

THE EFFECT OF PLUCKING ON SHOT-HOLE BORER ATTACK IN TEA

C. H. GADD

In 1939 an experiment was designed to test the planting opinion that hard plucking induces a heavier infestation by Shot-hole borer (*Xyleborus fornicatus* Eichhoff, *fornicator* Eggers) in tea than does light plucking.⁽⁴⁾ Six plots, each consisting of 10 rows of 20 bushes (approximately one-fifteenth of an acre) on Gonakelle Estate, Passara (elevation 3,500 feet) were used. All the bushes had been pruned alike in November/December, 1938, and all plots

received similar cultural treatments except for the type of plucking. Three plots were plucked normally, here termed "light," while the other three plots were subjected to a more severe form of plucking, here termed "hard." In the light plucked plots plucking was restricted to the plucking table, and the plucked shoots consisted of a bud and two leaves, one full leaf above the fish leaf being left on the bush. In the hard plucked plots everything above the

fish leaf was taken from all branches, no matter whether they occurred above or below the plucking table.

Such hard plucking is not entirely unknown in planting history. The object of using it in this experiment was to determine whether severity of plucking had any effect on the degree to which bushes become attacked by borer.

Plucking was started on 12th May, 1939 and continued till 29th September, 1941. Until the end of March, 1940 the plots were plucked regularly at 7-day intervals, but after that date the pluckings were arranged to synchronise with the estate pluckings in the remainder of the field outside the experimental block. In all, the bushes were plucked on 106 occasions, 47 at weekly intervals and 59 at more irregular intervals over a period of 78 weeks.

The examination of bushes for shot-hole borer attack was started on February 7th, 1940 when the bushes were 14 months from pruning, and was continued until November 29th, 1940; 15 examinations being made at 3-week intervals. In each plot were a few undersized bushes, probably replacements, and these were avoided at all examinations. The normal-sized bushes were numbered, and for each examination 10 numbers were selected at random for each plot. The bushes bearing these numbers were clean pruned, the new cuts being made about 4 inches above the previous cut, and all prunings were removed to the laboratory for examination. Thus at each examination 30 hard plucked and 30 light plucked bushes were pruned. The method of examination of the prunings has been described in a previous article.⁽²⁾

More bushes were examined towards the end of the experiment, during the period October 9th to December 3rd, 1941; five

examinations in all were made at fortnightly intervals. The size of the samples at these examinations varied somewhat and was never so large as at the earlier examinations, because the number of bushes available was insufficient. The number of bushes examined on each occasion is given in Tables 1 and 2 in which the results of all examinations are summarised.

DISCUSSION

Cessation of Attack.—In a previous article⁽²⁾ which dealt with the attack by shot-hole borer in the experimental area as a whole, up to November 29th, 1940, it was stated that "if the conditions ruling during the observed period continue, the attack must cease in the third year from pruning." The examinations between October 9th and December 3rd, 1941 were made to test that conclusion.

Between November 29th, 1940 and October 9th, 1941 the average number of galleries per bush increased from 25 to 100 in the lightly plucked plots and from 17 to 83 in the hard plucked plots. But between October 9th and December 3rd, 1941 the figures (Tables 1 and 2) do not give any evidence of a general increase in the average number of galleries per bush in either set of plots. In the light plucked plots the values obtained at the five examinations fluctuated about a mean of 91; in the hard plucked plots the fluctuations were about a mean of 73.4. It would appear that the number of galleries per bush had become stabilised about these numbers. In other words, no new galleries were formed; so the attack had ceased.

The position is perhaps more clearly shown when the numbers of occupied galleries are studied. By November 29th, 1940, in the light plucked plots, there was an average of 12.6 galleries per bush occu-

pied by beetles, but by October 9th, 1941, there were only 1.6 occupied galleries per bush. The corresponding figures for the hard plucked plots are 8.2 and 2 occupied galleries per bush. On no occasion during the period October 9th to December 3rd, 1941 were more than 2 occupied galleries per bush found in the plots under either treatment. Such falls in the number of occupied galleries indicate a diminution, amounting practically to cessation, of attack

If, instead of the number of galleries, the beetle population is used as the criterion, Tables 1 and 2 show that by November 29th, 1940 the light plucked bushes contained 87 beetles per bush, whereas between October 9th and December 3rd, 1941 the average content per bush never exceeded 8. The corresponding figures for the hard plucked bushes are 57 and 6. These figures clearly indicate that the beetle population ceased to increase at some time after November 29th, 1940; later, beetles died more rapidly than young were produced, until the population fell to an almost insignificant level by October, 1941, towards the end of the third year from pruning.

