status of the disease at each estate over years.

Materials and Methods

Description of the survey area

A smut survey was carried out monthly from August 2008 to July 2009 on irrigated sugarcane plantations in the central part of the main East African Rift Valley (Wonji-Shoa and Metahara) and in western part of Ethiopia (Finchaa). Wonji-Shoa Sugarcane Plantation is located at 8°30′N and 39°20′E at an altitude of 1540 m.a.s.l. The total area under the plantation is 7600 ha and it receives an average annual rainfall of 831 mm, with mean maximum and minimum temperatures of 27 and 15°C, respectively. Metahara Sugarcane Plantation is situated at 8°N and 39°52′E at an altitude of 950 m.a.s.l. The total area under the plantation is 10,200 ha and it receives an average of 554 mm annual rainfall, with mean maximum and minimum temperatures of 32.6 and 17.4°C, respectively. Finchaa sugarcane plantation is situated between 9°31′ to 10°00′ N latitude and 37°15′ to 37°30′ E longitude, at an elevation between 1350 – 1650 m.a.s.l. The total area under the plantation is ≈ 10,000 ha and receives an average of 1280 mm annual rainfall with mean maximum and minimum temperature of 30.4 and 14.4 °C, respectively. Sugarcane cultivation in the three plantations has been under way under irrigated i.e. furrow irrigation at Metahara, sprinkler irrigation at Finchaa, and furrow and sprinkler irrigation at Wonji-Shoa.

Survey Procedure

Assessment of smut was carried out on light, medium and heavy soil management groups of Wonji-Shoa and Metahara sugarcane plantations. While at Finchaa, it was conducted on Luvisols and Vertisols. The survey was carried out on monthly basis on the selected cane fields of the plantations having two to three months of age from August 2008 to July 2009. Cane fields were stratified into two crop-types: plantcane and ratoon crops. The ratoon crops were further stratified into first and last ratoon as used by Firehun and Tamado (2006). At Wonji-Shoa and Metahara, the first ratoon stage was a second cutting crop in all soil types, whereas the last ratoon stage was fourth cutting in heavy, fifth cutting in medium and sixth cutting in light soil management group. At Finchaa, the first ratoon stage was a second cutting crop in both soil types; whereas the last ratoon stage was the fourth cutting in Vertisols and fifth cutting in Luvisols.

From each stratum, six cane fields were surveyed (i.e. at Wonji-Shoa and Metahara 54 each and at Finchaa 36 fields) to determine smut incidence from plantcane and ratoon fields of the plantations. Cover method was used in each stratum as indicated by Wittenberg (2004). Ten parallel transects, each containing 6 evenly spaced 4 by 4.35 m sample areas (i.e. 60 quadrats from a range of 10 – 20 ha of land) were established. Transects were aligned along the furrows for simplicity. The exact spacing of the quadrats along transect depended on the length of the field. To ensure that transects are located at random, the surveyor arbitrarily identified one point within the selected field. This point then served as a benchmark to point the first transect and then used to position the remaining parallel equally spaced and equal-sized transects.

Data on the number of smut affected stools was taken from each quadrat on a monthly basis. Moreover, long year data on the number of rouged smut affected stools and cane yield losses were collected from the three sugarcane plantations. After each inspection, plants showing the disease symptom were uprooted and buried at the edge of the field to avoid subsequent re-counting.

Data Analysis

The data on the number of smut affected stools were summarized after the average number of infected stools recorded from each quadrat was converted to the total number of infected stools for the surveyed fields. To assess the trend of smut incidence in the plantations over time, the present survey data were compared with long year rouged smut affected stool data of the respective plantations (ten years data for Wonji-Shoa and Metahara, and seven years data for Finchaa).

