STREAK DISEASE OF SUGAR CANE: ITS ECONOMIC IMPORTANCE IN SOUTH AFRICA

By A. P. D. McCLEAN, and R. H. HALSE, Natal Herbarium, Durban.

Introduction.

Streak is the major disease of Uba cane in South Africa; and no effective method of control is possible as long as this variety remains the principal one under cultivation. The disease has become exceedingly widespread and will be found not only on every estate in Natal and Zululand but in every individual field in which the variety Uba is grown.

We have little or no information on the early history of the disease. We believe that it has its origin in Africa. No evidence exists that it has been introduced from outside this continent. It is not known when the disease first made its appearance in Uba cane. The earliest record dates back to 1924. The next reference is contained in some writings of Wuthrich [3,4] in 1920 and 1922: he states that yellow-stripe—a synonym for mosaic—was present in the cane fields of Natal in proportions far in excess of those anywhere else in the world. Wuthrich was mistaken in the identity of the disease, for he had observed the disease that Storey subsequently identified and described as streak. It appears, therefore, that streak had already become exceedingly plentiful in some districts by 1920. In 1922 Storey [2] found it was distributed generally through the cane belt, and he states that he could find no area in the whole of Natal and Zululand that was free. He observed in some districts that almost all the plants were affected, whereas in others the percentage of infection was less than one. From general observations he considered the proportion of diseased cane in the whole area to be about one-third of the total.

The first section of this paper records our observations over the past four years on the prevalence of streak disease in the variety Uba. We have endeavoured to estimate as accurately as possible the amount of infection that prevails in the different districts. The loss in yield from streak disease has been determined quantitatively by field trials at the South African Sugar Experiment Station [5]. With this information at our disposal we have attempted to calculate the total annual loss sustained by the industry from the disease. In the second section of the paper are recorded some preliminary observations on the behaviour of the new commercial varieties to streak disease.

We take this opportunity of expressing our thanks and appreciation to the many planters and milling companies on whose estates these observations were made, and to the Director of the South African Sugar Experiment Station for certain data placed at our disposal.

METHODS.

In order to estimate the percentage of streak disease in a district, there is no need for an examination of all the plants in the district. Such procedure would necessitate the employment of hundreds of inspectors. The desired result can be obtained by a shorter and quicker method, which involves the inspection of only a small proportion of the total number of plants. It has thus been possible to make a detailed streak survey of the whole cane area by the employment of only one cane inspector.

The method of procedure is as follows. The percentage of streak is estimated in a proportion of the fields in each district, the fields being chosen at points well distributed within the district. The average percentage of streak in the total area represented by the fields inspected is taken as the index for streak in the district as a whole. Wherever possible, two fields were inspected at each point: one of plant cane and one of ratoon cane. Time has not permitted an inspection of all districts with the same degree of thoroughness. In a few sections it was only possible to examine two or three fields, and it is realised that the results in these instances do not necessarily provide a true reflection of the incidence of the disease in the district as a whole.

The actual determination of the streak percentage in a field involves the inspection of only a small proportion of the total number of plants. The method of procedure is to examine narrow strips of cane, of a standard size, at intervals throughout the whole field. Each strip is approximately 83 yards long—the equivalent of 100 paces—and two cane rows in width. The strip contains 200 plants, on the basis of one plant occupying the length of row equivalent to one pace. The individual cane plant in a field is not well defined, and it is impossible to determine, apart from actual examination of the underground structure, where the shoots of one plant end and those of the next begin. It was therefore necessary to adopt some simple standard of gauging a cane plant.

Diagram 1 provides an example of the procedure in the inspection of a 50 acre field, in which 32 strips of cane—equalling a total of 8,000 plants—were examined. The diagram is drawn approximately to scale. The dimensions of the field are 550 yards by 440 yards. For convenience, the diagram shews 300 cane rows, each horizontal division representing every sixth row. Actually, the field was divided into 293 rows, at 4ft. 6in. intervals. The short horizontal lines, of broader type, denote the strips of cane examined, and the arrows shew the direction in which the strips progress. The strips

fall naturally into four groups, each group starting from a point on one of the sides of the field. They (the strips) are separated laterally by twelve rows and progress inwards and then outwards, in the manner illustrated in the diagram.

This principle of inspection was adopted throughout the survey. Such details, as the number of strips examined and the interval between them, have been varied according to the size and shape of the fields, the amount of infection, and the distributiton of diseased plants. For example: in smaller fields of 25 acres or less, if 32 strips were examined, the strips were separated laterally by six rows; and the same interval of separation was used in larger fields if the number of strips was increased to sixty-four. The actual number was governed partly by the size of the field but mainly by the percentage of diseased plants. The smaller the percentage, the larger the number of plants that must be examined; and this applies particularly if the distribution of diseased plants is very uneven. The progression and position of the strips in each section of a field was determined by the shape of the fields and the contour of the cane rows.

In order to test the reliability of the method, the streak percentage of a fifteen acre field, which was known to be low in disease, was determined in the most accurate way possible, by an examination of every plant in the field. The field was then reinspected three times by partial methods, the number of strips examined being 64, 10, and 5 respectively. The results, which are given in table 1, are remarkably close to the figure obtained from the complete inspection, and the difference is less than half a per cent.

The figures indicate a very even distribution of diseased plants within the field, and for this reason the examination of only 1,000 plants (approximately 2 per cent. of the total) was sufficient to give a true reflection of the percentage of streak in the field as a whole.

