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Determinants of Sugarcane Smut Prevalence in the Kenya Sugar Industry

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***Abstract* – Sugarcane smut is disease of economic importance in the Kenya Sugar Industry. On average, it contributes up to 38% loss to sugarcane production. The smut spore is spread particularly by aerial dispersal; some of which is contributed by human practices. This paper therefore seeks to identify the determinants of its prevalence in the Kenya Sugar Industry and recommend effective control measures. A multistage sampling was used where the sugar Industry was clustered into 13 sugar zones. From each zone, a further clustering into administrative locations was done and then a proportional random sample of 413 farmers was selected from the locations for interview and their plots/farms surveyed for the existence of smut. A mobile mapper GPS (global positioning system) was used to encode the position for each smut spotted farm at 1 m accuracy. Analysis of Variance to determine the varietal and zonal effect on prevalence of sugarcane smut as well as effect of source of seed cane and training was used to identify the significant determinants. Multiple linear regression models was used to determine the relationship between prevalence and sugar zones, varieties, row spacing, age of the crop, crop cycle, experience of the farmer and also training. The results indicated that prevalence was high (0.93%) in the crops whose farmers used self grown seed cane and those who sourced seedcane from the neighbors(0.72%), as compared to those who obtained seed cane from the factory (0.37%) and from Sugar Research Institute (SRI) (0.42%). Prevalence was also high among the old varieties compared to the new improved resistant varieties. We therefore recommend the adoption of the improved resistant varieties, with clean health history and planted in standard spacing. This would also apply in reducing prevalence of other sugarcane diseases because the improved varieties are more resistant to most of the diseases.**

***Keywords* – Disease Modeling, Prevalence, Spatial Distribution, Sugarcane Smut.**

I. INTRODUCTION

Sugarcane smut is caused by the fungus; *Ustilago scitmainea*[1] that exists in several physiologic races [2][3]. Smut incidence was first reported from Natal, South Africa in 1877 as reported by Luthra *et al* [4]. Smut disease has been important in nearly every sugarcane growing country spreading to most of the sugarcane producing areas viz. Mauritius, Rhodesia, Indonesia, the islands of Java, Sulawesi and Sumbawa, etc [5]. The disease was first reported in Kenya in 1958 in Nyanza and Coastal Provinces[6]. Currently, it occurs in all sugarcane-growing areas of Kenya. A recent yield loss assessment trial in Kibos, Kenya established yield losses of 21 to 38 % in plant cane in commercial cultivars under field conditions [7].

Smut is recognized by the emergence of black whip-like structures from terminal meristem or meristems of lateral buds of infected stalks. The whips may take different physical appearance viz; elongated short to long, twisted, multiple, pencil-thick growth, gray to black in color, etc. Other smut symptoms may be evident before the characteristic whip is seen such as tillering with spindly and more erect shoots with small narrow leaves with poor cane formation. Smut has other symptoms that are associated with smut infection that include leaf and stem galls, and bud proliferation general reduction in plant size, and increased tillering [8]. Some published work reported that cane grown under stress conditions such as sandland, dry and hot spring weather are more prone to develop smut [9].

The disease is spread by microscopic spores that are particularly dispersed aerially. The spores can be spread over great distances by wind currents in dry weather. In wet weather, large numbers of spores are washed down the stems to the base of the plant where buds are located. In any one season, cane growth begins in a bare field in which there are no stalks and no whips. However, some of the initial buds will already have been infected by the previous season's spores. Whips may begin to produce spores as little as 6 weeks after growth begins and may remain active for up to 3 months [7]. The spores originate from the whip at the rate of approximately one billion spores per whip per day released into the air. Once the spores get into contact with a cane plant, the cane gets infected at their buds. The infected buds remain dominant until then; cane is cut for seed and planted. If the infected cane is used as seedcane, the disease will spread and continue to multiply. The spores may also settle on the soil of cropped or nearly prepared fields, then once a disease free seedcane is planted on such fields, may get infected. However, the spores, only survive for a short time in the soil under normal soil moisture regimes. Smut spores germinate in moist condition and can cause infection only if the infection tube is so placed that it can penetrate between the buds scales. A bud will cease to be susceptible soon after it has started to sprout because the shoot develops a coating protective wax making it immune [10].