The number of smut affected stalks per field was also calculated from the number of smut affected tillers, which by itself was calculated from the number of smut affected stools of the field as described by Firehun et al. (2009). First total number of smut affected tillers (T_s) was calculated as $T_s = S_s * 7$, where S_s is total number of smut affected stools and *7* is the average number of tillers produced per stool. From the total smut affected tillers data, total number of smut affected stalks (ST_s) was calculated as $ST_s = (T_s * 56)/100$, where T_s is total number of smut affected tillers and *56* is the percentage of tillers that reach to millable stalk.

In addition, from the total smut affected stalk data, yield loss (YL) was estimated using the mean weight of smut-free stalks following the procedure of Firehun et al. (2009) as $YL = ST_s * ST_{wf}$, where ST_s is total number of smut affected stalks and ST_{wf} is the average weight of smut-free stalk (for Wonji-Shoa, Metahara and Finchaa, it is 1.68, 1.57 and 1.54 kg, respectively).

Finally, trend analysis was made to assess the importance of smut over time across the plantations. Percent infected stool was analyzed using SAS computer software after arcsine transformation. Besides, correlation of smut incidence with temperature and relative humidity over the surveyed months was performed.

Results and Discussion

Sugarcane Smut Incidence over Months across the Plantations

Smut incidence varied among the survey months within and across the plantations (Figure 1). High number of infected stools was rouged at Finchaa from June to July, and from April to June at Wonji-Shoa. Though the total number of smut affected stools rouged from Wonji-Shoa during 2008/09 cropping season was the highest in the two plantations, the highest smut affected stools rouged on monthly basis was from Finchaa. At Metahara, high number of smut affected stools was rouged from April to May. In addition, the lowest smut incidence was recorded at Wonji-Shoa in December and at Finchaa in January, while in November at Metahara. Similarly, except for Wonji-Shoa, long year data on the number of rouged smut affected stools per month basis indicated that the highest and lowest affected stools were recorded in the same months. At Wonji-Shoa, the lowest and highest incidence of the disease was recorded in October and April, respectively.

Smut incidence at Metahara during 2008/’09 cropping season was lower than the long year average (Figure 1). However, at Wonji-Shoa and Finchaa, the number of smut affected stools rouged during 2008/’09 cropping season was greater than the long year average in some months. Moreover, the result indicated that there was a positive correlation (r = 0.56) between smut incidence and temperature over the months across the plantations. Conversely, smut incidence was negatively correlated (r = - 0.47) with relative humidity. Similarly, the high temperature recorded at Wonji-Shoa from February to April coupled with the relatively low relative humidity increased the smut incidence during the same period and the following month. At Metahara and Finchaa, the ambient weather conditions for symptom expression also coincided with the high incidence of the disease. In agreement with this, McFarlane et al. (2007) indicated that the increase in the incidence of smut affected stools in different months has been found to correspond to a period of rapid growth of sugarcane as affected by high temperature and low relative humidity. Hence, the highest and lowest smut affected stool prevalence in the sugarcane plantations could be attributed to the difference in environmental conditions recorded in the study period.

Generally, the prevalence of the disease in all the three plantations was higher from February onwards than the previous months of the survey period (Figure 1). Similarly, Akalach and Touil (1996) reported that smut incidence attains highest level in the dry season, during which rapid shedding of spores from whips occurs. Thus, the high incidence of smut from February onwards in the sugarcane plantations of Ethiopia indicates that the disease prevalence and spread increases during the dry season than in the wet season.

Association of Sugarcane Varieties and Smut Incidence across the Plantations

The number of rouged smut affected stools varied among the varieties across the plantations (Figure 2). During the survey, high incidence (> 10%) of smut affected stools by *U. scitaminea* occurred in Co 421, mixed varieties (MV) and NCo 334 varieties at Wonji-Shoa; NCo 334, NCo 376 and Mex 54/245 at Metahara and in NCo 334 and N 14 at Finchaa. Similarly, Berhanu (1991) and Abera et al. (2009) observed that the distribution of smut in the sugarcane plantations varied with the varieties planted.