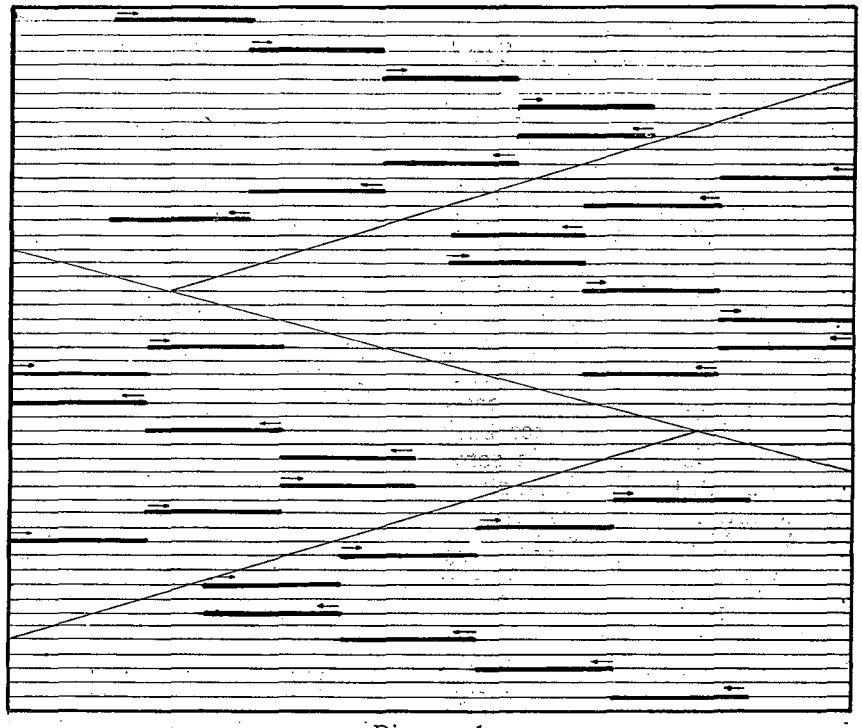

Diagram 1.

An illustration of the procedure in the inspection of a 50-acre field, 550 yards by 440 yards. Each horizontal division represents every sixth row; the short horizontal lines of broader type denote the strips of cane examined; and the arrows show the direction in which the strips progress. Each strip is 86 yards long and two cane rows in width. The diagonal lines mark off the four groups of strips, each group starting from one of the sides of the field.

TABLE 1.

TEST OF THE RELIABILITY OF THE PARTIAL METHOD FOR DETERMINING THE PERCENTAGE OF STREAK IN A FIELD

Size of field, 15 acres. Total number of plants in the field, 43,343. Number of plants streaked, 2,439. Actual percentage of infection, 5.6.

Number of strips examined and method of arrangement.		No. of Plants examined.	No. of Plants streaked.	Percentage infection.
1. 64, arranged in 4 groups of 16, each group being situated in a different section of the field, in the manner illustrated in diagram 1	(*a*)	4,000	229	5.7
	(*b*)	4,000	216	5.4
	(*c*)	4,000	207	5.2
	(*d*)	4,000	219	5.5
Total		16,000	871	5.4
2. 10, arranged in 1 group, situated on one side of the field		2,000	104	5.2
3. 5, arrangement as for 1		1,000	55	5.5

TABLE 2.

STREAK SURVEY OF ZULULAND.

DISTRICT.	Date of Inspection.	PLANT CANE.				RATOON CANE.			
		Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.	Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.
Amatikulu	1934	2	32	80	80	—	—	—	—
Gingindhlovu	1934	11	472	88–100	97	8	347	50–100	92
Mtunzini	1934	8	260	61–100	89	7	138	81–100	98
Eshowe...	1934	3	91	24– 95	66	1	35	100	100
Felixton—Umhlatuzi Flats	1934	11	463	70–100	93	13	456	90–100	99
Empangeni—Umtambanana	1933	20	507	10–100	81	26	618	17–100	83
Kwambonambi—Mposa	1934	12	526	17–100	95	12	477	69–100	97
Matubatuba—Umfolozi —St. Lucia	1934	11	325	10–100	94	12	443	12–100	92
Totals ...	... ...	78	2,676	10–100	90	79	2,514	12–100	92

TABLE 3.

STREAK SURVEY OF THE NATAL DISTRICTS, NORTH OF DURBAN.

DISTRICT.	Date of Inspection.	PLANT CANE.				RATOON CANE.			
		Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.	Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.
Mount Edgecombe ...	1932	14	543	4–14	9	12	978	3–18	8
(Durban—Ottawa)	1933	12	538	4–25	8	12	428	3–26	13
	1934	14	581	3–25	10	13	426	5–28	16
	1936	8	116	2–18	7	13	677	8–41	19
Verulam	1936	5	109	3–28	13	12	669	6–79	32
La Mercy	1932	1	31	9	9	2	110	7–13	10
Tongaat	1932	13	1,150	3–36	9	13	1,167	7–19	12
	1936	8	230	4–11	7	8	537	10–77	32
Compensation–Umhlali	1933	24	610	12–90	43	24	805	12–88	37
Chakas Kraal—Tinley Manor—Groutville	1933	18	501	8–79	37	18	549	8–86	41
Stanger	1932	7	279	8–50	25	5	414	42–84	50
Kearsney—Doornkop .	1935	7	279	18–75	37	9	443	11–88	35
Darnall	1935	3	68	8–61	50	10	585	20–100	53
Totals ...	... ...	134	5,035	2–90	19	151	7,788	3–100	26

TABLE 4.

STREAK SURVEY OF THE NATAL DISTRICTS, SOUTH OF DURBAN.

DISTRICT.	Date of Inspection.	PLANT CANE.				RATOON CANE.			
		Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.	Number of fields Inspected.	Total acreage of the fields.	Limits of variation of the Streak percentage.	Average Streak percentage.
Port Shepstone	1932	6	449	83–95	89	7	348	77–90	83
	1934	8	246	85–100	96	3	63	100	100
Umzumbi	1932	1	20	99	99	1	50	99	99
	1934	1	25	61	61	1	20	10	10
Hibberdene	1932	2	112	11–51	24	2	245	54	54
Sezela	1932	3	270	22–76	45	4	780	33–86	55
	1934	5	410	26–45	36	—	—	—	—
Esperanza	1932	3	277	9–20	13	2	320	4–83	48
	1934	6	349	16–86	50	1	43	31	31
Renishaw—Park Rynie	1932	4	335	18–74	35	3	171	13–76	36
	1934	4	339	50–67	61	1	124	65	65
	1936	2	156	33–50	44	5	376	10–95	55
Umkomaas	1932	3	106	11–13	12	2	80	17–34	21
	1934	5	150	11–75	33	3	130	41–91	73
	1936	1	60	29	29	3	195	50–97	63
Illovo	1932	2	96	57–70	63	2	138	13–66	36
	1934	4	310	30–33	32	—	—	—	—
Umbogintwini—Isipingo—Reunion—Merebank	1932	5	247	14–87	39	3	110	70–99	86
	1936	—	—	—	—	6	356	78–100	93
Totals ...	... ...	65	3,957	9–100	48	49	3,549	4–100	62

RESULTS OF THE SURVEY TO DETERMINE THE PREVALENCE OF STREAK DISEASE IN UBA CANE.