Sugarcane smut epidemics can results to serious reduction in yield and quality of sugarcane [11]. This may vary widely in different sugarcane growing areas of the world and is mainly dependent on the races of the pathogen present, sugarcane varieties and the prevailing environmental conditions [12]. A study by Whittle [13] reported a maximum potential loss of 12.4% to 25.6% in comparisons of yields of artificially inoculated and healthy varieties.

Despite the introduction of the smut resistant varieties into the Kenya Sugar Industry, sugarcane smut still remain a threat since adoption of the said variety has still not been met 100%. On the other hand, studies have shown that the

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evolution of new traces of *Ustilago scitmainea* may have broken the resistance of varieties to smut making it possible for the resistant varieties getting infected and cause upto 33% loss on yield [11] . Much of the earlier work in plant pathology was descriptive, or testing of different control measures. Today's control strategies require much more precision by first understanding the determinants that significantly contributes to the infection. This study therefore seeks to identify the determinant factors that significantly contributes to the spread of sugarcane smut.

II. Materials and Methods

During the project design stage, a pre-data collection exercise was conducted to collate the information into a database about the Kenya Sugar Industry in terms of the number of sugarcane farmers and their details. Based on the information in the database, a multistage sampling design was used where the sugar Industry was clustered into 13 sugar zones based on the existence of a milling factory. The zones included: Miwani, Chemilil, Kibos, Muhoroni, Mumias, West Kenya, Butali, Busia, South Nyanza (SONY), Transamara, Sukari, Soin and Kwale. From each zone, a further subdivision into locations was done then a random sample of farmers was conducted from each location of size proportional to the population in each zone. A sample of 413 farmer's plots (site) was selected, however only 326 farmers responded. Each farm selected, represented a sampling unit. Each sampling unit was then observed to determine the sovereignty of sugarcane smut. The same farmer was also interviewed to generate socioeconomic data.

Surveillance study in the sampling unit was conducted to determine presence or non-presence of smut (Sugarcane smut disease level). In each farm, 10 rows were selected randomly then the number of smut whips per stool was counted then expressed per hectare using the formula (1). The plot area (Ha), row spacing, row lengths (km), number of rows, geo-reference of the plot were also measured. Using the assumption that the average germination rate if 60%, the expected total number of stools per hector was estimated using the formula (1)

. The farmers whose plots were selected were also interviewed through a questionnaire administration to regenerate data on their cane managements and effort of controlling sugarcane smut, awareness, and preparedness of the diseases infection.

$$\textbf{No. of Infected Stool per Ha} = \frac{\textbf{No. of rows} \times \textbf{No. of infected stools in 10 rows}}{\textbf{10} \times \textbf{Area of the farm}} \quad (1)$$

$$\text{Expected total No. of stools per Ha} = \frac{\text{No. of rows} \times \text{Row length} \times 1000 \times 90 \times 0.60\}}{8 \times \text{Area of the farm}\}} \quad (2)$$

The field data collected was edited cleaned for any obvious errors. Data was analyzed using Statistical Package for Social Sciences (SPSS) Version 20 (statistical software) and R software by first estimating the prevalence using the formula **Error! Reference source not found.**, then descriptive and inferential analysis to give an overview of the baseline study. Analysis of Variance technique was used to determine significant differences in prevalence as per the factors that were being investigated to influence prevalence. Relationships were explored using Pearson's Correlation test then multiple linear regression model was fit to determine the significant factors that explained the variations in prevalence of sugarcane smut. Significance level was set at 5%.The linear regression model is as shown in formula (3). Finally, a geo-spatial maps relating the prevalence was also plotted.

$$\text{Prevelence} = \frac{\text{No. of Infected Stool per Ha}\}}{\text{Expected total No. of stools per Ha}} \quad (3)$$

$$Y = \beta_o + \beta_i X_i + \varepsilon \quad (4)$$

where;
Y= Prevalence
X_i= Smut prevalence determinants
$\beta's$= Regression parameters.

III. Results and Discussion

A. Descriptive statistics

Results in Table 1 indicated that farming was the main occupation for most of the respondents (77.3%). Only 10.2% of the respondents were occupied at salaried jobs and 12.4% occupied at business activities. Out of those whose occupation was farming, 90.1% had sugarcane proceeds as their main source of income. This is an indication that sugarcane farming is the core business and the income generating activity in the sugarcane growing zones and therefore controlling sugarcane diseases probably translates to high productivity and improved livelihood.

