

OBSERVATIONS ON AN ATTACK BY SHOT-HOLE BORER ON TEA

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INTRODUCTION

That Shot-hole borer (*Xyleborus fornicatus* Eichoff, *fornicator* Eggers) does not attack tea bushes to any appreciable extent during their first year from pruning has been amply demonstrated by Jepson. Concerning an experiment carried out on Sarnia Estate, Badulla, in a field which was pruned in August, 1920, he stated that it was not until February, 1922, (i.e., 18 months after pruning) that the attack by shot-hole borer, though still small, was sufficient for a comparison to be made between the various plots.⁽¹⁾ In a second experiment on the same estate, the field being pruned in August/September, 1920, it was not until May, 1922, (i.e., 20 months after pruning) that the attack was sufficiently advanced to be measurable.⁽²⁾ His third experiment was carried out on New Peradeniya Estate, New Peradeniya. There, the field was pruned in July, 1923, but it was not until September, 1924, (i.e., 14 months after pruning) that "the attack by borer was considered sufficiently severe to warrant the carrying out of a detailed examination in the field."⁽³⁾

His data, however, do not allow of a detailed study of the attacks which occurred during the second year of pruning. More recently, observations have been made concerning the incidence of shot-hole borer during a period of increasing attack, and the data then collected is here used for a study of that attack.

METHOD

The experiment was carried out on Gonakelle Estate, Passara, at an elevation of 3,500 feet. An area in a field which had been pruned in November/December, 1938, was divided into 6 plots, each being approximately one-fifteenth of an acre. Three of the plots were normally plucked and the other three were plucked harder. The experimental plucking started on 12th May, 1939.

At 3-week intervals between February 7th and November 29th, 1940, ten bushes selected at random in each plot were clean pruned. All the prunings of the 60 bushes were carried to the laboratory and there examined for shot-hole borer galleries.

Borer galleries can be classified as open or healed, according as the entrance is healed over or not. Newly healed galleries are comparatively easy to detect. Old 'heals' are sometimes only definitely disclosed by shaving away the surface until the obliterated gallery is revealed, or by splitting the branch longitudinally. Open gallery entrances, however, are unmistakable.

Galleries with open entrances, here termed *open* galleries, can after dissection be divided into those which are occupied by living beetles and those which are not. Open galleries have therefore been classified as *occupied* and *empty*. The empty galleries can again be sub-divided into those which have been vacated after a brood has been raised, and those which were abandoned before egg-laying started. These have been termed *vacated* and *abandoned* galleries respectively. There is no difficulty in distinguishing between an abandoned and a vacated gallery. The former is always much shorter than a normal gallery in which a brood is raised, and it gives the impression that the gallery has been occupied but for a short time. The presence of such galleries suggests that beetles after starting to bore may find conditions unsatisfactory and go elsewhere.

There are therefore four types of galleries — healed, vacated, abandoned and occupied. The first three contain no living occupants while the last-named does. The sum of the four different sorts gives the *total* galleries. Vacated and abandoned galleries together constitute what are here termed 'empty' galleries.

The numbers of galleries of all sorts found at each examination in the 60 bushes are given in Table I. The same information is given somewhat differently and in graphic form in Fig. 1.

The total numbers of galleries found at each examination are shown as small crosses in Fig. 1. It may be seen from Table I or Fig. 1 that the total number of galleries remained fairly constant until about the seventh examination on June 12th, but after that date the number steadily increased. Increases can often be expressed as interest, either simple or compound. If the increase in this case follows any interest law it obviously, from Fig. 1, is more closely allied to compound than to simple interest because the increases between examinations are not equal.

TABLE I

The number of Shot-hole borer galleries found in the prunings of 60 bushes. The bushes were previously pruned November/December, 1938.

Examination	Date 1940	Type of Gallery				Total
		Healed	Vacated	Abandoned	Occupied	
1	February 7th	31	16	1	8	56
2	" 28th	19	7	2	4	32
3	March 19th	26	15	—	8	49
4	April 9th	30	12	1	20	63
5	May 1st	25	8	4	17	54
6	" 23rd	32	4	2	32	70
7	June 12th	41	16	—	59	116
8	July 3rd	36	16	5	87	144
9	" 24th	19	28	2	109	158
10	August 15th	29	45	16	171	261
11	September 5th	43	59	13	204	319
12	" 24th	66	89	14	386	555
13	October 16th	100	187	40	461	788
14	November 6th	136	270	72	434	912
15	" 29th	228	327	81	622	1,256

Calculations* have been made to determine what compound interest curve would best fit the observations made between May 23rd and November 20th inclusive (see Appendix Note A). That curve is drawn as the solid line in Fig. 1 marked A (Total), and it will be seen that the observed values agree fairly well with the theoretic values given by the curve. The curve shows how 53 galleries on May 1st would increase at a rate of 10.7 per cent. per week, compound interest. At that rate of increase the number of galleries is doubled every 5.5 weeks.