The results of the streak survey are presented in tables 2, 3 and 4. Under each district is recorded the number of fields inspected, the total acreage of the fields, the lowest and highest percentage of streak recorded in individual fields, and the average percentage of streak prevailing in the total area inspected. The figures for plant cane and ratoon cane are given separately. For districts inspected more than once, the results appear separately under the year during which each inspection was made. Although the number of acres examined represents but a small proportion of the total, we believe our figures provide a close approximation—at least as close an approximation as it is possible to obtain—of the amount of streak prevailing in the fields of Uba cane to-day.

The figures illustrate in a striking manner the wide distribution of streak disease. Out of a total of 556 fields, varying in size from five to a few hundred acres, and scattered over the whole cane area, not one contained Uba that was entirely free from the disease. The extent of the infection varied greatly and was 2 per cent. on the one extreme and 100 per cent. on the other. In the Zululand districts 2,676 acres of plant cane and 2,514 acres of ratoon cane were inspected, and the streak percentage in the total areas averaged 90 to 92 respectitvely; in the Natal districts, north of Durban, 5,035 acres of plant and 7,788 of ratoon cane had an average streak percentage of 19 and 26 respectively; and in the districts, south of Durban, the average percentage in 3,957 acres of plant and 3,549 of ratoon was 48 and 62 respectively. These figures provide an approximation of the infection prevailing in each of the three main sections of the cane area. It is possible that the figures for Zululand

TABLE 5.

THE PERCENTAGE OF STREAK PREVAILING IN UBA OVER THE WHOLE AREA.

The figures for the acreage of Uba are taken from the Government Census Return fo 1934–35.

MAGISTERIAL DIVISIONS.	DISTRICTS.	PLANT CANE.		RATOON CANE.	
		Total number of acres of Uba grown.	Average Streak per-centage.	Total number of acres of Uba grown.	Average Streak per-centage.
Eshowe, Hlabisa, Lower Umfolozi, Mtunzini	All districts of Zululand...	17,831	90	86,575	92
Lower Tugela	Darnall, Kearsney, Doornkop, Stanger, Chakas Kraal, Tinley Manor, Groutville, Umhlali, Compensation	16,475	38	63,917	43
Inanda	Tongaat, La Mercy, Verulam, Mount Edgecombe	7,261	9	33,808	17
Durban	Merebank, Isipingo, Umbogintwini, Illovo...	1,231	39	11,071	79
Umzinto	Umkomaas, Renishaw, Park Rynie, Esperanza, Sezela, Hibberdene	7,278	38	48,498	54
Port Shepstone	Umzumbi, Port Shepstone	2,319	93	6,121	84
	Totals	52,395	54	249,990	61

are on the low side. In a subsequent inspection of Zululand districts (no records are tabulated because no actual counts were made), many fields were examined, and in a few instances only was the percentage less than one hundred.

In table 5. an attempt is made to compute the average percentage of streak prevailing in the cane area as a whole. The figures for the number of acres of Uba are taken from the Government census return for 1934-35. The districts of Zululand are treated collectively because of the uniformity of streak disease prevailing in this section. The Natal sections are split up into the magisterial divisions: this is considered advisable owing to the greater fluctuation in the streak percentage. It is interesting to note that within each division the degree of variation of the streak percentage of the component districts becomes less. The figures show that approximately 60 per cent. of all Uba cane is infected. Ten years ago Storey [2] estimated the proportion of diseased cane at about one-third of the total. Thus, in the intervening period the incidence of the disease has increased by almost 100 per cent.

The Inanda division stands in marked contrast to the remainder of the cane area in its comparative freedom from streak. It represents the one division in which a concerted effort is made to control the primary spread of the disease, by the selection of healthy cane for planting. This is to be attributed to the influence of two large milling companies, which own the greater part of the cane lands in the Mount Edgecombe and Tongaat districts. The procedure in selecting cane on the estates of these companies is of interest. A field, from which plant cane is to be selected, is subjected to a preliminary inspection by a gang of natives or Indians, trained to recognise streak disease. Infected plants are suitably marked and are omitted later by the cutting gang. The cut canes, with the green top attached, are examined again at the planting site for the purpose of discarding any streaked ones that may have escaped detection during the earlier inspection. This practice, which has been in operation since 1924, has been justified by the results, and the comparative freedom of the cane from the disease on the two estates is to be attributed entirely to the measures taken to control primary transmission. It is suggested by some that the control of the disease by selection is possible in these districts because they possess a low normal rate of secondary infection. It is true the rate of secondary infection is low, but this is because the number of diseased plants is low and not because of a scarcity of insect vectors, the agents of secondary transmission. Our evidence indicates that in both districts, particularly in the regions nearer the coast line, there exists a potentiality for rapid secondary infection. In table 6 are recorded the results of the streak percentages of some fields that were inspected in the plant stage and eighteen months later as first ratoon. Every field shows a substantial increase in the amount of infectiton. A striking example of rapid secondary spread occurred in a series of streak experiments that were conducted at the Sugar Experiment Station, which is situated

TABLE 6.

THE INCREASE OF THE PERCENTAGE OF STREAK IN FIELDS OF UBA CANE BY SECONDARY INFECTION.

The initial inspection of the fields was made in the plant stage, when the cane was from 8 to 12 months' old; and the second inspection about 18 months' later during the stage of first ratoon.

DISTRICT.	Acreage of Field.	Percentage Streak of the Field as		Percentage increase.
		Plant Cane.	First Ratoon.	
Mount Edgecombe (*a*)	12	6	24	18
,, ,, (*b*)	40	9	24	13
,, ,, (*c*)	35	6	8	2
,, ,, (*d*)	41	8	13	5
,, ,, (*e*)	60	5	10	5
,, ,, (*f*)	30	9	15	6
,, ,, (*g*)	103	10	19	9
,, ,, (*h*)	10	25	41	16
,, ,, (*i*)	90	12	28	16
,, ,, (*j*)	23	13	40	27
,, ,, (*k*)	40	9	19	10
Total acreage	484	9	20	11
Tongaat (*a*)	54	4	19	15
,, (*b*)	50	4	17	13
Total acreage	104	4	18	14
Renishaw	124	29	65	36

in the heart of the Mount Edgecombe district. Four small plots were planted with diseased Uba and were arranged alternately with four plots of healthy Uba. After two years 53 per cent. of the plants in the originally healthy plots had developed streak, and after four years, 70 per cent. In a similar experiment in which the variety was CH 64/21, the healthy plots were 75 per cent. diseased after two years. These observations give an indication of the rapidity with which the disease would increase in the absence of methods of control. Selection has kept the number of diseased plants reduced to a minimum, and this in turn has had the effect of reducing the amount of secondary spread.