That shot-hole borer attack ceases during the third year from pruning is not generally recognised. Possibly that is due to the fact that shot-hole borer in tea is usually demonstrated by the presence of galleries and not by the presence of beetles. A gallery once formed remains, and is recognisable as a gallery even though the entrance may be obscured by healing. Many galleries are empty because when a family of beetles has been raised the gallery is not normally used again for the same purpose. The young females leave and form new galleries for themselves in which to raise their broods. Towards the end of the third year from pruning a tea bush may contain many galleries but few beetles, as already noted. Only a periodic count of the

number of galleries or an examination of the gallery contents will show whether the attack has ceased or not. It is the number of beetles within the galleries that will determine the future of the bush as regards further attack. The facts that towards the end of the third year from pruning the total number of galleries in the bushes had ceased to increase, that the number of occupied galleries had decreased markedly, and that the beetle population had fallen to a very low level, all point to cessation of attack.

Course of Attack.—Shot-hole borer attack in the plots began to increase about May, 1940, i.e., nearly 18 months after pruning and continued at a steady rate until November 29th, 1940 when the first period of examinations was completed. It has been shown in the earlier article⁽¹⁾ that during the period May to November, 1940 the number of galleries in the whole area increased at a rate of 10.7 per cent per week compound interest. At that rate the number of galleries is doubled every 6.5 weeks.

The increase of a population, when the rate of growth is constant is usually in accord with the law of compound interest. But the rate of growth may be disturbed by forces which in the aggregate slow down and may finally stop the growth. From the fact that during the 8-week period October 9th to December 3rd, 1941 there was no real increase in the number of galleries — the number found on December 3rd was certainly not double that found on October 9th as would be expected if the rate of 10.7 per cent per week had been maintained — it is apparent that certain forces became operative mainly after November, 1940, and ultimately eliminated the inherent rate of increase. It is probable that such forces developed gradually, and did not become operative suddenly.

TABLE I
Galleries and their Beetle Contents from Light Plucked Bushes

Examination No.	Date	No. of bushes	TYPE OF GALLERY				Galls per bush	CONTENTS OF GALLERIES					MEAN CONTENTS	
			Healed	Empty	Occupied	Total		Eggs	Larvae	Pupae	Adults	Total	Per Bush	Per occupied gallery
1940														
1	Feb. 7	30	20	14	6	40	1.3	1	15	2	6	24	0.8	4.0
2	Feb. 28	30	7	2	3	12	0.4	3	5	—	5	13	0.5	4.3
3	Mar. 19	30	11	4	2	17	0.6	—	—	—	2	2	0.1	1.0
4	Apr. 9	30	13	9	5	27	0.9	6	7	—	5	18	0.6	3.6
5	May 1	30	16	7	13	36	1.2	26	39	9	22	96	3.2	7.4
6	May 23	30	11	3	18	32	1.1	23	21	10	22	76	2.5	4.2
7	June 12	30	16	3	26	45	1.5	24	53	10	51	138	4.6	5.3
8	July 3	30	22	19	69	110	3.7	56	128	28	149	361	11.9	5.2
9	July 24	30	9	21	65	95	3.2	77	199	30	117	423	14.0	6.5
10	Aug. 15	30	17	44	99	160	5.3	174	246	31	141	592	19.6	6.0
11	Sept 5	30	19	44	118	181	6.0	151	314	67	171	703	23.2	6.0
12	Sept. 24	30	38	42	253	333	11.1	305	478	107	512	1,402	46.3	5.5
13	Oct. 16	30	65	157	340	562	18.7	622	1,062	179	548	2,411	79.6	7.1
14	Nov. 6	30	69	184	285	538	17.9	613	734	112	405	1,864	61.5	6.5
15	Nov. 29	30	116	255	377	748	24.9	710	1,161	196	576	2,643	87.3	7.0
1941														
16	Oct. 9	12	894	293	19	1,206	100.5	13	31	1	19	64	5.3	3.37
17	Oct. 23	9	501	193	3	697	77.4	—	1	1	3	5	0.6	1.67
18	Nov. 5	12	871	229	19	1,119	93.3	11	34	—	19	64	5.3	3.37
19	Nov. 19	12	869	145	8	1,022	85.2	4	11	—	8	23	2.0	2.88
20	Dec. 3	11	971	111	22	1,104	100.4	27	33	1	24	85	7.5	3.86

