A STATISTICAL NOTE ON THE EFFECT OF PESTS ON THE YIELD OF SUGARCANE AND THE QUALITY OF CANE-JUICE.

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Introduction.

Rao Bahadur C. S. Misra, Assistant Entomologist, Pusa, has collected a great deal of data regarding the loss caused by cane-borers and white ants to the sugarcane crop in Bihar. The variety for which the accompanying primary data (given in Table 1) were obtained was Co.213 planted on the 13th February, 1931, in clayey loam soil without any irrigation, with mustard cake as manure applied at the time of planting sets. The crop was harvested from the 8th to the 13th February, 1932.

Four different sugarcane pests namely,

(1) Top-shoot Borer (Treatment II)

(2) Stem Borer (Treatment III)

(3) Root Borer (Treatment V) and

(4) Termites (Treatment VI)

together with 6 combinations of these:—

(5) Top-shoot Borer and Stem Borer (Treatment IV)

(6) Stem Borer and Root Borer (Treatment VII)

(7) Root Borer and Termites (Treatment VIII)

(8) Top-shoot Borer and Root Borer (Treatment IX)

(9) Top-shoot Borer and Termites (Treatment XI)

(10) Top-shoot Borer, Stem Borer and Root Borer (Treatment X)

formed ten types of insect-attack in this case, and to these were added a control, *i.e.*, a healthy crop free from any pest (Treatment I).

The ten different combinations together with the control formed the eleven treatments, each of which was replicated 6 times, and data for the following seven items (given in Table 1) were recorded and sent to us for statistical analysis.

(1) Weight of 25 canes.

(2) Weight of Juice per 25 canes.

(3) Weight of Juice (percentage).

(4) Sucrose (percentage).

(5) Glucose (percentage).

(6) Purity (percentage).

(7) Brix reading.

A brief statistical analysis of the data is given in this paper, but a full discussion from an agricultural point of view will be published in due course by Rai Bahadur C. S. Misra himself.