Proceeding northwards from Tongaat, the position rapidly changes. We come to districts in which the small planter predominates, and in consequence we find greater variation in methods of agricultural procedure. Each grower has his own opinion on the relative importance of the problems that confront him and adopts his own methods of combatting them. Thus at the outset the natural advantage of concerted action in dealing with any problem such as the control of streak disease, apart from that induced by legislation, is absent. This is reflected in the amount of streak disease that prevails in the districts between Tongaat and the Tugela River. The proportion of diseased plants now represents more than a third of the total. Yet, about 10 years ago Storey [2] stated that this area was comparatively free from streak, the proportion of affected plants averaging about 5 per cent. According to records on the files at the Natal Herbarium approximately 384 acres (25 fields) were inspected during 1924 between Umhlali and Darnall, and the average percentage of streak was under two. The amount of streak that occurs to-day on individual estates varies greatly. In young plant cane the percentage in single fields varied from 12 to 90, and in ratoon cane from 11 to 100. These figures illustrate admirably the variation in the measures of control. On the one extreme we find a few planters that have made every effort to control primary transmission, and they have been largely successful in checking the spread of infection on their estates. On the other extreme no attempt is made to select healthy seed-cane, and

this is reflected in the high percentage of disease prevailing on the estates concerned. Many planters practice what they term rogue-selection, which, in effect, is only a partial method. This involves the selection of all canes with healthy foliage, irrespective of whether other shoots of the same stool are diseased or not. It has been demonstrated that such canes, although shewing no symptoms on the leaves, may contain nevertheless streak virus and will develop in consequence fully diseased plants.

The incidence of streak reaches its highest level in the districts of Zululand. In both plant and ratoon cane the average percentage exceeds ninety and is probably not far removed from one hundred. This high percentage is uniform throughout all the districts. Twelve years ago certain areas were still comparatively free. Storey (2) states that there was little streak between the Tugela River and Amatikulu (about 5 per cent.), but that the percentage rose to a high figure from Amatikulu northwards, except in the regions away from the larger rivers, such as parts of Gingindhlovu and Kwambonambi. He found a small group of farms in the dry western end of the Empangeni concession, and the greater part of the cane grown at Eshowe to be almost disease-free. Some records made during 1924 are of interest. Five hundred and eighty-six acres inspected at Eshowe averaged 2.7 per cent., and 79 acres in the western section of Empangeni averaged 2.5 per cent. However, even at that time fields were found in the Eshowe district with infection as high as 50 per cent. But these areas no longer enjoy the same advantage, and streak has become as prevalent in them as in the other sections. The percentage of streak, however, is still somewhat lower in the western end of Empangeni: it is 60 per cent., as compared with 93 per cent. in other parts of the same district.

The figures recorded for the Amatikulu and Eshowe districts in table 2 are based on the inspection of only two or three fields. It was impossible to do a more thorough inspection at the time, but extensive observations were made in both areas the following year. Thirty-one farms were visited in the district of Eshowe and Entumeni. A few ratoon fields, selected at random, were examined on each estate, and in every case the cane proved to be totally diseased. No actual counts were made, and so no record is given in table 2. A similar state of affairs was found to exist in the cane fields situated between Amatikulu and the Tugela River, where thirteen farms were visited. There was, however, one interesting exception here: a farm situated in the district of Inyoni. This estate had approximately 330 acres under Uba, and the percentage of infection was estimated to be under fifty. Counts were made in two fields with the following result: twenty-five acres of plant cane, 22 months old, was 10 per cent. diseased, and forty acres of first ratoon cane was 19 per cent. diseased. It was interesting to learn that for a period of ten years the practice on this farm had been to plant only healthy cane. This was reflected in the general appearance of the cane and in its superiority over Uba on surrounding properties.

Practically no attempt is made in Zululand to secure healthy Uba for planting; and this has been the general practice for many years. To-day, unless Uba is obtained elsewhere, there is no choice but to plant diseased material. Here and there, a few growers make spasmodic efforts to select healthy cane, but as a rule the selection is only partial, and the early plant crop will show an appreciable proportion of primarily infected plants. Secondary transmission is very rapid in most districts, and this has caused many to abandon attempts at selection. In our knowledge. the farm in the Inyoni district, referred to above, is the only example in the whole of Zululand where the planting of healthy Uba has been practiced systematically.

In the districts south of Durban, the proportion of diseased plants amounts to more than half the total. Streak is most prevalent in the districts of Port Shepstone, Umbogintwini, and Isipingo, where the position is much the same as in Zululand. The Umkomaas farms. which were once relatively free (Storey (2) 1925), to-day shew a relatively high percentage of infection. Several estates make some attempt at selecting healthy seed-cane, but, with few exceptions, they adopt the unsatisfactory method of rogue-selection, which we described earlier. The desired result is only partially achieved, and an unnecessarily high percentage of primarily infected plants are established in the new fields. As the records indicate, no attempt is made in the Port Shepstone section to control primary infection.

FACTORS THAT HAVE CONTRIBUTED TO THE PREVALENCE OF STREAK IN UBA CANE.

Streak disease spreads by two methods; a primary one and a secondary one. The causal virus invades the plant systemically and becomes distributed throughout the tissues. As sugar cane is propagated vegetatively, an effective means is provided of perpetuating streak in successive vegetative generations. Thus cuttings from a parent stock that is diseased will produce only diseased plants. This is the primary mode of transmission and has as its agent the cane planter himself. Secondary transmission involves the passage of the virus from an infected plant to a healthy one; and the only known means by which this can be effected is through the agency of a specific insect—the maize leaf-hopper, **Cicadulina mbila.**

The importance of a disease like streak, which is so specialised in its method of transmission, depends primarily on the agent of secondary transmission. Its importance, for example, will be governed by the efficiency of the insect as a vector, and on the density of the vector population. Other factors, such as the available source of infection, and the degree of resistance of the important food plants of the vector to the virus, are also important.