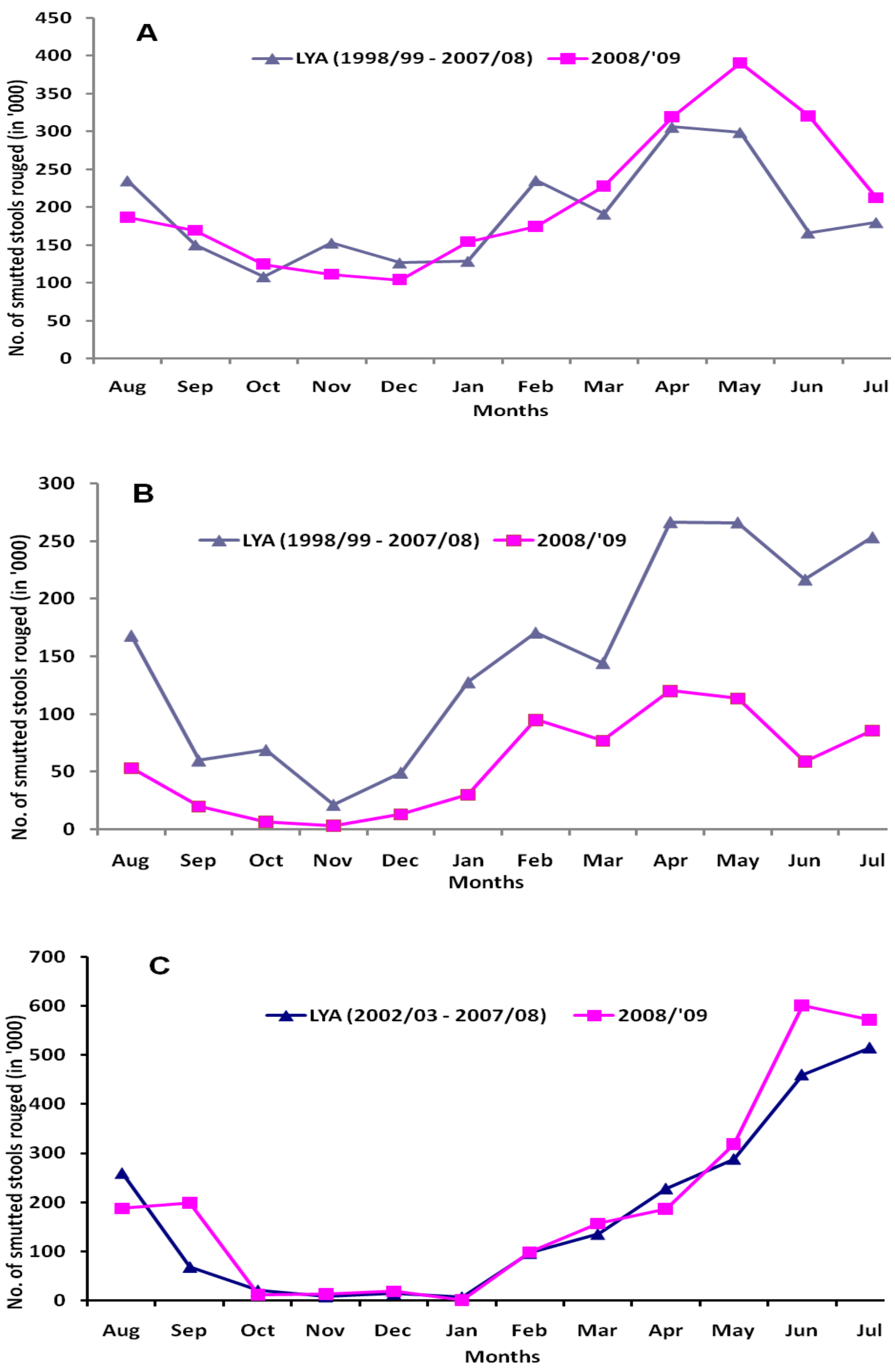

Figure 1. Incidence of sugarcane smut during 2008/'09 cropping season as compared to long year average at (A) Wonji-Shoa, (B) Metahara and (C) Finchaa sugarcane plantations