Table 1: Respondent main income generating activity by occupation

Main occupation		Sugarcane is main income activity		
		No	Yes	Total
Business	%	30.6	5.6	12.3
Farming	%	42.4	90.1	77.4
Salaried job	%	27.1	4.3	10.4
Total	n	85	233	318
	%	100.0	100.0	100.0

Table **2**. Neither 51.3% have no choice on varieties to plant. The ignorance on seed quality is common (70%) to farmers who develop their own seed cane did not have information about the seed cane. Since the cost of establishing cane is quite expensive, most farmers with cane would be reluctant to source seedcane from other reliable sources and therefore if the farmer didn't have knowledge of the previous cane, they will continue extend the ignorance. Note that majority of those who got their seed cane from Sugar Research Institute (SRI) were informed about the quality of seed cane they planted (85%) and all of them had a choice of which variety to plant. SRI in this cane played an important role in ensuring that the farmers are sensitized and empowered to make a choice in their sugarcane farming activity. This result is in agreement with the findings of Melinda *et al.* [14] that when farmers are given sufficient information about variety they tend to make good decisions on which variety to plant with the aim of improving productivity.

Table 2: Source of seed cane and farmers Knowledge on the seed cane quality

Source of seedcane	Information on seed cane quality		Choice on variety to grow	
	No	Yes	No	Yes
Factory	47%	53%	57%	43%
Neighbors	65%	35%	49%	51%
Self grown	70%	30%	57%	43%
SRI	15%	85%	0%	100%
Total	57%	43%	51%	49%

The variety grown by most farmers across the sugar industry was CO421 with 34.6% (Fig.1) despite its smut susceptibility reported by majority (52.8%) of farmers who planted it.

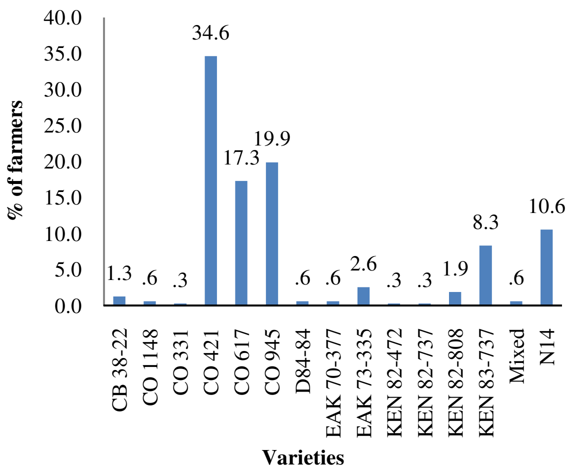

Fig.1. Varieties grown in the Sugar Industry

KEN 83-737 and N14 were not highly susceptible according to the farmers with only 2.4% and 7.2% of the farmers respectively saying they are susceptible. CO421, CO617 and CO945 are categorized as Old varieties while KEN series are classified as New/ improved varieties.

B. Determinants of prevalence

Analysis of Variance (ANOVA) in Table 3 was performed to determine the effect on sugarcane smut prevalence. The results indicated that there was significant difference in prevalence among sugar zones and also among the varieties grown (P-values less than 0.05) as shown in Table 5. However, (interaction of zone and variety) the prevalence of smut on varieties was not influenced by the zone where it was planted (P-Value=0.99173)

Table 3: ANOVA for zonal and varietal effect on prevalence

	Df	SS	MS	F value	Pr(>F)
Zone	14	41.30	2.9503	5.648	1.4e-09 ***
Variety	13	16.26	1.2505	2.394	0.00465 **
Zone:Variety	31	7.80	0.2517	0.482	0.99173
Residuals	267	139.47	0.5224		

Different sugar zones experienced different level of sugarcane smut prevalence. On the other had different varieties have different levels of prevalence. This indicates that when recommending varieties for different zones, this assessment on zonal smut prevalence will be important. The mean zonal prevalence is as shown in Fig.2. Chemelil sugar zone had the highest prevelence followed by Kibos then West Kenya where as Kwale and Transmara had the least percent of smut prevalence. .