Answers to such questions, as the origin of streak virus and the manner of its adoption of cane as a host plant, can at present be only speculative. The virus associated to-day with Uba cane may be identical to a parent form that existed originally in a wild grass, or it may represent a form that has become modified and adapted to an existence in cane. We have definite evidence that more than one form of streak virus exists. One, for example, is commonly associated with maize, in which it produces a severe disease; but it is without effect on cane. However, whatever the origin of streak may be, the fact remains that a form arose that proved readily transmissable to Uba cane.

Uba was introduced into South Africa at the beginning of the present century and within a few years was being grown almost to the total exclusion of other varieties. The stage was thus prepared for the invasion of streak disease. The casual virus was provided with an efficient vector, which included cane amongst its food plants; and the cane plants were mostly of the susceptible variety, Uba. We cannot say when the first cases of infection occurred. It is possible that the virus had already adapted itself to cane before Uba was introduced. The appearance of streak in fields of Uba was probably at first gradual and would be the result of secondary transmission. But it would not be long before primary transmission exerted an influence and contributed to an increase in the amount of infection. In those early days, the disease appears to have escaped observation, or if it had been noticed, no special importance was attached to it. When streak was eventually recognised as a definite transmissable disease, it had already become widely distributed, and in some districts had invaded more than half the plants.

Uba, though it acquires infection readily, possesses a fair measure of tolerance; and, except in the earlier stages of growth, the contrast between healthy and diseased plants is not usually striking. For this reason the importance of the disease has not been realised sufficiently by the majority of growers, and is probably why they have made little or no attempt to prevent primary transmission. Cane, for planting, is selected indiscriminately, diseased with the healthy; so the number of diseased plants is increased, and for every parent plant that was streaked, a dozen or more in a similar condition will be established in the new field. This factor of primary infection has undoubtedly contributed largely to the prevalence of streak in many districts. The section of Natal between the Umgeni River and Tugela River provides a good illustration. In 1925 Storey [2] wrote that these districts were relatively free of disease, the percentage of infection being about five. To-day we find that only a part of this area, from the Umgeni to Tongaat, has a small proportion of diseased plants; in the remaining districts the incidence has increased to 40 per cent. and more. When we enquire into the practice adopted in each region to control streak, we learn that only in the former has any thorough and systematic attempt been made to select healthy seed-cane.

Secondary transmission undoubtedly operates throughout the cane area and must also have played an important part in the establishment of the high percentage of streak. The amount of secondary infection occurring in different districts, and even in different localities of the same districts, appears to be very variable. But our records on this aspect of the problem are scanty; and we have no information, whatsoever, on such important factors as the density of the vector population in different sections of the cane area, and the influence of environmental conditions on the vector population. It is difficult, therefore to express an opinion as to the actual contribution of secondary transmission to the general prevalency of streak. As Storey [2] pointed out, the quantity of streak occurring in a particular field does not necessarily provide an index of the activity of secondary transmission in the locality, because of the factor of primary infection.

There is some evidence to support the view expressed by Storey [2] that secondary transmission played an important part in building up the high percentage of streak in Zululand. The development of cane lands in this section took place in more recent years. The first fields were established in the Amatikulu section about 1905, and thereafter there was a gradual and progressive extension northwards. The first seed-cane would undoubtedly have come from the districts south of the Tugela and would in the main have been healthy. When the first observations were made on the incidence of streak, between 1922 and 1924, the disease had already reached a high percentage in the districts of Zululand adjoining the larger rivers, whereas south of the Tugela the percentage was about five. It seems probable, therefore, that severe secondary infection occurred in certain localities at some period after the original planting. The disease. if it was observed, would not have been regarded seriously; so once a high percentage became established it would be maintained in the new fields by primary transmission. We now have definite evidence that, under conditions existing to-day, secondary infection is high in many parts of Zululand. Fields, planted with healthy material, become totally diseased within a period of one to two years. In other regions secondary transmission is not so active. One farm in the western end of the Empangeni district has an average streak percentage of about twenty-five, mainly as the result of carefully selecting seed-cane in recent years. Adjoining farms, where no selection is made, are almost totally diseased. In 1924 this section of the district is reported to have been almost free of streak. Although secondary transmission appears to be sufficiently low to have enabled satisfactory control to be maintained by selection, little or no attempt has been made in this direction; and to-day the greater number of the plants is diseased. This

TABLE 7.

THE LOSS IN TONS OF UBA CANE HARVESTED DURING SEASON 1934-35, FROM STREAK DISEASE.

The figures for the number of tons harvested are taken from the Government Census Return for 1934–35. The loss in tonnage is calculated on the proportion of cane affected, on the basis of 11 per cent. loss of weight. The cane is valued on the price fixed for 1934–35 : 14/2 per ton.

MAGISTERIAL DIVISIONS.	PLANT CANE.			RATOON CANE.		
	Number of tons Harvested.	Per cent. Streak.	Loss in tons from Streak Disease.	Number of tons Harvested.	Per cent. Streak.	Loss in tons from Streak Disease.
Zululand (Eshowe, Hlabisa, Lower Umfolozi, and Mtunzini)	284,472	90	31,643	771,540	92	87,731
Lower Tugela	307,242	38	14,431	663,872	43	35,282
Inanda	183,923	9	2,046	408,649	17	8,587
Durban	28,770	39	1,387	150,229	79	14,668
Umzinto	119,298	38	5,603	489,032	54	32,639
Port Shepstone	13,110	93	1,507	54,864	84	5,696
Total	936,815	54	56,617	2,538,186	61	184,603

Total Loss in Plant and Ratoon Cane = 241,220 tons.
Value of Cane (14/2 per ton) ... ... = £170,864.

section, however, still retains the distinction of having the lowest streak percentage in Zululand. There are undoubtedly other regions, both in Zululand and Natal, where secondary infection is low, and yet most of the plants are diseased.

THE LOSS IN YIELD OF UBA CANE FROM STREAK DISEASE.