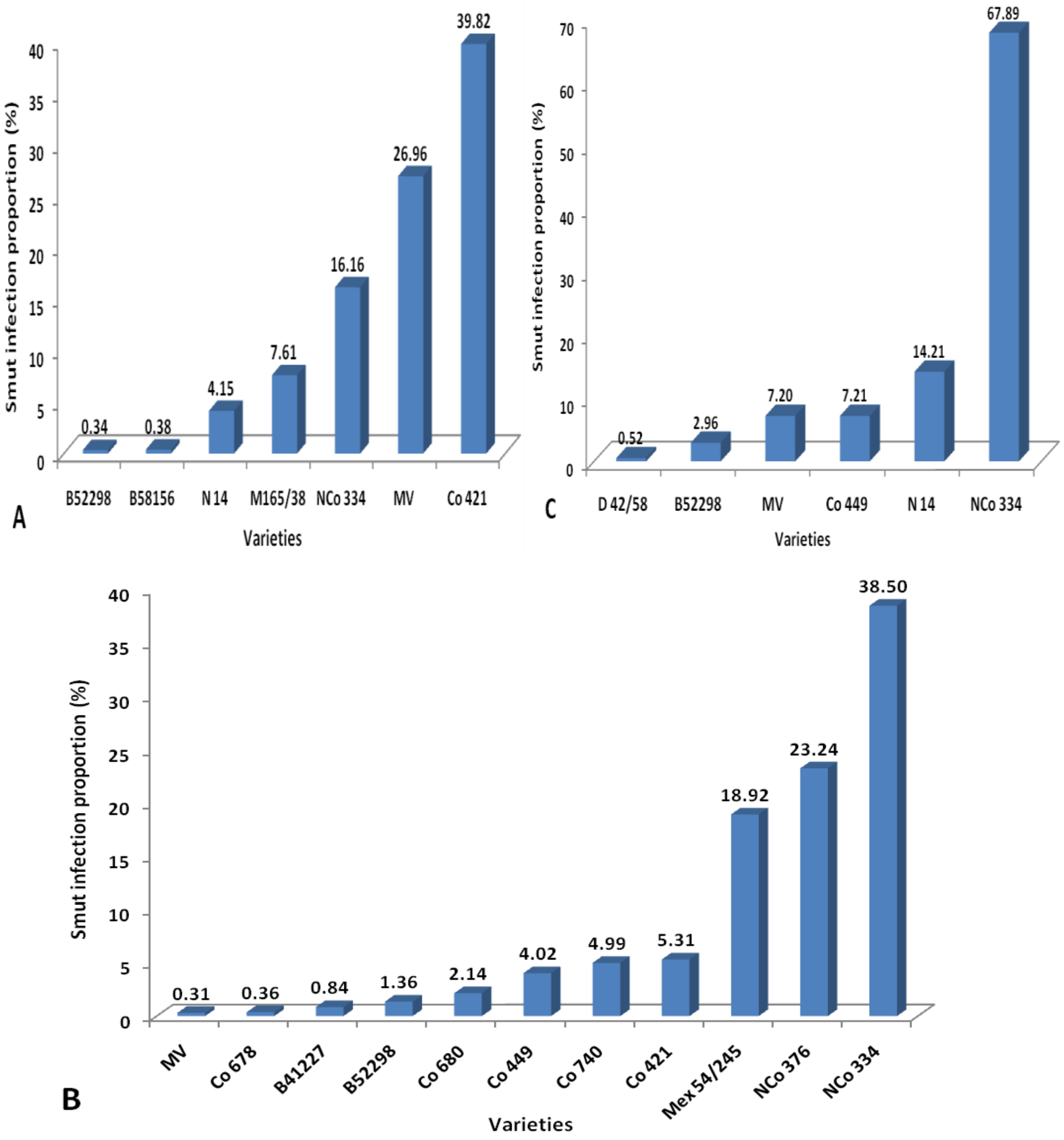

Figure 2. Proportion of rouged smut affected stools among sugarcane varieties at (A) Wonji-Shoa, (B) Metahara and (C) Finchaa sugarcane plantations