Similarly, the number of healed galleries found at each examination is indicated by a small circle; and a compound interest curve which best fits the last six observations has been calculated (Appendix B) and is shown by the solid line C (Healed). This curve represents a rate of increase of 14.7 per cent. The number of healed galleries is consequently doubled every 4.7 weeks.

* Formulae and mathematical methods are relegated to an appendix as these will be of little interest to many readers.—C. H. G.

A third curve B is also shown in Fig. 1. This curve represents the rate of increase of healed *plus* empty galleries. The observed values are shown as small triangles. The curve represents a rate of increase of 14 per cent which is approximately equal to that found for healed galleries (Appendix C).

DISCUSSION

Before proceeding to make any deductions from the theoretic curves derived from the observed data, it is advisable first to ascertain what reliability can be placed on such conclusions. It is well known that two totally different formulæ may, within a certain range of values, equally express the relationship between two variables. In this instance, compound interest formulæ have been found to express tolerably well the rate of increase in the number of galleries within a certain range of observations. But there is no certainty that the same formulæ will express equally well the rates of increase at other times. Consequently, any conclusion involving the use of a compound interest formula outside the period from which it has been calculated must be regarded with caution. Such conclusions can at best be merely tentative until confirmed by other observations, preferably direct observations.

CESSATION OF ATTACK

It will be evident that as the healed *plus* empty galleries are increasing at a more rapid rate than the total galleries, there will be a time when the empty *plus* healed galleries will equal the total galleries, if the two rates are maintained. Theoretically, that would occur about the middle of April, 1941, (Appendix D) when the total galleries would number 8,920 or 149 per bush. Then, as all the galleries would be either empty or healed there could be no occupied galleries from which beetles could emerge to continue the attack. In other words, the attack must cease by the middle of April in the third year.

No great importance can be attached to the actual number of galleries calculated, nor perhaps to the actual time. It will be sufficient to conclude that if the conditions ruling during the observed period continue, the attack must cease in the third year from pruning. If that is true, certain conditions must be operating all the time, even before November 29th, 1940, which ultimately stop the attack.

We must therefore first determine whether there is any evidence which supports the conclusion that shot-hole borer attack ceases during the third year. The only published data which throw any

light on this point are Jepson's.⁽²⁾ His experiment was carried out on Sarnia Estate, Badulla, with 25 plots. The bushes had been pruned in August/September, 1920. At each examination, the galleries in 5 bushes from each plot, i.e., 125 in all, were counted. The first examination was made in May, 1922, 20 months after pruning. After that date 3 other examinations were made at approximately 6-month intervals.

In Table II the information given in the first 7 columns has been obtained from Jepson's published data; that given in the last 3 columns has been obtained by simple calculation. It will be seen that between the first and second examinations there was an increase of 7,550 galleries; in the following six months the increase was only 2,251, and in the final period there appeared to be a decrease in the number of galleries.

TABLE II

Jepson's data regarding Shot-hole borer attack

Exami- nation	Age from pruning months	No. of bushes	Number of galleries				No. occupied		
			Total	Open	Dissec- ted	Occupied	% Occupied	Total	Per bush
1	20	625	10,774	6,320	625	513	82.08	5,188	8.3
2	26	625	18,324	8,227	625	311	48.76	4,094	6.6
3	32	625	20,575	2,979	625	374	59.84	1,783	2.8
4	38	625	16,680	2,872	625	364	58.24	1,673	2.7

That decrease is somewhat difficult to understand as a gallery once formed cannot disappear entirely. But the entrance may be healed and thereby become less obvious. Jepson's observations were made in the field and he has commented on the difficulty of determining accurately the number of healed galleries under those conditions. We may therefore assume that the short count of galleries was mainly, if not entirely, of healed galleries.