The effect of streak disease on the yield of Uba was determined by field experiments (the results are summarised in an earlier paper [1]) conducted at Umbogintwini and Mount Edgecombe. The plots planted with diseased Uba shewed a loss in weight on the plant crop of 11 per cent., as compared with plots established from healthy cane. The difference became progressively less in the subsequent ratoons; but this was attributable to the influence of the spread of streak into the healthy plants. Although 70 per cent. of the plants in the healthy plots were diseased after four years, a difference as high as 7.9 per cent. in favour of the healthy plots was registered at the cutting of the second ratoons. This resut may give support to the expectation that the ill effects of streak are cumulative and will become more pronounced in subsequent ratoons; but it is difficult to obtain reliable quantitative information on the point from field experiments because of the uncontrolable factor of secondary transmission.

In table 7 we record our estimate of the loss in yield of Uba cane during the season 1934-35. Our evaluation is based on the results of the streak survey and on the 11 per cent. loss of weight. The figures for the number of tons harvested are taken from the Government census return. The total loss of cane (both plant and ratoon) is calculated to be 241,220 tons; on the basis of payment for the season 1934-35 (14/2 per ton) this would be valued at £170,864.

How far we are from the true figure it is impossible to say, but at least our estimate represents the minimum loss that can be expected from streak disease, under the present conditions. It is very probable that the loss is considerably greater in Zululand than our figures would indicate. For ten years at least the big proportion of seed cane in Zululand has been diseased, and the continual replanting with diseased material must inevitably tend towards deterioration of the stock. This may be reflected in the fact that the districts all show a progressive fall in the average yield of Uba per acre over the past ten years. [6] A sign of deterioration is even reflected in the general appearance of the cane, and on crossing the Tugela into Natal one is im-

mediately struck by an improvement in the general condition of Uba; it appears to be more vigorous and has a richer green colour. The Kwambonambi district is one of the most streak-stricken areas in Zululand. The cane, already having to suffer from disadvantages of soil and climate, appears under these conditions to have become less tolerant to the streak virus. It may be of interest to record one observation from this area. A section of a field, four acres in extent, was planted with healthy Uba, which had been obtained after much searching through fields on the estate; and the remaining portion of the field was planted in the customary manner with unselected cane. One of us inspected the field after twelve months: the selected portion contained 15 per cent. infection, and the other 90 per cent. The contrast in the appearance of the cane in the two sections was more than striking, it was a revelation.

THE BEHAVIOUR OF THE NEW COMMERCIAL VARIETIES TO STREAK DISEASE AND ITS BEARING ON CONTROL.

Since 1930, eight new varieties have been released for commercial planting. Their extension has been rapid, and at the end of last season they occupied collectively an area of 53,000 acres, 15 per cent. of the total area under cane. The time is opportune to consider the effect of this change on the problem of streak disease. Storey wrote in 1925 that the greatest hope of a solution to the problem lay in the introduction of new varieties. The disease has become so widespread and so completely dominant in certain districts that its control and general elimination by any direct methods is impossible as long as Uba remains the principal variety in our cane lands.

A knowledge therefore of the behaviour of the new varieties to streak disease is of special importance. During the course of the survey on streak disease an opportunity was presented to make extensive observations on these varieties in all sections of the cane belt, and since 1933 a total of 20,000 acres has been inspected. The eight varieties are classified below into three groups, according to the readiness with which they acquire infection under field conditions.

Very susceptible	CH 64/21
Resistant	Co 290
	POJ 2725
Very resistant	POJ 2714
	POJ 2727
	POJ 2878
	Co 281

N.B.—We have no precise information yet on the behaviour of Co 301.

The variety CH 64/21 possesses the same measure of susceptibility as Uba and acquires infection very readily under field conditions. It has been planted to a very limited extent and is not likely to be of any importance in this country.

Co 290, Co 281, POJ 2878, and POJ 2725 have been planted the most extensively, and it is on their measure of resistance that the control of streak will depend.

Of these varieties by far the largest number of infections has been recorded in Co 290; but at the present time the annual amount of infection is under half a per cent. It is interesting to note that the spread of the disease into this variety has been remarkably uniform over the whole cane area. Even in districts of Zululand, where experience has shewn secondary transmission to be rapid in Uba, the proportion of diseased plants is much the same as in districts, such as Tongaat and Mount Edgecombe. The percentage of streak recorded in fields of plant cane from different parts of Natal are summarised in table 8. The average infection is under half a per cent. The highest percentage of streak observed in one field was ten: seven acres of plant cane in the Empangeni district. But it was definitely established that the greater proportion of the diseased plants had developed from infected cuttings.

TABLE 8.

PERCENTAGE OF STREAK IN FIELDS OF Co 290 (PLANT CANE) IN THE NATAL DISTRICTS.

District.	Number of acres Inspected.	Percentage Streak.
Hibberdene	30 ...	0.25
Sezela	159 ...	0.25
Esperanza	180 ...	0.25
Renishaw	98 ...	0.0
,, ...	10 ...	0.3
Illovo	99 ...	0.5
Umbogintwini—Isipingo... ...	401 ...	0.25
Mount Edgecombe...	404 ...	0.25
Tongaat	459 ...	0.74
Stanger	293 ...	0.3
Darnall...	195 ...	0.25

Our field records indicate that streak spreads less readily into Co 290 than into Uba. This is confirmed by some observations from the streak experiments that were conducted at the Sugar Experiment Station to determine the effect of the disease on the yield of four varieties. The experiments, which are mentioned earlier in this paper, were planned on the same lines, and consisted of plots of healthy cane alternating with plots of diseased cane of the same variety. In table 9 are recorded the figures for the amount of secondary infection that developed in the healthy plots during the first two years of each experiment.

TABLE 9.

COMPARISON OF THE RATE OF SPREAD OF STREAK DISEASE IN FOUR VARIETIES.

Variety	Date	Percentage of infection in healthy plots after 2 yrs.
Uba	1927-29	55
CH 64/21	1931-33	75
Co 290	1933-35	.5
POJ 2725	1933-35	0

Three plants of POJ 2725 developed streak in the early part of 1936.

Streak was observed in POJ 2725 in most districts of Zululand, but only in a very small proportion of the plants (less than .1 per cent.). Outside of Zululand our only records are from Isipingo and the Sugar Experiment Station. This variety appears to acquire infection even less readily under field conditions than Co 290.

POJ 2878 is the only other variety that has been observed with streak, three plants being found in the Empangeni district. There is still no record of infection in the variety Co 281, POJ 2727 and POJ 2714.