TABLE 2
Galleries and their Beetle Contents from Hard Plucked Bushes.

Exmi- nation No.	Date	No. of bushes	TYPE OF GALLERY				Galls. per bush	CONTENTS OF GALLERIES					MEAN CONTENTS	
			Healed	Empty	Occupied	Total		Eggs	Larvae	Pupae	Adults	Total	Per bush	Per occupied gallery
1940														
1	Feb. 7	30	11	3	2	16	0.5	4	12	—	2	18	0.6	9.0
2	Feb. 28	30	12	7	1	20	0.7	—	—	—	1	1	0.0	1.0
3	Mar. 19	30	15	11	6	32	1.1	3	—	—	15	18	0.6	3.0
4	Apr. 9	30	17	4	15	36	1.2	40	40	11	23	114	3.8	7.6
5	May 1	30	9	5	4	18	0.6	14	33	2	5	54	1.8	13.5
6	May 23	30	21	3	14	38	1.3	37	30	6	15	88	2.9	6.3
7	June 12	30	25	13	33	71	2.4	62	100	9	46	217	7.2	6.6
8	July 3	30	14	2	18	34	1.1	26	13	2	35	76	2.5	4.2
9	July 24	30	10	9	44	63	2.1	57	114	24	66	261	8.6	5.9
10	Aug. 15	30	12	17	72	101	3.4	167	210	30	109	516	17.0	7.2
11	Sept. 5	30	24	28	86	138	4.6	170	276	47	150	643	21.2	7.5
12	Sept. 24	30	28	61	133	222	7.4	91	235	86	255	667	22.0	5.0
13	Oct. 16	30	35	70	121	226	7.5	202	316	33	151	702	23.2	5.8
14	Nov. 6	30	67	158	149	374	12.5	321	460	94	206	1,081	35.7	7.3
15	Nov. 29	30	110	153	245	508	16.9	492	742	126	367	1,727	57.0	7.1
1941														
16	Oct. 9	15	816	398	30	1,244	82.9	16	30	—	30	76	5.1	2.53
17	Oct. 23	11	546	162	12	720	65.5	10	18	3	15	46	4.2	3.83
18	Nov. 5	17	1,083	205	4	1,292	76.0	—	—	—	4	4	0.2	1.00
19	Nov. 19	16	1,213	173	14	1,400	87.5	3	32	8	23	66	4.1	4.71
20	Dec. 3	16	782	99	11	892	55.7	18	41	5	22	86	5.4	7.82