The counting of open galleries is less liable to error. Of these, the occupied galleries are the more important as it is from these galleries future attacks will be carried on. The occupied galleries were not counted separately, but from the fact that a number of open galleries were dissected and sorted into 'empty' and 'occupied' it is possible to estimate the percentage of the open galleries that were occupied. From that percentage and the number of open galleries found at each examination, it is possible to get an approximate estimate of the number of occupied galleries at each occasion. These estimates are shown in the last two columns of Table II as 'Total occupied galleries' and as 'Occupied galleries per bush.'

From these figures it will be seen that the number of occupied galleries decreased at each examination after the first, the greatest decrease occurring between the 26th and 32nd month, *i.e.*, in the 3rd year from pruning. The first examination was not made until 20 months from pruning because then only "the attack by borer was sufficiently advanced to provide information upon which calculations could be based." It is evident from the figures that it was made at the time when the attack had increased and was increasing rapidly, and probably had nearly reached its maximum. In the third year, the attack decreased until ultimately the low level of 2.8 occupied galleries per bush was all that could be found.

There is evidence from outside sources therefore, that shot-hole borer attack, though it may not cease entirely in the 3rd year from pruning, is very materially reduced; in fact, the number of occupied galleries found in the third year is less than one-third of the number found 20 months after pruning. We may therefore look with confidence for causes of the cessation of attack.

PERIODS OF OCCUPATION AND HEALING

From Fig. 1 it is possible to determine the theoretic values of the number of occupied, empty or healed galleries at any time by measuring vertically, using the vertical scale, the distance between the appropriate lines; it is also possible to measure the mean time of occupation and the mean time of healing by measuring horizontally the distance between the same lines, using the horizontal scale. For instance, on November 29th the date of the last observation, there were, theoretically, 223 healed galleries represented by the height of line C on that date; empty galleries numbered 450, and occupied galleries 628, represented by the vertical distance between lines B and C and between A and B respectively. The total is 1,301, represented by the vertical height of line A. The numbers actually found on that date, from Table I, were, healed 226, empty 408, and occupied 622, making a total of 1,256.

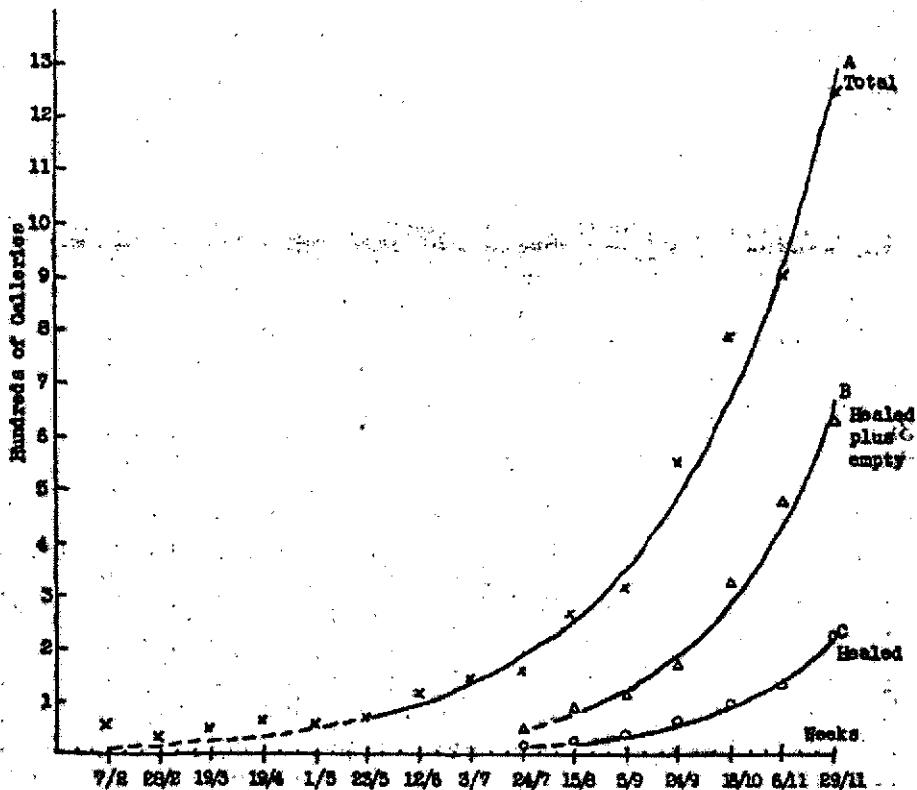


Fig. 1.—Graph showing actual and theoretic values for the number of galleries found in the prunings of 60 tea bushes. Data of Table I.