TABLE 1. EFFECT OF SUGARCANE PESTS ON YIELD AND QUALITY

Treatment		Number of Canes	Weight of 25 Canes (in lb.)	Average weight of Canes (in lb.)	Weight of Juice (in lb.)	Percentage Juice	Percentage Sucrose	Percentage Glucose	Percentage Purity	Brix Reading
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
I. Healthy	1	25	64·5	2·4	48·5	67·4	17·3	0·21	88·2	19·6
	2	,,	64·0	2·5	43·0	67.1	16·6	·26	81·0	20·6
	3	,,	64·0	2·5	44·0	69·8	16·6	·25	85·7	19·4
	4	,,	62·0	2·4	42·0	67·7	17·2	·21	84·2	20·5
	5	,,	63·0	2·5	43·0	68·2	17·1	·20	84·2	20·4
	6	,,	62·0	2·4	42·0	67·7	16 5	·24	84·7	19·4
II. Top-shoot Borer	1	25	42·0	1·6	27·5	65·4	16·2	0·45	82·3	19·7
	2	,,	42·2	1·6	28·5	67·4	14·2	·70	79·6	17·8
	3	,,	46·0	1·8	31·2	67·9	15·6	·51	82·1	19·0
	4	,,	43·0	1·7	28·2	65·7	15·5	·56	82·4	18·8
	5	,,	41·5	1·6	28·2	68·0	16 1	·46	82·8	19·4
	6	,,	43·7	1·7	29 7	68·0	14·5	·66	79·1	18·3
III. Stem Borer	1	25	48·0	1·9	31·5	65·6	16·8	0·26	84·5	19·8
	2	,,	40·5	1·6	26·7	65·0	15·2	·38	81·9	18 6
	3	,,	48·0	1.9	32·0	66·6	15·8	·32	83·2	19·0
	4	,,	41·7	1·6	27·7	66 4	15·8	·35	82·7	19·1
	5	,,	47·0	1.8	30·5	64·8	16·9	·27	85·1	19·8
	6	,,	46·0	1·8	30·0	65·2	16·8	·32	83·5	19·5
IV. Top-shoot and Stem Borer	1	25	28·0	1·1	16·7	59·8	13·7	0·60	77 2	17·6
	2	,,	23·7	0·9	14·2	62·1	13·6	·68	77·1	17·7
	3	,,	30·0	1·2	19·5	65·0	12 9	·83	76·5	16·8
	4	,,	30·0	1·2	20·2	67·5	13·6	·70	78·0	17·5
	5	,,	29·2	1·1	19·0	64·9	14·4	·58	80·0	18·0
	6	,,	24·0	0·9	14·5	60·4	13·0	·88	76·3	17·1
V. Root Borer	1	25	40·0	1·6	26·5	66·2	16·1	0·29	83·2	19·3
	2	,,	44·2	1·7	29·2	66·1	16·9	·21	83·8	20·2
	3	,,	35·5	1·4	24·5	69 0	15·4	·38	81·6	18 8
	4	,,	49·7	1·9	34·2	68·8	15·6	·33	82·5	18 9
	5	,,	40·2	1·6	26·5	65·8	16·3	·35	83·1	19·6
	6	,,	38·5	1·5	24·5	63·6	17·2	·17	83·1	20 7
VI. Termites	1	25	40·5	1·6	27·0	66·6	16·1	0·35	82·1	19·5
	2	,,	49·0	1·9	32·0	65·3	16·6	·26	83·1	19·9
	3	,,	46·0	1·8	30·0	65·2	16·9	·27	84·2	20·1
	4	,,	47·0	1·8	31·0	65·9	15·5	·37	81·3	19·0
	5	,,	45·2	1·8	30·5	67·4	16·2	·36	82·1	19·8
	6	,,	46·0	1·8	31·0	67·3	16·4	·31	82·6	19·9
VII. Stem Borer and Root Borer	1	25	43·0	1·7	27·2	64·2	16·3	0·29	83·2	19·6
	2	,,	43·2	1·7	28·2	67·4	16·3	·33	82·7	19·7
	3	,,	37·5	1·5	24·0	66·6	16·2	·31	82·8	19·6
	4	,,	42·5	1·7	28·0	65·3	15·3	·37	81·7	18·8
	5	,,	42·0	1·6	27·0	64·8	16·8	·23	84·0	20·1
	6	,,	39·7	1·5	26·5	66·1	16·2	·33	82·9	19·6
VIII. Root Borer and Termites	1	25	47·5	1·9	30·5	66·9	15·8	0 30	82·4	19·2
	2	,,	41·5	1·6	28·0	66·8	15·9	35	81·7	19·4
	3	,,	39·0	1·5	26·0	65·0	16·3	·33	82·1	19·8
	4	,,	49·0	1·9	32·0	65·9	16·9	·23	83·8	20·2
	5	,,	42·0	1·6	27·2	65·2	17·5	·19	83·5	21·0
	6	,,	50·2	2·0	33·2	66·9	17·0	·22	83·5	20·4

TABLE 1. EFFECT OF SUGARCANE PESTS ON YIELD AND QUALITY—*contd.*

Treatment		Number of Canes	Weight of 25 Canes (in lb.)	Average weight of Canes (in lb.)	Weight of Juice (in lb.)	Percentage Juice	Percentage Sucrose	Percentage Glucose	Percentage Purity	Brix reading
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
IX. Top-shoot Borer and Root Borer	1	25	35·5	1·4	28·7	68·8	14·7	0·66	79·0	18·6
	2	,,	38·5	1·5	25·7	61·5	16·1	·46	81·6	19·7
	3	,,	25·0	1·0	16·2	64·7	18·9	·64	77·9	17·9
	4	,,	36·7	1·4	24·2	67·7	18·4	·78	75·4	17·8
	5	,,	30·2	1·8	20·2	66·8	11·8	·94	78·0	16·1
	6	,,	34·5	1·2	22·5	66·0	18·4	·74	76·0	17·5
X. Top-shoot Borer, Stem Borer and Root Borer	1	25	29·7	1·9	19·0	71·4	15·6	0·47	80·9	19·8
	2	,,	39·7	1·6	25·7	65·6	14·0	·82	77·8	18·1
	3	,,	41·0	1·5	25·2	66·6	16·0	·56	81·7	19·5
	4	,,	45·7	1·8	31·0	67·5	15·5	·54	80·7	19·2
	5	,,	41·5	1·6	27·7	66·2	15·0	·59	80·0	18·8
	6	,,	39·0	1·5	25·7	65·8	15·3	·52	81·5	18·8
XI. Top-shoot Borer and Termites	1	25	35·0	1·4	25·0	71·4	18·5	0·78	76·1	17·7
	2	,,	25·5	1·0	16·7	65·6	14·4	·58	77·8	18·5
	3	,,	30·7	1·2	20·5	66·6	11·7	·89	72·5	16·2
	4	,,	42·2	1·6	28·0	67·5	15 9	·42	82·1	19·4
	5	,,	40·0	1·6	27·0	66·2	14·7	·60	79·5	18·5
	6	,,	41·0	1·6	27·0	65·8	15·7	·53	80·1	19·6

Fisher's method of analysis of variance was used throughout. As the procedure in this method is well known, details of calculations have been left out, and only the final results are given in Table 2 (actual figures), and two subsidiary Tables 3 (percentages), and Table 4 (percentage damage).