Further evidence of the greater resistance of these varieties to streak disease was obtained from transmission experiments conducted by the senior writer at the Natal Herbarium* Susceptible varieties, such as Uba and CH 64/21, are infected readily by exposing them to infective hoppers, and the feeding of one hopper on the leaf of a young active shoot has often been allowed by the development of streak. Infection is of a permanent nature, and the progress of development of the symptoms is rapid in young active shoots.

Co 290 and POJ 2725 were more difficult to infect, and positive transmission resulted only after the exposure of plants to larger numbers of hoppers. Co 290 could not be infected by exposure to 5 hoppers, but the disease sometimes developed when 10 hoppers were fed on a plant. A higher percentage of positives were obtained when plants were exposed to groups of 50, 100, and 200 hoppers. In similar experiments with POJ 2725, no infection resulted from groups of 5, 10, or 20 hoppers, but a few positives occurred when the number of hoppers was increased to fifty. Both varieties tend to retain infection permanently, though a few examples of recovery have been noticed in each. The rate of development of the symptoms is slower than in Uba. It has been shewn at the Sugar Experiment Station that streak has no effect on the yield of Co 290.

Both POJ 2878 and Co 281 were infected artificially, but only after exposure to large numbers of infective hoppers (100-300). The plants developed systemic symptoms, which persisted for a time and then gradually decreased in frequency on the new leaves and finally failed to appear. In every case, recovery was permanent. The infected plants did not develop the high frequency of chlorotic markings that is characteristic of Uba, and their young leaves shewed only comparatively few streaks with a sparse distribution.

The new varieties thus provide a promising solution to the problem of streak control in this country. Although both POJ 2725 and Co 290 acquire infection to some extent in the field, their resistance is sufficiently high to enable reasonable control of secondary infection by direct methods. The other varieties are even more resistant. There is every prospect, therefore, that the incidence of streak disease will be reduced to negligible proportions when Uba becomes extensively replaced by these varieties.

In conclusion we would emphasise the importance of controlling primary infection in Co 290. Streak is only spreading very slowly in this variety, and it is most desirable that the amount of infection is not further increased by the indiscriminate planting of diseased seed-cane. The variety may exhibit high tolerance to the disease, but that is no reason why it should be used as a means of perpetuating the disease, and thus maintaining a fruitful source of infection, to which future varieties may be endangered. It is important that every endeavour should be made to reduce the prevailing source of infection to a negligible quantity.

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* Details of this work will be published in a later paper.

Mr. DODDS: Mr. Chairman, this paper is a most illuminating one, and it is unfortunate that almost the whole of the planting community, to whom it is of the greatest possible importance, appear to be absent. The losses due to the streak disease, as you have heard, are enormous, and it shows what an opportunity has been lost through lack of control of this disease, which would have been possible a few years ago. I mentioned yesterday in my paper that the yield of cane in the Inanda District had steadily increased from the lowest to the highest of any Magisterial Division in Natal, whereas the contrary has taken place in some of the Zululand districts. There is no doubt that lack of control of streak disease has had a good deal to do with the falling off in yield in Zululand, although other things have contributed, while there is also no doubt that the contrary practice of controlling streak disease in the Inanda Division has made possible increased yields through irrigation and improved agricultural practice. Year by year the yields of cane in Zululand relative to those of the rest of Natal have decreased, until the superiority shown by Zululand in that respect up to about eight years ago is now quite reversed.

I must admit that I was one of those to whom Mr. McClean refers, who considered that the occurrence of streak disease was not entirely a question

of control, and that there was some ecological difference between the different districts in the natural spread of secondary infection, owing perhaps to relative differences in the frequency of the insect vector. It seems now to be quite clear from recent experience, as shown by Mr. McClean, that such is not the case, and that the relative freedom from streak disease in the District of Inanda for example is largely due to the efforts at systematic control by the two estates he refers to, the Natal Estates and Tongaat. As he has pointed out, other districts which had an equal or even better chance, such as Chaka's Kraal, Eshowe, and Umkomaas, have lost their opportunity for ever of getting rid of streak disease from Uba cane; their only hope now of eliminating streak disease is through the new streak-resistant varieties. I should like to add a word of appreciation of the work of the other author of the paper, Mr. Halse. I can appreciate to some extent the kind of work that he has undertaken. One of my earliest introductions to Experiment Station work in Lousiana was the inspection of fields of cane for disease, and I know how laborious and tedious that work can become. The thanks of the whole Industry are due to the two writers for this excellent work and the way in which it has been described to us.

Mr. MUNRO: Mr. Chairman, the most important part of Mr. McClean's paper is contained in the last paragraph. He urges control to prevent the spread of streak in the new varieties. Will Mr. McClean please enlarge upon methods of control.

Mr. McCLEAN: The only direct, practical method of checking the spread of streak is by the control of primary infection. The success of the method will depend upon the rate at which secondary infection occurs. It has been stated that our new commercial varieties possess a high resistance to streak, and even the most susceptible one. Co. 290, acquires infection much less readily than Uba. The number of new infections, from secondary transmission, that occur annually in Co. 290 is comparatively small—under half a per cent. In consequence, careful methods of selection will enable the farmer to maintain a satisfactory check on the spread of the disease. It is important that only healthy cuttings are planted in new fields. Train men to recognise the disease, so that infected plants can be suitably marked, and thus can be avoided, in the fields in which cane is being cut for planting.

Mr. BOOTH: I would like to ask Mr. McClean in the case of infection of Co. 290 where only one stick of cane in a stool showed infection, whether it would be safe simply to pull out that stick and let the rest of the stool remain?

Mr. McCLEAN: The removal of the single visibly affected shoot from the stool would not necessarily mean that the stool as a whole had been freed from infection. This would depend upon whether the virus had moved down into the underground portion of the plant. If this is the case, then streak symptoms will reappear at some future date in other shoots, and eventually the whole stool will become infected. Although only one shoot is bearing streak symptoms, the whole plant must be regarded as diseased.

Mr. COIGNET: Are there any cases recorded of transmission of streak disease other than by insects?

Mr. McCLEAN: The only known method by which streak can be transmitted from a diseased to a healthy plant is by means of the maize leaf hopper. We have been unable to transmit the disease mechanically by transferring the juice from an infected plant to a healthy one.