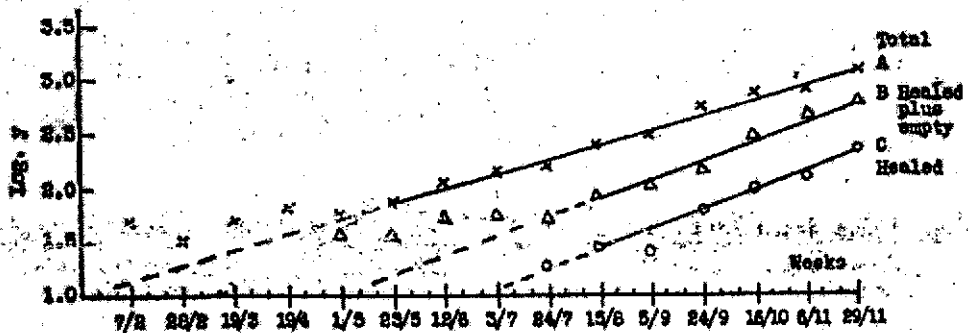


Fig. 2.—Straight lines fitted to Logarithms of Data of Table I.

The mean time taken for galleries to heal after being vacated is represented by the distance between lines B and C measured horizontally. Because the rate of increase of healed *plus* empty galleries is almost the same as the rate of increase of healed galleries alone, this distance remains almost constant. This is best seen in Fig. 2, where healed and healed *plus* empty galleries are represented by straight lines; the lines B and C are almost parallel.

If the lines were absolutely parallel it would be immaterial at what point their distance apart is measured; it would be the same at all points. The deviation however is so small that it may be attributed to a small experimental error. That explanation is preferable to the alternative, that there is a slight shortening of the period of healing during the course of the experiment.

When, however, the period of occupation is considered, the position is very different. It has been shown that the lines A (total) and B (healed *plus* empty) would meet about the middle of April, 1941, and at that time there would be no occupied galleries. This implies that the mean time of occupation of galleries is continually diminishing. It decreases from 11.7 weeks in the middle of July to 6.2 weeks at the end of November and ultimately to 0 weeks in April, 1941. As stated earlier, there are two sorts of empty galleries, vacated and abandoned. The former are occupied for sufficient time for a brood to be raised while the latter are occupied for a very short time. The apparent shortening of the mean time of occupation of the galleries may be due therefore to (1) an increasing proportion of abandoned galleries, (2) a real shortening of the time of occupation or to (3) a combination of both the above causes.

It will be seen from Table 1 that the number of abandoned galleries found in 60 bushes did not exceed 5 till August 15th when there were 16. At that date and at the 5 later observations, abandoned galleries amounted to 11.1, 13.5, 11.9, 12.7, 14.9, 18.0 per cent respectively of the empty galleries. Obviously the proportion of abandoned galleries is increasing steadily towards the end of the experiment.

This observation also means that it is impossible to express accurately the rate of increase of the abandoned galleries in terms of compound interest, because the rate of interest is steadily increasing. This point may be illustrated by calculating the rate of interest which best fits the observations made at the last 6 and at the last 4 examinations. For the last six observations the rate of increase was 13.6 per cent per week, whereas for the last 4 it was 19.5 per cent, a very appreciable increase.

Although it may not be possible here to express accurately the rate of increase of the abandoned galleries, it is obvious that, with the passage of time, more and more beetles after starting to bore a gallery find conditions uncongenial and abandon the job. If such increase continues, the time would arrive when all the new arrivals would fail to complete their galleries. That would amount to a cessation of attack.

Why should shot-hole borer abandon the galleries without raising a brood? We should have to look to physiological evidence for the complete answer to that question. It will be sufficient here to suggest that possibly as a result of plucking — the data here studied is from bushes in plucking and consequently the conclusions may not be applicable to bushes not plucked — growth is restricted with resultant changes, possibly, in the hardness of the wood, or its moisture content, or other characters which make it unsuitable for the borer's purpose. The purpose of this paper is not to explain the cause of abandonment but to demonstrate that increasing abandonment, as has been observed, must lead ultimately to a marked diminution, if not complete cessation, of attack.