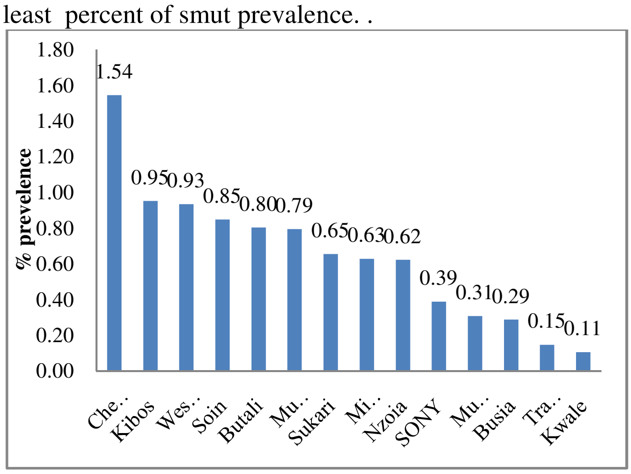

Fig.2. Zonal Smut Prevalence

Table 4: Variety grown by Sugar Zone by respondents

Zone	Variety Grown		Zone	Variety Grown	
	New	Old		New	Old
Busia	0%	100%	Mumias	31%	69%
Butali	5%	95%	Nzoia	5%	95%
Chemilil	0%	100%	Soin	30%	70%
Kibos	13%	87%	SONY	3%	97%
Kwale	88%	13%	Sukari	4%	96%
Miwani	6%	94%	Transmara	58%	42%
Muhoroni	0%	100%	WestKenya	7%	93%

Further results in Table 4 reveal that Kwale zone whose smut prevalence was lowest had grown majority (88%) of its cane as new variety which are associated with smut resistance while Chemelil had planted old varieties which are associated with susceptibility to smut. There is evidence that the type of sugarcane variety can contribute to the spread of sugarcane smut.

Analysis of variance results in Table 5 was performed to determine the effect of the source of seedcane on prevalence. The ANOVA results indicated a highly significant (P-Value=2.67e-05) difference in prevalence among the sources of seed cane.

Table 5: ANOVA showing the effect of the source of seed cane on prevalence of sugarcane smut

	Df	SS	MS	F value	Pr(>F)
Source of seed cane	4	16.1	4.026	6.847	2.67e-05 ***
Residuals	321	188.7	0.588		

The prevalence for the farmers whose seedcane were sourced from Factory (Millers) and SRI was lower than the seedcane that was sourced from neighbors and self grown (see Fig.3).

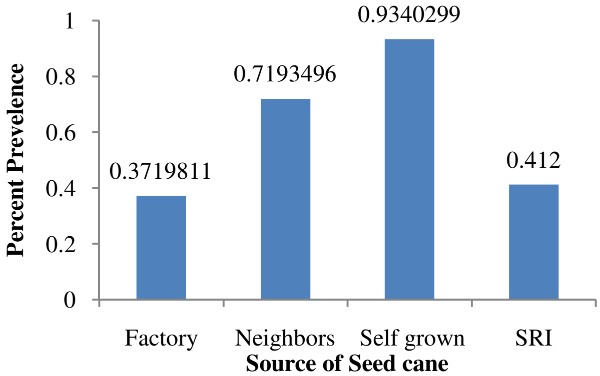

Fig.3. Smut prevalence by source of seed cane

A linear regression model was fit to determine the relationship between prevalence and the explanatory variables; crop cycle, the variety grown, the source of seed cane, and the row spacing. The fitted model significant and explained up to 99% variation in the prevalence Table 6.

Table 6: Regression model on effect of variety category (new or old), crop cycle and source of seedcane on prevalence

	Estimate	Std. Error	t value	Pr(>F)
(Intercept)	0.79369	0.15586	5.092	0.01464 *
Crop Cycle - Ratoon	0.95308	0.12876	7.402	0.00510 **
Variety -CO 331	-0.04955	0.09456	-5.240	0.01353 *
Variety -CO 617	0.06000	0.09134	0.657	0.55816
Variety– KEN 82-808	-1.27500	0.12507	10.194	0.00201 **
Variety– KEN 83-737	-0.08000	0.09866	0.811	0.47680
Variety– N14	-0.53000	0.06459	-8.206	0.00379 **
Source - Factory	0.17946	0.08888	-11.02	0.00160 **
Source – Neighbours	0.41446	0.09456	-4.383	0.02199 *
Source –Self grown	0.90446	0.08690	-10.41	0.00189 **
Row spacing	-0.27231	0.12237	-2.225	0.11249