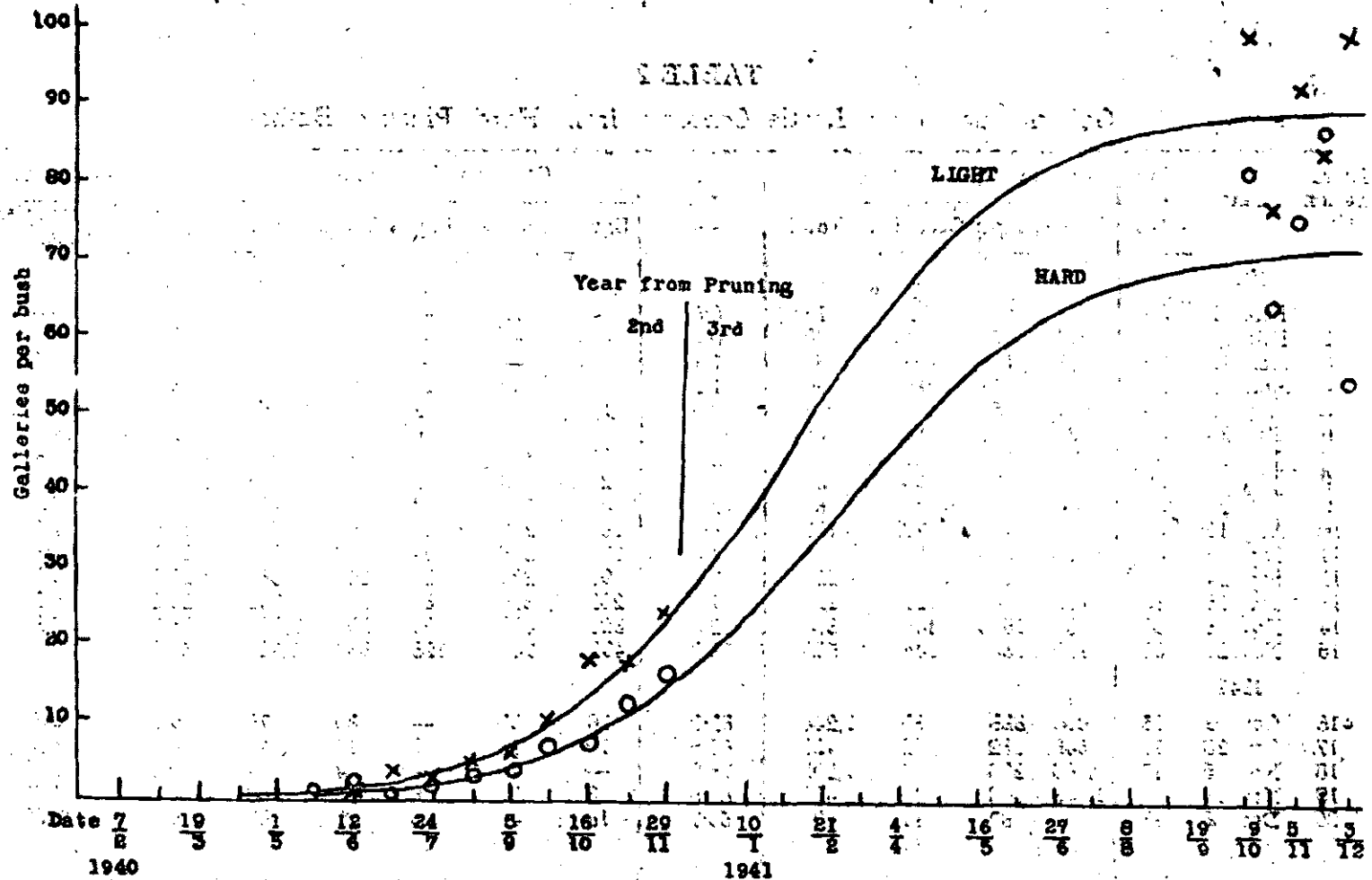


Fig. 1 The number of Shot-hole borer galleries in hard and light plucked tea bushes during the second and third year from pruning.

The course of attack over the whole period is better represented by such curves as are shown in Fig. 1 than by compound interest curves such as were used previously.⁽³⁾ It should be noted that the data collected over the period ending November, 1940 can be expressed fairly accurately in terms of compound interest, but those terms do not represent in any way the course of attack known to occur later. The curves drawn in Fig. 1 are known to biometricians as "logistic" curves, and they have been calculated (Appendix) from the data given in Tables 1 and 2 by Pearl's method.⁽⁴⁾ The observed data from the light plucked plots are represented by small crosses in the figure, and from the hard plucked plots small circles. It will be seen that the curves fairly represent the data from which they have been calculated. Unfortunately no data are available for the period November, 1940 to October 1941, so some doubt must remain that the curves represent accurately the trend in the increase of the number of galleries during that period.