We may conclude therefore that while the attack is increasing in intensity, simultaneously there are certain undefined changes occurring within the bush which ultimately cause the attack to diminish materially. These changes operate by causing the beetles to abandon their galleries before egg-laying, and may also, though this has not been determined, result in such galleries as are used for raising a brood being used for that purpose for a shorter time.

From what has been said concerning the mean period of occupation, the length of that period will depend largely upon when it is measured. A measurement, taken before abandonment has become extensive, will give a near approximation to the time a gallery is normally occupied when a brood is raised. The basic date here used for measuring both the period of occupation and the period of healing after the gallery becomes empty, is July 24th.

Measuring through the point representing the number of healed plus empty galleries on July 24th along a horizontal line cutting curves A and C the following results are obtained: —

Period of occupation = 11.7 weeks.

Period of healing after the gallery is emptied = 8.4 weeks.

So far as the writer is aware, no previous attempt has been made to estimate the length of time a gallery is normally occupied by shot-hole borer beetles. When describing the life-history of the

beetle⁽¹⁾ the writer stated that eggs would completely disappear from the galleries after 64 days. He pointed out that that was an average figure but that it applied only to those galleries in which large numbers of eggs were laid. That figure, however, does allow an estimate of the period of occupation to be made. To it has to be added the larval period (15 days) and pupal period (7 days), and a few days also must be allowed for the adults to vacate the gallery (say 7 days). That would give a period of 93 days or 13 weeks as an estimate of a maximum period of occupation. In that light, an estimate of an average period of 11.7 weeks as obtained from the present data does not appear amiss.

The writer first made an estimate of the healing period in 1928 from Jepson's data.⁽²⁾ The time measured on that occasion was from the time the gallery was formed (not vacated) till it was healed; consequently, it includes the time of occupation also. As now shown, much depends upon the time such a measurement is made. Concerning the control plots, the writer stated "the healing process may be taken as occupying 3.75 months, i.e., the mean of 3.2 and 4.3 months." That estimate is shorter than the one made from the present data, which is 20 weeks or 5 months from the time the gallery is made till it is healed. The present data are more complete than Jepson's, and the writer is of the opinion that the present estimate is the more reliable. It must be pointed out, however, that Jepson's data were collected from a different district at a different elevation. Such differences may affect both the times of occupation and of healing.

King⁽³⁾ has also published data concerning the healing of galleries. New entrance holes were observed for a period of 115 days. During that time 8 out of 49 were healed. The time taken to heal varied from 36 days to 103 with a mean of 77 days. It seems highly probable that most, if not all, of these galleries were abandoned, as the time measured includes the period of occupation as well as of healing. Unfortunately, no information is given concerning the galleries, but obviously, such times as 36 and 47 days are too short for both raising a brood and the healing of the gallery. 115 days is too short a time for an experiment of this nature where the mean time for healing plus occupation may, as determined here, be as much as 20 weeks or 140 days.

ORIGIN OF ATTACK

Fig. 1 shows that on June 12th, there were 78 galleries of all sorts (Total) by the theoretic curve as compared with 70 actually found. The curve has been continued backwards towards the beginning of the experiment as a broken line. The curve shows that if

the rate of increase had remained constant from the beginning of the experiment, only 14.7 galleries would be necessary to give rise to the curve studied (Appendix E). On February 7th when the first observation was made, 56 galleries were found, i. e., nearly 4 times as many as the expected value. We may conclude, therefore, that the rate of increase between February 7th and June 12th was much less than that observed later, viz. 10.7 per cent.

If the increase had been 10.7 per cent, the 56 galleries on February 7th would have become 112 six and a half weeks later, and would have more than doubled again by June 12th, whereas we know that in the whole of that period the 56 galleries had only increased to 73. The attack therefore only became of real importance about June 12th, 18 months after pruning.

The 56 galleries found on February 7th were from 60 bushes, so they represent an average of 1 gallery per bush, or more correctly, the prunings from one bush. Those prunings represent the growth of 14 months. It will be evident therefore that if after pruning there is but one occupied gallery per bush, possibly much less, and that number can be maintained for 18 months till the new wood is suitable for attack, there will be sufficient beetles to ensure a severe attack later.

The fact that an extremely small number of occupied galleries left in a field after pruning is sufficient, without outside help, to give rise to a severe attack 18 months later, when the new wood is more suitable for the beetles, is not generally recognised. The requisite number is so very small that any attempt to reduce it seems futile.