Notes:
Ref.categories: Crop Cycle – Plant; Variety - CO 421; Variety category – Susceptible; source - SRI
1. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
2. R^2=0.9944
3. Residual standard error: 0.06976
4. F-statistic: 52.98 on 10 and 3 DF, p-value: 0.003762

The results indicate that while holding all other variables constant, the prevalence would reduce by 0.26 units for every one unit increase in row spacing, increase by 0.95 units from plant crop to ratoon, increase by 0.9 units when the seed source change from SRI to self grown.

IV. Conclusion

Sugarcane smut prevalence was reported more among the old varieties like CO 421, CO 617 and CO 945 compared to the new varieties like KEN 83-737 and EAK 7. Therefore adoption of the new and improved varieties would go a long way to reducing the sugarcane smut prevalence in the sugar industry.

Using quality seed would also reduce disease prevalence. This was evident due to the fact that prevalence was high for crops whose farmers used self grown seed cane as well as seed cane obtained from the neighbors. Seed cane obtained from the factory(s) and those obtained from SRI had relatively lower prevalence.

The survey results also revealed that prevalence among varieties was not dependent on the sugar zone where the varieties were planted. However, there were slight differences in prevalence in the sugar zones with Chemelil and Kibos recording the highest prevalence and Kwale recording the lowest prevalence. This could have been contributed by the fact that a high proportion of farmers (88%) in Kwale Sugar Zone planted a more resistant variety (KEN 83-737) while those in the zones that recorded high prevalence planted the more susceptible varieties (CO 421, CO 617 and CO 945).

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REFERENCES

[1] Notizen Uber Ushlagineen. Sydow, H. 1924, Ann. Mycol, Vol. 22, p. 277.
[2] Anon. Annual Report. National Sugar Research Centre (NSRC). 1984. pp. 41-42.
[3] Agnihotri, V P. Diseases of Sugarcane. s.l. : Oxford and IBH Publishing Company, 1983. pp. 65-86.
[4] Experiments on the control of smut of sugarcane Vol. Luthra, J C, Sutta, A and Sandhu, S S. 1940, Proceedings in Indian Academy of Sciences, Vol. 12 (B), pp. 118-128.
[5] A Mini-Review on Smut Disease of Sugarcane Caused by Sporisorium scitamineum. Ramesh, A. Sundar, et al. [ed.] Dr. John Mworia. 2012.
[6] Sugarcane smut,. Robinson, R A. 1959, East African Agricultural and Forestry Journal, Vol. 24, pp. 240-343.
[7] Characterization of physiologic races of sugarcane smut (Ustilago scitaminea) in Kenya. Nzioki, H., S., et al. 16, s.l. : African Journal of Microbiology Research, 2010, Vol. 4, pp. 1694 -1697.
[8] Undertaking genetic mapping of sugarcane smut resistance. Rott, Glaszmann P. and D'Hont. 2001, Proceeding of South Africa Sugar Technology Association, Vol. 75, pp. 94-98.
[9] Comstock, J C and Lentini, R S. Sugarcane Smut Disease. Florida Sugarcane Handbook. 2005.
[10] Models of Sugarcane Smut Diseases and their implication for testing variety resistance. Elston, D.A. and Simmonds, N.W. 1, s.l. : British ecological society, 1988, Journal of Applied Ecology, Vol. 25, pp. 319-329.
[11] James, J.E. and Nike, H.S. Assessment of yield loss due to sugarcane smut (ustilago scitaminea) infection in Kenya. 2006.
[12] Lee-Lovick, G.L. Smut of Sugarcane-Usilago scitaminea. . Rev. Plant Pathology. 1978, Vol. 57, pp. 181 - 188.
[13] Yield loss in sugar-cane due to Culmicolous smut infection. Whittle, A.M. 3, 1982, Trop.Agric. (Trinidad), Vol. 59, pp. 239-242.
[14] Variety Characteristics and the land Allocation Decision of Farmers in the Center of maiz diversity. Smale, Melinda, Bellon, Mauricio and Aguirre, Alfonso. Salt Lake : s.n., 1998. Annual Meeting of the American Association of Agricultural Economist.