TECHNIQUE FOR SCREENING
OF SUGARCANE VARIETIES RESISTANT TO TOP BORER,
SCIRPOPHAGA NIVELLA F. (*)

BY

R. A. AGARWAL (1), J. P. SINGH (2) & C. B. TIWARI (3).

(1) Division of Entomology, IARI, New Delhi-12, India.
(2-3) Haryana Agricultural University, Hissar, India.

Studies on the resistance to top borer *(S. nivella)* in sugarcane varieties were made in the plant and ratoon crops. Eight varieties, namely, P. 12235, Co. 1007, Co. 1107, Co. 1148, Co. 1328, G. 12061, CoJ.46 and CoL.9 were grown in 4 replications of 6 rows of 30 meters each. Samples of stalks were taken from 5.0 per cent row length and also four samples of 10 stalks each under the graded incidence of 0,10, 20, 30, 40, 50, 60, 70, 80, 90 and 100.0 per cent from 400 stalks, cut at random and pooled, in each variety. It turned out that CoL.9 hitherto considered as a susceptible variety towards the top borer, obtained the overall rated value 1, having the least total loss for the sum of characters (stalk length, number of internodes, girth, weight, sucrose and C.C.S.). It was suggested that in top borer endemic areas CoL.9 and P.12235 may be preferred both as plant and ratoon crops.

Simple and partial correlations worked out between the per cent of incidence and different loss characters showed that there existed a positive and significant relation between them. The regression coefficient showed a linear relationship between them. The regression equations were also worked out. It was found that from the incidence values alone the relative amount of losses caused in different varieties by the top borer could be confidently predicted.

It was concluded that the sugarcane varieties could be screened for resistance to top borer simply by recording the percentage of borer incidence.

The top-borer *Scirpophaga nivella* F. is a most serious pest of sugarcane in India. It occurs in Formosa and Indonesia also. It has 4 to 7 generations in a year. The different generations overlap with the result that no suitable method to control this pest has been evolved, so far.

The progeny tests of sugarcane crosses between the internode borer *(Proceras indicus* K.) resistant and susceptible parents and their reciprocals (AGARWAL, unpublished) have shown that the resistant and the susceptible progenies were widely distributed and that there were continuous variations in the population. Evidently the resistance to borers in sugarcane appeared to be a polygenic character.

In general sugarcane being highly heterozygous polyploid poses several problems in isolating clones of the desirable types that are resistant to stem borers. However, once a geno-type is fixed, further multiplication of the plant type is assured by its vegetative propagation.

During the early stages of selection the sugarcane clones undergo a vigorous testing against the various insect pests and diseases. This is done at the research institutes working for breeding and distribution of new hybrid varieties suited to local conditions.

Screening of sugarcane clones on the basis of all characters contributing to resistance is a tedious and time consuming process. Studies were, therefore, undertaken to evolve an easy and quick technique i.e. without involving a quantitative assessment of characters contributing to resistance against the top borer from the clonal stage onwards.

Such a technique included the determination of correlations between the per cent borer incidence and its influence on the reduction in stalk length, number of internodes, girth, weight, sucrose and commercial cane sugar (C.C.S.), and also comprised the fixation of their rated values.

It turned out that these studies were useful in establishing a character upon which more emphasis can be placed by the entomologist for screening the clones resistant to the top borer and which could also be utilized as an index in selecting the prospective varieties in highly endemic areas e.g. the subtropical belt in India.

Review of the literature

Several methods of sampling cane stalks have been applied by various workers. The percentage of canes bored per unit length or in randomly selected clumps was widely adopted by HAZELHOFF (1930), KHANNA & BANDYOPADHAYA (1951), PRADHAN & PRASAD (1953), GUPTA (1953, 1959) & SIDDIQUI (1961).

Doss (1954), GUPTA (1959) and LEE & CHIEU (1961) estimated that the losses during the early stage of the crop were to the extent of 20.0 per cent in shoot mortality, in addition to 40.0 per cent showing stunted growth. However, ISSAC (1939), JEPSON (1954), AGARWAL & PRASAD (1956), KALRA & SIDHU (1960), VENKATRAMAN (1962) KALRA & CHAUDHRY (1964) and AGARWAL & SIDDIQUI (1964) have suggested an overall loss of 20 to 85.0 per cent in different seasons and locations in India due to S. nivella.