That all attempts to eliminate shot-hole borer by mechanical methods such as trapping the insects, burning, banding, pruning of infested portions of plants, etc., have proved futile, is vouched for by Jepson.¹¹ He gives as the reason: "It is impossible without ruining the bush to eliminate all individuals present." He, however, goes on to say, "The proper disposal of prunings is the only practical method whereby a large number of insects can be destroyed. This may be effected by the wholesale burning of the prunings immediately after pruning."

Those who have tried the effect of burning the prunings, and many have, have realised that it makes no material difference to later attack and the practice has rightly fallen into disuse. Periodically, the same idea is resurrected, judging from enquiries coming into the Institute. It may therefore be worth while to consider the matter further.

It must be admitted that the burning of prunings must destroy a large number of beetles. But it seems immaterial how many are destroyed so long as even very few remain established in the bushes. No special precautions were taken before the experiment under consideration was started. The prunings were not burnt nor buried. The beetles which may have emerged from the prunings did not find their way back into the pruned frames and breed there satisfactorily, else there would have been a much heavier attack later. More probably they died, or went to another field. The latter, as will be shown later, is unlikely. The whole of the data demonstrates beyond doubt that the attack observed originated from a very small number of beetles, and not from numerous galleries as would be expected if the frames were heavily infected. The burning of prunings therefore can do no good, and practical experience has amply confirmed that conclusion.

MORTALITY AFTER EMERGENCE

The total number of galleries has been shown to increase *only* at the rate of 10.7 per cent compound interest. Admittedly since at that rate the number of galleries is doubled every 6 weeks (approximately), astronomic numbers would be reached in a relatively short time if that rate could be maintained. Nevertheless, that rate of increase seems ridiculously small when conditions are favourable for the beetle, *i.e.*, when suitable wood is available.

The writer has shown elsewhere ⁽¹⁾ that adult beetles emerge from occupied galleries at the rate of 0.26 per day and of these 27 per cent may be males. We may therefore put the emergence rate of female offspring as 0.19 per day or 19 in 100 days, *i.e.*, 1 every 5 days. As many as 34 adults may emerge from one gallery, but that number is rarely exceeded. If every female that emerged from one gallery established herself in the same bush, there would be 2 galleries after 5 days, 3 after 10 days and so on. This is an increase of more than 100 per cent per week simple interest. But it might be argued that the offspring do not stay in the same bush but fly elsewhere. They might fly to other bushes in the same field or to other fields. If their migration is restricted to the one field, as many beetles are likely to arrive at one particular bush from surrounding bushes as would leave that particular bush on flight. So the rate of increase should be the same. But suppose they fly to other fields. If the field they leave is a second year field and therefore most suitable for attack, unless they go to another second year field — when the exchange would be much the same as between bushes in the same field — they must fly either to fields in their first or third year from pruning. The wood in these fields is less

suitable for attack, as has been shown, and, as it seems very unlikely that the beetles would migrate to less suitable conditions, we must conclude that they most likely stay in the field in which they were raised.

There is, however, no information from direct observation by entomologists concerning the flight of the shot-hole borer apart from the fact that the beetle has wings and can fly. The suggestion is here put forward that they do not normally fly far but tend to remain near to the gallery in which they were raised.

This point does not materially affect the argument, but it will be evident that if the beetles fly from a heavily infested second year field they must die in large numbers because the wood in 1st and 3rd year fields is not eminently suitable for attack. All statistics available point to that conclusion. If they remain in the same field they must still die in very appreciable numbers, because the rate of increase observed in the number of galleries is very much less than what is expected from the rate of increase of female beetles.

We may therefore conclude, at least tentatively, that in addition to a heavy mortality within the galleries shown elsewhere ⁽¹⁾ there is also a further large destruction of beetles after they emerge from the galleries. It would be interesting to compute more exactly the percentage of beetles which do not live long enough to form a gallery for themselves. On the present evidence, the destruction of beetles seems so great under existing conditions that it is likely to exceed what could be brought about by any parasite. In view of the demands made in certain quarters that the world should be combed for such a parasite the matter is worthy of further attention. No such parasite is known and, if the writer's views are further substantiated, it would appear a waste of time to look for one.