TABLE 2. MEAN YIELD OF CANES, JUICE ETC.

	Treatment	Weight of 25 canes (in lb.)	Weight of Juice (in lb.)	Percentage Juice	Percentage Sucrose	Percentage Glucose	Purity	Brix
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I	Control	63·25	42·92	67·98	16·88	0·23	84·7	19·9
II	Top-shoot	43·17	28·88	67·07	15·35	·56	81·4	18·8
III	Stem	45·20	29·78	65·77	16·13	·32	83·5	19·3
IV	Top and Stem	27·48	17·35	63·35	13·53	·71	77·5	17·4
V	Root	41·35	27·57	66·58	16·25	·29	82·9	19·5
VI	Termites	45·62	30·25	66·28	16·28	·32	82·6	19·7
VII	Stem and Root	41·32	26·82	64·87	16·18	·81	82·9	19·5
VIII	Root and Termites	44·87	29·48	65·73	16·57	·27	82·8	20·0
IX	Top and Root	33·40	22·08	66·12	13·88	·70	77·2	17·9
X	Top, Stem, and Root	39·43	25·72	65·08	15·23	·58	80·4	18·9
XI	Top and Termites	35·73	24·00	67·18	14·32	·68	78·0	18·3
	Standard Error	1·64	1·16	0·67	0·35	·04	0·75	0·30

TABLE 3. PERCENTAGE ON CONTROL (HEALTHY)

Treatment		Weight of 25 Canes (in lb.)	Weight of Juice (in lb.)	Percentage Juice	Percentage Sucrose	Percentage Glucose	Purity	Brix
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
I	Control	100·00	100·00	100·00	100·00	100·00	100·00	100·00
II	Top-Shoot	68·25	67·29	98·66	90·94	248·48	96·10	94·47
III	Stem	71·46	69·27	96·75	95·56	189·13	98·58	96·98
IV	Top and Stem	43·45	40·42	93·19	80·15	808·69	91·50	87·44
V	Root	65·87	64·24	97·94	96·27	126·09	97·57	97·99
VI	Termites	72·13	70·18	97·50	96·45	139·13	97·52	98·99
VII	Stem and Root	66·91	62·49	95·42	95·85	134·78	97·87	97·99
VIII	Root and Termites	70·94	68·69	96·69	98·16	117·39	97·76	100·50
IX	Top and Root	52·81	51·44	97·26	82·23	304·35	91·14	89·95
X	Top, Stem, and Root	62·34	59·93	95·73	90·23	252·17	94·92	94·97
XI	Top and Termites	56·49	55·92	98·82	84·23	273·91	92·09	91·96
	Standard Error	2·59	2·70	0·99	2·07	17·39	0·88	1·50

TABLE 4. PERCENTAGE DAMAGE*

Treatment		Weight of 25 Canes (in lb.)	Weight of Juice (in lb.)	Percentage Juice	Percentage Sucrose	Percentage Glucose	Purity	Brix
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
II	Top Shoot	31·75	33·71	1·34	9·06	-143·48	3·90	5·53
III	Stem	28·54	30·73	3·25	4·44	-39·13	1·41	3·02
IV	Top and Stem	56·55	59·58	6·81	19·85	208·69	8·50	12·56
V	Root	34·63	35·76	2·06	3·73	-26·09	2·13	2·01
VI	Termites	27·87	29·52	2·50	3·55	39·13	2.48	1·01
VII	Stem and Root	33·09	37·51	4·58	4·15	-34·78	2·13	2·01
VIII	Root and Termites	29·06	31·31	3·31	1·84	-17·39	2·24	-0·50
IX	Top and Root	47·19	48·56	2·74	17·77	-204·35	8·86	10·05
X	Top, Stem, and Root	37·66	40·07	4·27	9·77	-152·17	5·08	5·03
XI	Top and Termites	43·51	44·08	1·18	15·77	-173·91	7·91	8·04
	Standard Error	8·66	8·82	1·40	2·93	24·59	1·24	2·13

*It should be noted that the Glucose content had increased in every case.