Low smut incidence (< 3%) was observed on B58156 and B52298 at Wonji-Shoa; B52298, B41227, Co 678, Co 680 and MV at Metahara and B52298 and D 42/58 at Finchaa (Figure 2). Abera et al. (2009) also reported that the cane varieties NCo 334, NCo 376, Co 421, Mex 54/245 and N 14 had susceptible reaction to the disease, whilst B41227, B52298, B58156, Co 680 and Co 678 were resistant to *U. scitaminea*. Thus, the difference in smut incidence among the varieties across the plantations could be attributed to the differential reaction of the varieties to the disease.

Based on the proportion of rouged smut affected stools, variety Co 421 seems to have intermediate reaction to the disease at Metahara unlike its reaction at Wonji-Shoa. The reason for this was due to the difference in the variety area coverage at Metahara and Wonji-Shoa, the coverage being higher at Wonji-Shoa due to its tolerance reaction to water-logging. In addition, at Wonji-Shoa, the majority of the fields containing MV were having varieties whose reaction to the disease was susceptible like Co 421 and NCo 334 as their major components; whereas at Metahara, B41227 (highly resistant variety) was found to be grown in association with other varieties in most cases. Thus, the difference observed in smut incidence of Mixed Varieties (MV) across the plantations might be attributed by the type of varieties and their mix composition.

Sugarcane Smut Incidence over Crop Types across the Plantations

The survey data on smut incidence over the sugarcane crop types (plantcane, first and last ratoons) indicated that there was a significant difference between the crop types within and across the plantations. Among the crop types, incidence of smut increased towards the last ratoon in all the three sugarcane plantations (Table 1). From the surveyed fields of the plantations, the highest smut incidence was recorded on the last ratoon crop at Wonji-Shoa, followed by Finchaa and Metahara. Whereas, the lowest smut incidence was recorded on plantcane fields of Metahara, Finchaa and Wonji-Shoa. Berhanu (1991) also reported that the number of smut affected stools at Wonji-Shoa increased with an increase in the number of cuttings. Similarly, studies conducted in different countries confirmed that ratoons are the most susceptible crop types to sugarcane smut than plantcane as sugarcane smut is a systemic disease, and thus its incidence might get increased in successive ratoons because of the increase in amount of inoculum (McFarlane et al., 2007). In addition, Akalach and Touil (1996) reported that percentage of affected stools increased from 23% in the plantcane crop to 85 and 98% in the first and second ratoon crops, respectively.

Table 1. Percentage of infected stools rouged from the different crop types at Wonji-Shoa, Metahara and Finchaa sugarcane plantations

Site	Infected stools (%)*			Mean
	Plantcane	First ratoon	Last ratoon	
Wonji-Shoa	1.02 (42.34)	25.79 (37.98)	73.19 (48.38)	**(42.90a)**
Metahara	1.43 (16.11)	28.37 (11.29)	70.20 (12.55)	**(13.32b)**
Finchaa	1.06 (41.55)	36.43 (50.73)	62.51 (39.08)	**(43.78a)**
Mean	**1.17c**	**30.20b**	**68.63a**	

* Values in parenthesis along a column are the infection percentage of the crop types across the plantations; values without parenthesis along a row are the infection percentage of the plantations across the plant types and means having the same letter along a column or row are statistically non-significant at P $\leq$ 0.05 by DMRT

Wada et al. (1999) reported that replanting of sugarcane fields with fresh clean seedcane each year has been an effective management tool for smut in Louisiana as compared to repeated ratooning, which encourages smut build up. However, Shrivastava (2006) reported that sugar production profitability is mainly dependent on the number of successive ratoons cultivated following plantcane. On the other hand, the advantage of ratooning over the plantcane crop lies in its reduced cost of production, high sugar recovery during early periods of crushing and reduced crop life cycle (Verma, 2004). Thus, the highest rouged smut affected stool recorded on the last ratoon crop from the sugarcane plantations would make sugar production uneconomical. Therefore, the plantations need to strengthen the management of smut with special emphasis on use of disease-free planting materials and practice rouging timely and efficiently.