SUMMARY OF CONCLUSIONS

1. Attack by shot-hole borer does not become of economic importance during the first year from pruning.
2. The main period of attack is usually in the later half of the second year when the number of galleries may increase at a rate of 10.7 per cent compound interest.
3. The attack dies out during the third year.
4. Sufficient occupied galleries are left after pruning to ensure an attack during the next pruning cycle. The number of occupied galleries left need not exceed one per bush, and a much smaller number is all that is necessary.

5. Such measures as the burning of prunings can do little or nothing towards preventing a later attack.
6. The cessation of attack during the third year is due to factors which are operative and whose effects become increasingly deterrent as the attack progresses. These factors cause an increase in the percentage of beetles that abandon the galleries before egg-laying.
7. The effect of the same factors is shown by an apparent reduction in the mean time of occupation of the galleries by the beetles. When abandoned galleries are few the mean time of occupation is 11.7 weeks.
8. Healing is completed on the average 8.4 weeks after the gallery becomes empty.

More tentative conclusions include

9. The flight of the borer is probably very short. The proximity of heavily attacked tea is not a serious source of danger now. Every field liable to attack will always contain sufficient beetles to initiate the attack when the wood is suitable.
10. The heavy mortality amongst adult beetles, coupled with the mortality that occurs in the galleries, raises doubt that the presence of a parasite would materially improve matters.

ACKNOWLEDGMENTS

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APPENDIX

- A. The formula for a compound interest curve is $y = Ae^{rx}$ where y is the capital and accumulated interest, A the original capital, r the rate of increase and x the time during which the interest has accumulated, $e=2.718$.

The same formula may be written as $\log y = a + bx$ where $a = \log .10^4 A$ and $b = r \log .10^4 e$. The graph for this formula is of course a straight line.

The procedure for determining the best compound interest curve was to fit the best straight line to the logarithms of the observations.⁽⁹⁾ For total galleries that line is represented by $\log. y = 1.724 + .046x$, x being the time in weeks counting from May 1st. Converting as above, A , the capital is 53 and r is found to be .107 or 10.7 per cent.

- B. Only six observations have been used for the calculation of the curve to represent healed galleries as it is only from about July 24th that the logarithms of the observations approximate a straight line. This line is represented by the equation $\log. y = 1.196 + .064x$ which gives A a value of 15.7 galleries on July 24th, and r a value of .147 or 14.7 per cent.
- C. The healed plus empty gallery curve is calculated for the same period as for healed galleries. $\log. y = 1.736 + .061x$. This gives the increase rate of .140 or 14 per cent, and the number of galleries on July 24th as 54.5.

The graphs for the above three lines are given in Fig. 2 which also shows the data from which they were calculated. In Table III these and other equations are brought to a common zero time, viz. July 24th.

- D. The time when the two lines meet is when $2.280 + .046x = 1.736 + .061x$; i.e., when $x = 36.3$ weeks after July 24th.
- E. The actual value has, of course, been calculated from the appropriate equation.

TABLE III

The Values of a and b of the equation $\log. y = a + bx$ with July 24th as zero time.

Type of gallery	a	b	A	r	Period used for calculation
Total	2.280	.046	190.5	.107	May 23rd-Nov. 29th, 1940.
Healed	1.196	.064	15.7	.147	Aug. 15th-Nov. 29th, 1940.
Empty + Healed	1.736	.061	54.5	.140	do.
Vacant	1.463	.081	29.0	.140	do.
Abandoned	0.853	.059	7.1	.136	do.
do.	0.485	.085	3.1	.195	Sept. 24th-Nov. 29th, 1940

REFERENCES

- (1). Gadd, C. H.—The life-history of the Shot-hole borer of Tea. *Tea Quarterly*, XIV, pp. 5-22 (1941).
- (2). Gadd, C. H. and Jepson, F. P.—The effect of manures on the Shot-hole borer of Tea. *Dept. Agric. Ceylon Bull.* 56, (1922).
- (3). Jepson, F. P. and Gadd, C. H.—The Control of Shot-hole borer of Tea. *Dept. Agric. Ceylon, Bull.* 72, (1925).
- (4). — — — — — Manuring in relation to the control of Shot-hole borer in Tea. *Dept. Agric. Ceylon, Bull.* 78, (1926).
- (5). King, C. B. R.—Annual Report of the Entomologist for 1939. *T. R. I. Bulletin* 21.
- (6). Yule, G. U. and Kendall, M. G.—An introduction to the theory of statistics, London, 1937.