Mr. COIGNET: Has the relative inefficiency of the leaf of the streak diseased cane no effect on the sucrose content of the cane?

Mr. McCLEAN: According to analyses, the disease does not affect the percentage of sucrose in the cane. It reduces the weight of cane and so will reduce the total amount of sugar produced in the cane.

Mr. DODDS: There is no significant difference in the sucrose content of diseased cane compared with healthy. The difference appears to be almost solely in the yield of cane, primarily through the effect of the disease on the leaf, in putting part of the leaf surface out of action, which is reflected again in the root system. We have observed at the Experiment Station that the root systems of streak diseased canes are particularly deficient in the fine, hairlike feeding roots.

Mr. MUNRO: We have been using a preparation called "Ceresan." We have had very very interesting results. We had photographs taken a year ago of a field which was treated in two portions. The fertilising was identical. The seed was treated in one portion but not in the other. The untreated plants were about nine to ten inches high; the treated plants were at least double. I understand that this preparation is used very frequently in other countries on all cereal crops and against a disease certainly very similar to streak, and we are experimenting to see what its effect will be on cane. It is a powder and is very difficult to apply to cane satisfactorily. A satisfactory method has not yet been found.

Dr. McMARTIN: With regard to the use of "Ceresan," it is trne that cereal crops have been treated with "Ceresan" before being sown, but I think the position is slightly different as regards streak disease. For instance, some diseases of the oat crop to a certain extent are controlled by "Ceresan." About 50% of the oat farmers of Scotland treat their seed with "Ceresan" with very good results indeed, but then the spores of the fungus causing the disease is transmitted on the outside

of the seed coat, and naturally any disinfectant applied to the outside of the coat destroys this disease. I do not see myself very well how the treatment of the outside can control such a disease as streak, which is propagated by means of a virus inside the plant.

Mr. FOWLIE: I would like to enlarge a little on what Mr. Dodds said about the effects of streak. We found when taking the results of that streak experiment on Uba, that when we counted the number of sticks from the streak plots, there were actually more sticks of cane on the streak plots than on the healthy plots, but the sticks individually were much lighter. The inter-nodes were shorter, and there were actually more nodes on the sticks. It looked as if the plant, in trying to make up for the harm that was being done to it and one way was pushing out more shoots. The effect of the disease seems to be to prevent the growth, not only of the sticks to their full size and thickness, but the actual nodes were shorter and smaller. But the number of sticks was greater than in the healthy ones, although even by that method the plant could not make up in the total weight.

Mr. BOOTH: There is an impression abroad that the presence and the application of filter press cake as manure tends to cause unfavourable effects on the growth of cane. I have my own opinion on the matter, but I should like it put on record now if Mr. McClean or anyone else has any observations on those lines.

Mr. McCLEAN: None at all.

Mr. BOOTH: The Chairman has been in the habit, I understand, in his capacity of Manager of the Tongaat Company, of applying 50 tons per acre on his fields.

The CHAIRMAN: Mr. Booth is not quite correct as to the quantities of filter cake we use at Tongaat —more of the order of 20 tons per acre. We have never conceived the idea of connecting filter press cake with the existence of streak disease. However, we recognise the idea, without any proof, that certain soils seem to be more productive of streak diseased cane than others. Where we put filter cake over Table Mountain sandstone on the inland side of the sugar belt, the soil seemed to grow much more streak diseased canes than the heavy loams and black shales between the two sand series, but we have not attributed the fact to the filter cake.

There is another fact of this problem which has not so far been introduced into the discussion, and that is what appears to me to be the increasing material effect on the plant which is suffering from streak. I would very much like to have that discussed here, because, from our superficial observations there seems to be a very definite increase of the pathological effect of the disease on the plant infected, so much so that a number of years back one had to examine the canes fairly carefully to see whether they were streak diseased or not, whereas to-day, in a first ratoon field on certain soils, one can pick out the uninfected stools by their vigour, and it remains a very easy job to find the infected stools of cane, because they are all stunted.

Mr. McClean mentioned the case of Kwambonambi where streak exists to a very great extent, and seemed to indicate a connection between the high infection with streak and the other agricultural difficulties—drought and so on. And that introduces, to my mind, another feature of streak disease, namely the fertilisation of cane, and perhaps some person here to-day has something to offer in connection with the fertilisation of ratoons and its affect on the presence of streak disease.

Mr. POUGNET: I should like to ask whether there has been noticed a tendency to the increase of the prevalence of streak disease in the districts mostly infected by drought?

Mr. McCLEAN: We consider that under drought conditions the effect of the disease may be more severe, but there is no evidence that these conditions favour the spread of the disease. On the contrary observations have indicated that the disease may spread more slowly in the drier areas. For example it was found by Dr. Storey in 1923 that streak was most prevalent in the districts of Zululand adjacent to the larger rivers, whereas the percentage of streak was comparatively small in the drier areas away from the rivers.

In our experience there is no method of controlling streak either by the application of fertilisers or by the addition of an inorganic salt to the soil. I believe it was stated by someone in the Umfolozi district that streak could be cured by the application of a salt of manganese to the soil. I repeated the experiment, but my results were negative.

Mr. DODDS: We certainly found that manganese applied to the soil, both at Umfolozi and at the Experifent Station, had the effert of delaying the symptoms of streak disease for some time. It was merely a question of delay, however; the disease was there, and sooner or later its symptoms were shown.

Mr. McCLEAN: In my experiments, the symptoms appeared as readily in plants treated with the manganese salt as in the controls. I found no delay in the development of the symptoms.

Mr. LINTNER: With an insufficiency of potash, plants are more susceptible to disease. Does Mr. McClean think there might be any connection between insufficiency of potash and streak disease?

Mr. McCLEAN: As as rule the conditions that favour the development of a virus disease are those that promote most active growth. This applies to streak disease of cane.

Dr. McMARTIN: On the subject of the effect of fertilisers on disease, I cannot recollect anything which has been done with any fungus disease or virus, but I believe that some evidence has been got somewhere that on mealies the incidence of certain insect pests does show a correlation with the application of fertiliser, and I think they attributed this to the slight alteration of the sap with regard to pH and certain salts, the insects liking to feed better on some than on others.

The CHAIRMAN: If there is no further discussion, I have much pleasure in proposing a vote of thanks to the joint authors of this paper. It has been very interesting.