HAZELHOFF (1929 and 1932) found that the hardness of the leaf bud was a main factor in the relative susceptibility of sugarcane varieties to this borer. HART (1932) concluded that the dry substance ratio and the hardness of the growing point attributed to the resistance

to the top borer. Issac (1939) and Rao (1941, 1947) found that the varieties having greater lignification in the mid rib were more resistant. Cane varieties with long spindle (Khanna & Ramnathan, 1946) and varieties with greater number of denticules per unit length in the mid-rib (Verma & Mathur, 1950) were found resistant to this borer. Varieties with greater foliage dimensions, lower moisture, greater dry matter, greater ash and silica content, reduced nitrogen content in leaves and midrib and a high concentration of ionizable salts in the leaf cell sap, contributed towards the resistant behaviour of the sugarcane varieties to top borer (Adlaka, 1964).

Methods and materials

Our studies were conducted in two experiments. In the first experiment the amount of losses, due to the top borer, was determined in eight varieties and rated values were fixed both for plant cane and ratoon crop conditions. In the second experiment the correlation between the percentage of incidence (damage) and the corresponding loss values was ascertained.

Experiment 1. The varieties P. 12235 (early season), Co. 1007 and Col. 9 (mid-season), Co. 1107, Co. 1148, Co. 1328, G. 12061 and CoJ.46 (late-season) were selected for studies during 1964 to 1967. They were planted in randomised block designs with four replications. Each replication had 6 rows of 30 meters. Stalks falling in 5 per cent row length were cut at the ground level in each replication. They were counted for healthy and damaged stalks whereas the percentages of incidence were assessed statistically. Fourty stalks were picked at random from each of the healthy and damaged stalk groups to make per variety samples of 10 stalks that fall in class intervals of 10 % incidence (0, 10, 20, 30 % etc. incidence).

The per cent losses of the following plant characters were determined : length, number of internodes, girth, weight, sucrose and commercial cane sugar. The per cent commercial cane sugar (C.C.S.) was calculated according to Writer's and Carpe's formula. Results are presented in tables 1 and 2. The variety showing the least loss for a character was rated as 1 and 2 to 8 in order of increasing losses. The rated values are listed in table 3.

Experiment 2. The correlation studies were based on 400 randomly collected stalks each from healthy and damaged samples. Later, 40 stalks were picked at random from each of the healthy and damaged samples to make 4 samples of 10 stalks of each category, again representing class intervals of 10 per cent incidence. These stalks were then examined for the plant characters mentioned before.

Results are presented in tables 4 to 7.

TABLE 1

Percentage of losses in sugarcane varieties (plant crop) due to top-borer damage

Percentage loss in	Co. 1007	Co. 1107	Co. 1148	Co. 1328	CoL. 9	CoJ. 46	G. 12061	P. 12235	Average	C.D. at 5%	C.D. at 1%
Length	22.6	31.7	11.6	47.6	16.6	18.8	33.9	32.2	26.8	7.6	10.4
Internodes	32.8	35.5	22.7	57.6	16.4	32.1	41.2	32.7	33.9	12.9	17.5
Girth	6.0	5.5	1.3	-4.6	-4.6	11.2	2.1	-2.6	1.8	4.1	5.6
Weight	26.0	43.0	6.8	55.2	20.1	28.4	34.6	34.4	31.1	9.1	12.4
Sucrose content	27.3	33.2	28.6	43.4	19.0	35.8	43.8	27.0	32.3	15.4	21.4
C.C.S.	37.8	35.0	33.9	45.8	21.4	34.7	48.9	31.5	36.1	11.5	16.0

TABLE 2

Percentage of losses in varieties (ratoon crop) due to top-borer damage

Percentage loss in	Co. 1007	Co. 1107	Co. 1148	Co. 1328	CoL. 9	CoJ. 46	G. 12061	P. 12235	Average	C.D. at 5%	C.D at 1%
Length	36.5	18.5	31.1	23.3	21.3	46.2	32.9	17.1	28.4	11.1	15.1
Internodes	42.2	18.4	32.9	27.0	32.7	45.8	39.0	14.5	31.5	8.5	11.6
Girth	13.3	3.0	16.3	6.7	4.2	23.1	15.7	7.3	11.2	10.0	13.4
Weight	18.4	24.0	29.4	33.4	21.7	62.2	50.3	11.7	31.4	10.3	14.0
Sucrose	14.3	18.5	14.6	26.2	15.2	22.1	25.7	12.0	18.6	10.8	14.7
C.C.S.	16.0	20.1	16.2	29.1	18.5	24.6	28.2	12.5	20.6	10.3	13.9