Analysis of percentage of total stool infection among the plantations indicated that there was a significant difference ($P \leq 0.05$) in the plantations (Table 1). Among the plantations, the mean smut percent infection at Metahara was significantly lower ($P \leq 0.05$) than the two plantations, whereas there was no significant difference between Wonji-Shoa and Finchaa in their percent smut infection. Similarity in the prevalence of the disease between the recently established plantation (< 15 years) i.e. Finchaa and the plantation with more than 50 years of smut history i.e. Wonji-Shoa, indicated that the disease is spreading within a short period of time at Finchaa. Hence, the plantations should give due attention for the management of sugarcane smut.

Yield Loss Due to Sugarcane Smut

Long year data on cane yield loss due to sugarcane smut indicated that there was a significant yield loss at Wonji-Shoa, Metahara and Finchaa plantations over the years (Figure 3, 4 and 5). However, the rate varied among the plantations. At Wonji-Shoa, the loss due to the disease varied from year to year with a decreasing trend; however, the trend was not significant i.e. $R^2 = 0.49$ (Figure 3). The non-significant decreasing trend in the number of rouged smut affected stools at Wonji-Shoa could be attributed to the non-consistent management practice employed for the management of smut. Though there is a decrease in cane yield loss due to the disease over the years, it could not be sufficient enough to contain the disease and result in a significant reduction as exhibited at Metahara.

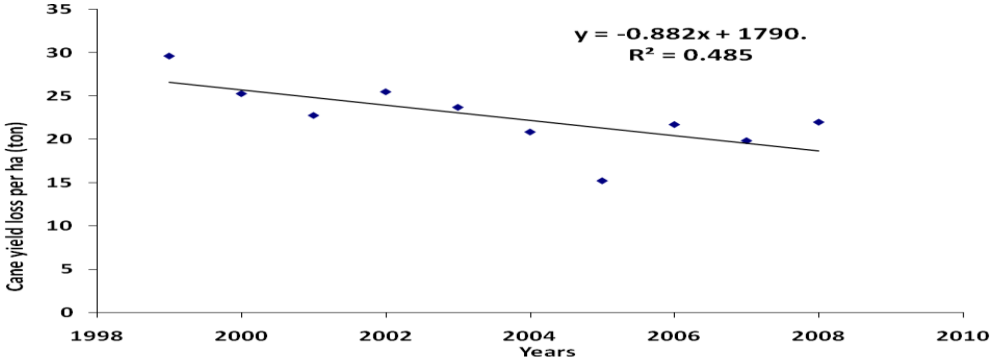

Figure 3. Cane yield loss due to smut over the years at Wonji-Shoa sugarcane Plantation

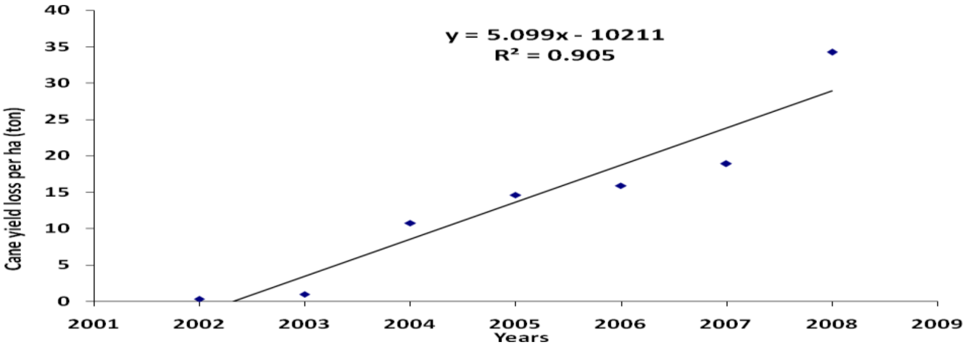

Figure 4. Cane yield loss due to smut over the years at Finchaa sugarcane plantation