Yield of Cane.

The mean values of yield of 25 canes for the different treatments are shown in column 2 of Table 2, and percentages based on the healthy canes ('control') have been presented in column 2 of Table 3.

All the pests caused considerable decrease in the yield of cane. Acting by itself each class of pest caused on an average a decrease of 30 per cent. in the yield, and the differences in the damage caused by the different pests were not significant.

Among the binary combinations, Top shoot Borers plus Stem Borers (Treatment IV) are the worst as the cane-yield was reduced to less than half.

It will be seen from the figures given in Table 4 that in binary combinations IV, IX and XI, in all of which the Top Shoot Borer is involved, the loss in yield of cane was of the order of 50 per cent., while in combinations VII and VIII, in which the Top-shoot Borer did not occur, the damage done was of the order of 30 per cent. or about the same as the damage caused by the pests acting singly.

It is interesting to note that in case of treatment IV the damage has been approximately additive. Table 6. But this does not hold good for the other binary combinations.

Treatment X was a combination of three of the pests, but strangely enough the damage done was only 38 per cent., and was not appreciably different from the damage caused by pests acting singly or in combinations of two.

Yield of Cane Juice.

The decrease in the total yield of juice closely follows the decrease in the yield of cane, and the results given in columns 2 and 3 of Tables 2, 3, and 4 follow practically the same order. In fact the peculiarities of the binary combinations already noted in the case of yield of cane also persist in the case of yield of juice as can be easily seen from the data for juice given in Tables 5 and 6.

Table 5. Relative effect of Top-shoot and Root Borer

Treatment		Percentage Decrease in	
		Cane	Juice
IV	Top and Stem	56·55	59·58
IX	Top and Root	47·19	48·56
XI	Top and Termites	43·51	44·08
	Mean ...	49·08	50·74
VII	Root and Stem	88·09	87·51
VIII	Root and Termites	29·06	31·86
	Mean ...	31·08	84·44

TABLE 6. ADDITIVE EFFECT OF TOP-SHOOT AND STEM BORERS

Treatment		Percentage Decrease in Yield	
		Cane	Juice
II	Top-shoot Borer	31·75	33·71
III	Stem Borer	28·54	30·73
	Total (II+III)	60·29	64·44
IV	Top and Stem (Combined) ...	56·55	59·58

The above results are corroborated by the fact that the ratio of the weight of juice extracted to the weight of cane is comparatively stable. In fact while the coefficients of variation of the yield of cane and the yield of juice are 68 per cent. and 24 per cent. respectively, the coefficient of variation of the ratio of juice to cane (*i.e.* of percentage juice extracted) is only 6 per cent.

As regards individual combinations we find that the lowest yields of juice are given by treatment IV, IX, XI and X in order. All of these involve the Top-shoot Borer. We may, therefore, tentatively conclude that the Top-shoot Borer combinations cause relatively greater damage to the yield of juice than the other pests.

QUALITY OF THE JUICE.

Columns 7 and 8 of Table 2, 3, and 4 give the data for the 'percentage purity,' and the 'Brix reading.' For a mature cane the Brix reading is about 20. The healthy cane has a reading of 19·9, but treatments II, IV, IX, X and XI, all of which involve the Top-shoot Borer, show significant decreases in the reading.

The data for percentage purity also show a practically parallel decrease in the case of treatments IV, IX, X and XI. The decrease in the case of treatment II is also on the verge of significance. It is clear then that Top-shoot Borers (but not the other pests) cause an appreciable decrease in the Brix reading and the percentage purity of the juice.

CONTENT OF SUCROSE.

The data for the damage to the percentage Sucrose content are given in column 5 of Tables 2, 3, and 4. Treatments II, IV, IX, X and XI (all involving the Top-shoot Borer) show appreciable decrease in the percentage content of Sucrose, while the other treatments do not differ significantly from control.

It appears therefore that it is the Top-shoot Borer again which is primarily responsible for the reduction in the percentage content of Sucrose.

It will be remembered that the reduction in the yield of juice was also primarily due to the Top-shoot Borer. An analysis of the total content of Sucrose in the cane therefore, becomes important, and the necessary data were obtained by multiplying the total yield of juice and the percentage content of Sucrose.

The total Sucrose content in 25 canes is shown in Table 7.