Results

AGARWAL (unpublished) found that on an average 36.6 % of the stalks were damaged by the top borer during 1951 to 1967. The lowest and the highest values ranged between 7.9 and 53.9%. The early, mid or late maturing varieties were equally damaged by this borer. However, during the same period, the varieties grown as a ratoon crop showed a significantly higher infestation than when grown as a plant crop. The reason might be that the ratoon crops were available for the overwintering moths from the beginning of March. Thus, they were exposed to the moths for a longer period than the plant crop. The latter, becoming vulnerable only from May onwards, escaped the attack of the first borer generation.

The early maturity or the high sugar content of a variety did not seem to exert any influence on the intensity of attack of this pest. The reason for this is that the borer is confined to the top of the cane stalk i.e. to the youngest portion of the cane stalk where the differences in sugar content are not marked.

(a) LOSSES IN LENGTH OF STALK. On the average a loss of 26.8 and 28.4 % was found for the cane varieties cultivated as plant cane and ratoon crop, respectively. This difference was not significant. However, there were appreciable differences in the reduction in stalk length in the individual varieties in both crops. The highest reduction in length was observed in Co. 1328 (47.6 %), followed in decreasing order by G. 12061 (33.9 %), P. 12235 (32.2 %), Co. 1107 (31.7 %), Co. 1007 (22.6 %), CoJ.46 (18.8 %), CoL. 9 (16.6 %). The least reduction was observed in Co.1148 (11.6 %). It was found that, except to CoL. 9 and G 12061, the varieties grown as plant cane and ratoon crop did not manifest the same sequence in the rated loss values ($\pm$ 1 value) (Table 3).

(b) LOSSES IN THE NUMBER OF INTERNODES. On an average 33.9 and 31.5 per cent internodes were less formed in the damaged stalks both in the plant and ratoon crops, respectively. The different varieties showed almost the same reaction and also followed almost the same sequence in the rated values ($\pm$ 1 value) as were observed for the losses in stalk length.

(c) LOSSES IN GIRTH. Losses in girth of the stalk of the cane varieties ranged from minus values to 11.2 % in the plant crop and from 3.0 to 23.1 % in the ratoon crop. As a rule the reduction in the thickness of the stalk was more pronounced in a variety when grown as a ratoon crop than when grown as plant cane; an overall average of 1.8 and 11.2 % reduction was observed in the plant cane and the ratoon crop, respectively. This was because the ratoon crops became vulnerable to attack by this borer earlier than the plant crops. The

TABLE 3

Rated value of sugarcane varieties to top-borer damage.

Attribute		Co. 1007	Co. 1107	Co. 1148	Co. 1328	CoL. 9	CoJ. 46	G. 12061	P. 12235
% loss in length	P-	4	5	1	8	2	3	7	6
	R-	7	2	5	4	3	8	6	1
% loss in internodes	P-	5	6	2	8	1	3	7	4
	R-	7	2	5	3	4	8	6	1
% loss in girth	P-	6	5	3	1	1	7	4	2
	R-	5	1	7	3	2	8	6	4
% loss in weight	P-	3	7	1	8	2	4	6	5
	R-	2	4	5	6	3	8	7	1
% loss in sucrose	P-	3	5	4	7	1	6	8	2
	R-	2	5	3	8	4	6	7	1
% loss in C.C.S.	P-	6	5	3	7	1	4	8	2
	R-	2	5	3	8	4	6	7	1
Aggregate	P-	4	5	2	6	1	4	7	3
	R-	4	2	5	6	3	8	7	1
Overall value		3	2	2	4	1	4	5	1

P = Plant Crop. R = Ratoon crop. Least number (1) assigned to variety showing minimum losses and 2 to 8 in order of increasing losses.

minus values obtained in a few varieties grown as plant crop seem to be the result of a blocking of the longitudinal growth due to the injury to the growing point which then caused a slight increase in girth. The varieties Co.1007 and CoL. 9 and CoJ. 46, showed almost similar rated loss values ($\pm$ 1).

(d) LOSSES IN WEIGHT. It has been established by several workers (Doss, 1954; GUPTA, 1959; KHANNA et al., 1951; AGARWAL et al., 1956; AGARWAL et al., 1964) that top borer caused severe reduction in weight of sugarcane irrespective of variety, season or location. The present studies have also shown that infested stalks weighed about 31.0 % less as compared to healthy stalks. The losses in the different cane varieties ranged from 6.8 to 55.2 % in plant cane and from 11.7 to 62.2 % in the ratoon crop. Co. 1007, CoL. 9 and G. 12061 revealed almost the same rated values for both crop types.