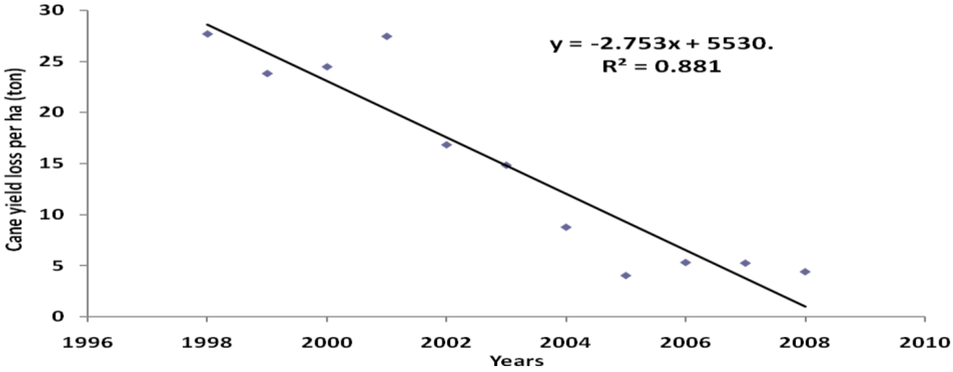

Figure 5. Cane yield loss due to smut over the years at Metahara sugarcane plantation

Though Finchaa is a recently established plantation as compared to the others, smut prevalence and its economic importance increased significantly over the years (R^2 = 0.91). Moreover, rate of the disease increment over the years indicated that there was an alarming spread of smut at the plantation (Figure 4). However at Metahara, the cane yield loss due to sugarcane smut showed a significant declining trend (R^2 = 0.88) over the years (Figure 5).

Firehun et al. (2009) reported that the area coverage of some varieties at Metahara has decreased drastically. Besides, at Metahara, NCo 376 and Co 419 varieties have been totally put out of production due to their high susceptibility to smut. On the other hand, replacement of susceptible varieties by resistant ones has a significant effect on the management of smut (Watson, 2007). Thus, the low incidence of the disease at the plantation over the years could be the result of the replacement of susceptible varieties by resistant ones, efficient rouging practice and use of fungicides to treat cuttings prior to planting.

Smut has been well managed by intensive application of field control measures, provided that the varieties grown are not extremely susceptible (Watson, 2007). Moreover, sugarcane smut could be managed most effectively if control measures are taken at an early stage of the disease development. However, findings of the present survey indicated that majority of smut-affected stools at Wonji-Shoa and Finchaa were removed after whip emergence. Similarly, Abera et al. (2009) reported that more than 96 % of smut-affected stools were removed after whip emergence both at Wonji-Shoa and Finchaa. Efficiency of rouging decreases significantly if it is practiced after whip emergence (Watson, 2007). Thus, rouging practice should be strengthened in the two plantations.

Despite the different management strategies employed to manage and contain sugarcane smut in the sugarcane plantations of Ethiopia, the decline in incidence at Wonji-Shoa was non-consistent as compared to Metahara. It also showed a rapid increment in terms of economic importance and disease status at Finchaa, which could be attributed to the low efficiency of rouging and other cultural practices employed. Moreover, there were a strong and positive correlation between smut incidence and dry season. Besides, smut incidence increase as ratooning increases. Therefore, the plantations need to strengthen smut management with special emphasis on use of disease-free planting material, resistant varieties and rouging efficiency. Sugarcane smut management control strategy should also treat each crop type and plantation differently.

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