Infestation.—No data are available concerning the increase in the number of galleries in bushes not plucked, so it is not

possible to demonstrate directly that plucking has any effect on shot-hole borer attack. In the experimental plots, however, the attack which was increasing during the later half of 1940 terminated towards the end of 1941 owing to the operation of factors, of which plucking may be one. If plucking was not one of those factors, the progress of the attack in both the light and hard plucked plots should have followed a similar course. But it is evident from Fig. 1 that the attack in the light plucked plots was the more severe. At the final examinations, towards the end of 1941, there were, on the average, more galleries in the lightly plucked bushes than in those which had undergone harder plucking. Contrary to planting opinion⁽⁵⁾ harder plucking resulted in lighter infestation by shot-hole borer.

In order to compare further the progress of the attack, data for the period August 15th to November 29th, 1940 have been studied in more detail, and a summary of calculations made from Tables 1 and 2, by methods described in a previous article⁽³⁾ is given in Table 3.

TABLE 3.

Shot-hole borer attack during the period August 15th to November 29th, 1940.

	Type of Pluck	
	Hard <i>Hard</i>	Light <i>Light</i>
Rate of increase (compound interest) per week in the number of all galleries	10.9%	10.6%
Rate of increase per week in occupied galleries	10.9%	7.3%
Rate of increase per week in number of beetles	10.4%	7.3%
Mean content of occupied galleries	6.4%	6.6%
Mean time of occupation of galleries	9.0—7.1 wks.	8.0—5.0 wks.

From the latter table it will be seen that during this period, before the adverse factors had a very marked effect, the rate of increase in the *total* number of galleries was approximately equal for both types of plucking, but the number of *occupied* galleries increased more rapidly in the light plucked plots, *viz.* 10.9 per cent as compared with 7.3 per cent per week for the hard plucked plots. This suggests that, given equal risks of infestation, the beetles in the hard plucked bushes either abandon more galleries without using them for breeding purposes, or occupy them for a shorter time than is usual in the more lightly plucked bushes. In either case, the beetle population would tend to increase more slowly in the hard plucked bushes and that, ultimately, would result in less damage being done by borers.

It will be seen from Table 3 that the rate of increase in the beetle populations followed closely the rates of increase in the occupied galleries. This was to be expected from the fact that there was little real difference in the mean contents of occupied galleries; under both types of plucking the mean content was about 6.5.

The mean content of galleries gives no indication of the number of individuals raised within the galleries; (2) the length of time galleries are occupied would afford a better measure of the number of beetles likely to emerge. This value cannot be determined with any great accuracy, but by using the method described elsewhere (3) the values for the mean time of occupation of the galleries have been calculated as 7 to 9 weeks in the light plucked and 5 to 8 weeks in the hard plucked bushes, there being a gradual decrease in the mean time of occupation of the galleries by beetles as the bushes increase in age from pruning.

Yields.—During the whole plucking cycle from May, 1930 to September, 1941 1,706 lb. (dry weight) were harvested from the hard plucked plots and 1,363 lb. from the light plucked plots. This represents an increase of 343 lb. or 25 per cent in favour of hard plucking. A statistical examination of the data shows that this difference is very probably real and not due to chance. The weights given above cannot be converted to an acreage basis because of the bushes thrown out of plucking from time to time as they were pruned for borer examinations. Whether hard plucked plots would continue to give the higher yield in later cycles may be open to doubt, but it is not the intention here to discuss the relative merits of the two types of plucking from the point of crop production. It will be sufficient merely to indicate the effect of type of plucking on yields. The increase in yield demonstrated by the hard plucked bushes is to be attributed directly to the type of plucking and not to the diminished shot-hole borer attack.

Physiology.—The majority of species of *Xyleborus* are borers of dead wood, but it is not every piece of dead wood of the right species which is liable to attack. Beeson (4) gives the following conditions as essential for attack: The moisture content should be high, decomposition of cell contents incomplete, invasion by saprophytic wood-destroying fungi scarcely commenced, and in all but a few cases it is necessary that the bark should be present for the initial boring in. The larvae do not feed on wood, but on a fungus, the ambrosia, that grows on the walls of the galleries. The satisfactory feeding of the young therefore depends upon conditions being suitable for the growth of the ambrosia fungus, and the period during

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which the fungus can grow in an assimilable form will depend, when dead branches are attacked, on the rate of desiccation of the wood. *Xyleborus fornicator*, the tea shot-hole borer, is somewhat exceptional in that it attacks living branches. Nevertheless not every branch is suitable for attack. Branches about half-inch in diameter seem to be preferred, but even then, some galleries are deserted shortly after they have been made.