(e) LOSSES IN SUCROSE AND C.C.S. Along with losses in weight appreciable losses in sucrose and commercial cane sugar were found. The varieties under plant crop conditions manifested an average reduction in sucrose and C.C.S. of 32.3 and 36.1 %, respectively. For the ratoon crop these losses amounted to 18.6 and 20.6 %. Varieties Co. 1107, Co. 1148, Co. 1328, G. 12061 and P. 12235 were assigned almost the same rated values for these characters.

TABLE 4

Correlation coefficient values between percentage of incidence and other loss characters (pooled data)

Between % incidence and percent losses in	'r' Value		Significance
	Plant crop	Ratoon crop	
1. Internodes	+0.81	+0.80	0.01± .11
2. Length	+0.77	+0.83	0.19± .11
3. Girth	+0.46	+0.70	0.47± .11
4. Weight	+0.72	+0.76	0.09± .11
5. Sucrose	+0.87	+0.86	0.05± .11
6. C.C.S.	+0.80	+0.79	0.04± .11

All values were significant at 1.0 percent level.

The data presented in tables 1 and 2 reveal that the different varieties show highly significant (1 % level) differences in loss values, to all characters.

(f) CORRELATION COEFFICIENT AND REGRESSION VALUES. Pairwise total correlations were worked out between the percentage of borer incidence and the percentage of losses in length, internodes, girth, weight, sucrose and commercial cane sugar, according to the procedure

suggested by PANSE & SUKHATME (1961) and HAYES *et al.*, 1942. From the data it was found that all the characters studied were positively and highly correlated for each variety and crop. The average correlation coefficient between the percent incidence and the above characters was also high and significant at 1.0 % level (Table 4). The homogeneity test for the eight varieties and crops made according to RIDER (1939), showed that the correlation coefficient for different varieties and crops were obtained from equally correlated populations.

TABLE 5

Correlation coefficient values between the characters influenced by top-borer damage (80 observations).

Correlation between		'r' Value		Difference
		Plant crop	Ratoon crop	
1. Percent less in length	Percent less in weight	+0.96	+0.98	+0.25±0.11
2. Percent less in length	Percent less in sucrose	+0.65	+0.69	+0.07±0.11
3. Percent less in weight	Percent less sucrose	+0.74	+0.73	+0.02±0.11

Values significant at 5% level.

The magnitude of the simple correlation did not differ significantly in the plant cane and ratoon crop. Therefore, the data of the two crops were pooled to find out the combined correlations. It was observed that all correlations were highly significant in the combined data also (Table 5). The intensity of the attack was, however, found to greatly influence the other characters.

The regression coefficients in relation to the different characters were also studied in order to understand the exact contribution of the independent variate to the dependent variate. The regression formula was worked out. On the basis of regression formula, the prediction relationship was found for the various characters for both crop types individually (Table 6). From the values obtained the precision of the equations were tested by comparing the observed and the calculated values. It would be observed that the predicted values, were fairly close showing the correctness of the regression equations.

(g) PARTIAL CORRELATIONS. A change in one character is often accompanied by changes in several other characters. Therefore, partial correlations assume particular reference. The partial correlation coefficients were worked out between all possible pairs of 4 characters, namely, per cent incidence, per cent loss in length, weight and sucrose

TABLE 6

Regression coefficient (incidence as independent variate)

Characters as percent loss in	Factor	
	Plant crop	Ratoon crop
1. Length	Y = 0.64+0.26x	Y = 0.89+0.26x
2. Internodes	Y = 1.13+0.34x	Y = 1.44+0.32x
3. Girth............	Y = 0.7 +0.05x	Y = 0.8 +0.07x
4. Weight	Y = 2.71+0.30x	Y = 2.44+0.31x
5. Sucrose	Y = 1.47+0.30x	Y = 1.4 +0.15x
6. C.C.S.	Y = 1.37+0.32x	Y = 0.84+0.18x

(Table 7). It was found that weight exhibited little direct relationship with per cent loss in sucrose. However, other relationship revealed a high positive and significant correlations among themselves. The results of partial correlations fully stressed the importance of the incidence in the loss values. Thus indicating the reliability and usefulness of the percentage of incidence for rapid screening of the sugarcane varieties to top borer resistance.