TABLE 7. TOTAL WEIGHT OF SUGAR IN 25 CANES

Treatment		Weight of Sucrose (in lbs.)	Weight of Glucose (in lbs.)	Total Sugar (in lbs.)
I	Control ...	7·25	0·10	7·85
II	Top-Shoot ...	4·43	0·16	7·59
III	Stem ...	4·81	0·09	4·90
IV	Top and Stem ...	2·35	0·12	2·47
V	Root ...	4·47	0·08	4·55
VI	Termites ..	4·93	0·10	5·03
VII	Stem and Root ...	4·35	0·08	4·43
VIII	Root and Termites ...	4·89	0·08	4·97
IX	Top and Root ...	3·09	0·15	3·24
X	Top and Stem and Root	3·91	0·15	4·06
XI	Top and Termites ...	3·47	0·15	3·62
Standard Error ..		0·16	0·01	0·16

All the pests effectively reduce the total yield of Sucrose. The effect of Top-shoot is, however, comparatively more prominent. There is not much difference between the pests acting singly, but all the Top-shoot combinations show an average yield of 47·5 per cent. (as compared to the control) against 64·6 per cent for combinations not involving the Top-shoot Borer.

CONTENT OF GLUCOSE.

It will be seen from column 6 of Tables 2, 3 and 4, that treatments II, IV, IX, X and XI (all involving the Top-shoot Borer) show significant increases in the percentage content of Glucose. But these are the treatments which show appreciable decreases in the content of Sucrose. It is clear then that the increase in the Glucose content is closely connected with the decrease in the Sucrose content.

The total Sucrose and Glucose contents in 25 canes under the different treatments are shown in Table 7. It will be seen from this table that the total Glucose content is appreciably constant, the differences between treatments in this respect being often negligible.

This remarkable constancy of the total quantity of Glucose may be explained on either of the following two hypothesis :—

(1) That the insect pests do not cause any appreciable change in the total Glucose content of the canes.

(2) Or that the plants automatically adjust the Glucose content (possibly at the cost of the Sucrose) and make good the loss caused by the pests.

The weight of Glucose being very small, the results for the total weight of Sugar (Glucose + Sucrose) given in Table 7 are similar to those for Sucrose.

Conclusion.

The present paper gives a statistical analysis of data regarding the loss caused to the sugarcane crop in Pusa (Bihar) from sugarcane pests: (1) Top-shoot Borer, (2) Stem Borer, (3) Root Borer and (4) Termites, acting singly and in various combinations,

(1) Each of the pests acting singly caused about 30 p.c. damage to the yield of cane.

(2) Top-shoot Borer, in combinations with any of the other pests produced a damage of about 50 p.c. in cane.

(3) The other binary combinations caused approximately a damage of between 30 and 37 p.c. of the Control (healthy canes).

(4) The loss of cane-juice was practically parallel to the loss in the yield of cane.

(5) Although the yield of juice was considerably reduced by the pests, the ratio of yield of juice to canes was practically constant.

(6) The percentage of sucrose in the juice obtained under the different treatments varied between 14 p.c. and 17 p.c., the Top-shpot Borer combinations giving the lowest figures.

(7) The combined decrease in the quantity of juice and in the percentage of sucrose reduced the total sucrose content to half or sometimes less than half that of the healthy canes.

(8) The Purity indices were on an average 5 p.c. lower for the canes attacked by pests. Here also the greatest damage was caused by the Top-shoot Borer combinations.

(9) Brix readings were reduced by the insect attacks in all cases except one (Root Borer and Termites); the decrease was about 10 p.c. in the case of Top-shoot Borer combinations, while in other cases it was about 3 p.c. below that for the healthy canes.

(10) Glucose percentage, however, showed increases under the insect pests. Significantly enough Top-shoot Borer by itself and in combination gave the highest values of glucose percentage.

(11) The total glucose content, in consequence, remained practically constant for 6 of the treatments. This constancy may be attributed either to: (*a*) a preferential consumption of the sucrose by the insects, or (*b*) to a process of compensatory production of glucose by the plants.

(12) The effect of the pests in combinations was additive in a few cases, but this was not generally true. In fact, a combination of three pests sometimes caused less damage than certain combinations of two pests.

Finally, it is a pleasure to express our indebtedness to Rao Bahadur C. S. Misra for kindly supplying us with the original records and to Dr. McRae, Director, Imperial Institute of Agriculture, Pusa, for permission to use the data for this statistical note.

(*September, 1933.*)