At present it is impossible to define the exact conditions which the tea borer finds essential for breeding purposes within a tea branch. The texture of the wood by being too hard or too sappy may cause the beetle to abandon the boring before the gallery is complete. A suitable hardness may satisfy the beetle's own requirements, but before the gallery becomes ideal for breeding purposes the requirements of the ambrosia fungus have also to be satisfied. Such requirements are likely to include suitable water and food conditions.

The continual removal of young leaves, by plucking as crop, soon after they are formed must affect many vital processes of the bush. Two of the most obvious effects of plucking are the stunting of the bush and the proliferation of branches. The proportion of twiggy branches, not favoured by the borer, is increased, but it seems improbable that the cessation of attack by the beetle in the third year can be due entirely, or even largely, to a deficiency of branches of the required thickness. What is more likely is that plucking results in a number of changes within the bush itself which in the aggregate make the bush unsuitable for borer attack. What these changes may be are unknown, but it seems probable that a better knowledge of the physiology of the tea bush would throw considerable light upon the more intimate relationship of the borer with its host.

An experiment to determine the effects of hard and light plucking on the incidence of shot-hole borer is described. The hard plucked bushes were less severely attacked than the more lightly plucked bushes as shown both by the number of galleries formed and by the smaller beetle population within the lightly plucked bushes.

The attack was most severe during the second year from pruning; later, the attack diminished and was ultimately reduced to negligible proportions. The forces which led to the cessation of attack developed mainly during the third year from pruning and it is suggested that at least some of those adverse factors are intimately connected with the effect of plucking on the physiological processes of the bush.

Logistic curves which illustrate the course of the attacks have been calculated.

ACKNOWLEDGMENTS

The experiment was originally designed by Mr. C. B. Redman King; the writer had charge of it from 13th February, 1941. The data were collected by Messrs. G. D. Austin and W. T. Fonseka at the Passara Sub-Station. We also acknowledge with thanks the facilities afforded by the Management, Nayabedde Estates Co., Ltd., at Gonakelle Estate, Passara; Superintendent Mr. G. Kent Deaker.

APPENDIX

The simple, symmetrical logistic curve is represented by the equation

$$y = \frac{K}{1 + Ce^{rt}}$$

where y denotes population and K, C , and r are constants. K is the distance between the upper and lower asymptote; C is a constant of integration; $e = 2.7183$; r is the

inherent rate of growth of the population, and t is the time interval, in this instance in weeks with February 7th, 1940 as the zero time.

The upper asymptotes have been taken as the mean numbers of galleries for the period October to December, 1941, viz., 91 for the light plucked and 73.5 for the hard plucked plots. The lower asymptote is 0.

The curves given in Fig. 1 are represented by the equations

$$y \text{ (light plucked)} = \frac{91}{1 + 337.3e^{-.1142t}}$$

$$y \text{ (hard plucked)} = \frac{73.5}{1 + 387e^{-.1101t}}$$

REFERENCES

1. Beeson, C. F. C.—The Biology of the Genus *Xyleborus* with more new species. *Indian Forest Records* XIV, pp. 209-272 (1930).
2. Gadd, C. H.—The life history of the Shot-hole Borer of Tea. *Tea Quarterly*, XIV, pp. 5-22 (1941).
3. Gadd, C. H.—Observations on an attack by Shot-hole borer on Tea. *Tea Quarterly*, XIV, pp. 132-146 (1941).
4. King, C. B. R.—Report of the Entomologist for 1939. *Tea Research Institute of Ceylon, Bull.* 21, pp. 38-43 (1940).
5. Planters' Association of Ceylon.—Year Book of the Planters' Association of Ceylon (Kandy) for the year 1940, p. 77. Colombo (1941).
6. Pearl, R.—Introduction to Medical Biometry and Statistics, 3rd Edition. Philadelphia and London (1940).