TABLE 7

Partial correlation between 4 components

Character	'r' Value
r. AB.CD	+0.9738
r. AC.DB	+0.9707
r. AD.BC	+0.9115
r. BC.AD	+0.9954
r. BD.AC	+0.9025
r. CD.AB	+0.2460

A = Percentage of incidence; B = Percentage loss in length; C = Percentage loss in weight; D = Percentage loss in sucrose.

Discussion

The eight cane varieties studied, though similar in many characters, responded differently towards *S. nivella*. This heterozygous pattern has been demonstrated by the rated loss values, assessed in relation to the percentage of attack, for a number of characters, namely, stalk length, number of internodes, girth, weight, sucrose and C.C.S.

The gross average differences in loss values of stalk length, number of internodes and weight for the cane varieties grown under plant crop and ratoon crop conditions were non-significant. However, the average loss values for sucrose and C.C.S. were significantly greater in the plant cane. The girth was not appreciably affected by top borer damage in the ratoon crop.

It was found that CoL. 9, hitherto been considered as a susceptible variety towards the top borer, showed the least loss in internodes, girth, sucrose and C.C.S., when grown as plant cane. Judging the overall rated values it may be suggested that in top borer endemic areas CoL. 9 and P. 12235 may be preferred both for plant and ratoon crops. Considering the varietal complex in relation to top-borer incidence and the losses, it was concluded that a cane variety maintained the resistant or the susceptible property for different characters, irrespective of whether it is grown as plant cane or a ratoon crop.

The correlation coefficient studies have shown that the losses in sugarcane varieties were mostly proportionate to the intensity of attack and the same pattern was manifested in all the varieties; ' r ' values were very high in magnitude, sign and in significance. All the correlations in respect of the plant and ratoon crops were significant at 1.0 per cent level. Therefore, borer incidence alone could be used as an indication for estimating the relative losses in different varieties. The latter i.e. the quantitative losses are otherwise determined with great labour and time.

It was observed that the interdependance between any two characters was considerable and any character could be utilized for screening out the varieties. Amongst them the assessment of the percentage of incidence was quite easy and less time consuming. The incidence values could be taken as an independent variate and cane varieties showing low values may be selected as resistant to top borer with confidence.

The study of the regression of the percentage incidence on the percentage losses in length, weight and sucrose were worked out separately for each character on the assumption of the existence of a linear relationship between them. The trend of the regression was studied and the regression equations were obtained to observe the degree of the detrimental effect of the attack on the loss characters. Even after considering the varietal variations, the regression coefficient gave sufficient evidence of similarity between them. It was, however, found that the unit increase in the percentage of incidence, there was a considerable increase in the loss values also. Further that from any two characters (X and Y), line of « best fit » could be easily determined.

RÉSUMÉ

Technique de sélection de variétés de canne à sucre
résistantes au foreur *Scirpophaga nivella* F.

L'étude de la résistance à *S. nivella* de variétés de canne à été faite dans des champs de plants et de repousses. Huit variétés ont été cultivées en 4 répétitions de 6 rangs de 30 mètres chacun. Pour chaque variété des échantillons de tiges furent prélevés sur 5 % de la longueur du rang ainsi que 4 échantillons de

10 tiges, chacun selon une échelle progressive de 10 en 10 % allant de 0 à 100 % pour 4 000 tiges coupées au hasard et mises ensemble. Il en ressort que la variété Col. 9 considérée jusqu'à présent comme sensible au foreur, a obtenu la valeur maximum de 1 correspondant aux pertes totales les plus faibles pour la somme des caractères : longueur de la tige, nombre d'internœuds, circonférence, poids, teneur en sucrose et en C.C.S. Il est proposé que dans les régions où le foreur est endémique les variétés Col. 9 et P. 12235 soient préférées pour les champs de plants et ceux de repousses.

Les corrélations simples et partielles établies entre le pourcentage d'attaques et les différents critères de pertes montrent qu'il existe entre eux une relation positive et significative, avec un coefficient de régression correspondant à une droite. Il apparaît que d'après les seuls degrés d'attaque il est possible de prévoir avec assurance les taux relatifs des pertes provoquées par le foreur chez les différentes variétés.

On en conclut que les variétés de canne à sucre peuvent être choisies pour leur résistance au foreur simplement par la notation du pourcentage d'attaques.

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