STUDIES OF SHOT-HOLE BORER OF TEA

2—GALLERIES

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Many boring beetles, of which *Xylebo-rus fornicatus* is one, make tunnels, circular in section, in timbers. If the holes resemble those made by small shot, *i.e.*, anything larger than the equivalent of a pinprick up to 3 mm. in diameter, the beetles are commonly termed "shot-hole" borers. Many of them, including their young, do not eat the wood but feed on a fungus (the ambrosia) which grows on the walls of the tunnels; such beetles are often termed "Ambrosia" beetles. The shot-hole borer of tea is also an ambrosia beetle. The majority of ambrosia beetles attack newly-felled trees, their liability to attack lasting for a relatively short time, till the sap dries out. The shot-hole borer of tea is an exception to this general rule as it attacks living stems, and in consequence has become an important tea pest in Ceylon.

If the making of tunnels in wood were the sole injury resulting from the beetle's activities, the pest in tea would be of little economic importance. The tunnels reduce the mechanical strength of the wood, with the result that infested branches tend to break rather easily during such operations as plucking, forking and pruning. The loss of branches during the plucking cycle results in loss of crop though its amount is impossible to estimate accurately. Other damage, such as the dieback of pruned stems, can also be traced to the presence of galleries.

Places of Entry.—The entrance to a gallery (exit is by the same aperture) is seen as a small round hole, the shot-hole. Green (1903) first drew attention to the fact that the entrance is "usually at a leaf scar or immediately below a side shoot." Leaf scars can often be distinguished on tea stems even after the bud has developed into a lateral branch, and evidently, it is a matter of indifference to the beetle whether the bud has burst and grown into a stem or not at the time of entry. If, however, entry is made through the scar before the bud has grown, it is very unlikely that the bud will grow later. The reason for this statement is that although the bud itself is not damaged, the wood vessels through which water must pass to the bud to cause it to burst and grow, are usually severed during the boring. The failure of buds to break becomes of importance after pruning.

One method of demonstrating this preference of the tea borer is by counting the galleries in suitable branches and noting the numbers at the nodes and between them. More holes are found at the nodes than would be expected if the beetles entered the stem anywhere, haphazard. Experimentally, the beetles have been tested with suitable severed tea branches, the beetles being allowed to move freely and select their own places for entry. Of 43 beetles that started to make galleries 32 began boring at the nodes, usually through the leaf scars, and only 11 entered the internodes.

Gallery Formation.—The galleries are made by females soon after maturity and emergence from the parent gallery. Each begins with an entrance tunnel, which is invariably directed radially towards the centre of the stem. Later construction seems to depend largely upon the diameter of the stem.

The best known galleries in tea are those made in stems about half-an-inch in diameter or less as they are much more common, more easily dissected, and can be studied without completely destroying whole bushes in the process. In such stems Green (1903) described and illustrated two main types of gallery.

The first occurs mainly in stems about half-an-inch in diameter. In Green's words "The beetle first drives a straight tunnel almost through the branch but stopping just short of the other side. From the extremity of this tunnel it runs a circular gallery in an ascending spiral above and a similar gallery in a descending spiral below." The straight arm, or entrance gallery passes through the centre of the stem; either through the pith or slightly to one side of it, but always stops before the cambium on the far side is reached. From this end the circular branches follow the curvature of the woody cylinder very accurately: they often run very close to the external surface yet never touch it or damage the cambium.

The second type occurs in thinner twigs. Again in Green's words "A longitudinal tunnel may run down or up the pith for an inch or more before the construction of the spiral gallery." In its simplest form there is no circular arm, only a longitudinal gallery in the pith, (Fig. 5) but more frequently a gallery has both longitudinal and circular or spiral arms (Figs. 3 and 6).

Often the circular arms do not form a spiral, but run in the same plane as the entrance gallery, with the result that they return to the straight entrance gallery near to the entrance; but they always stop just

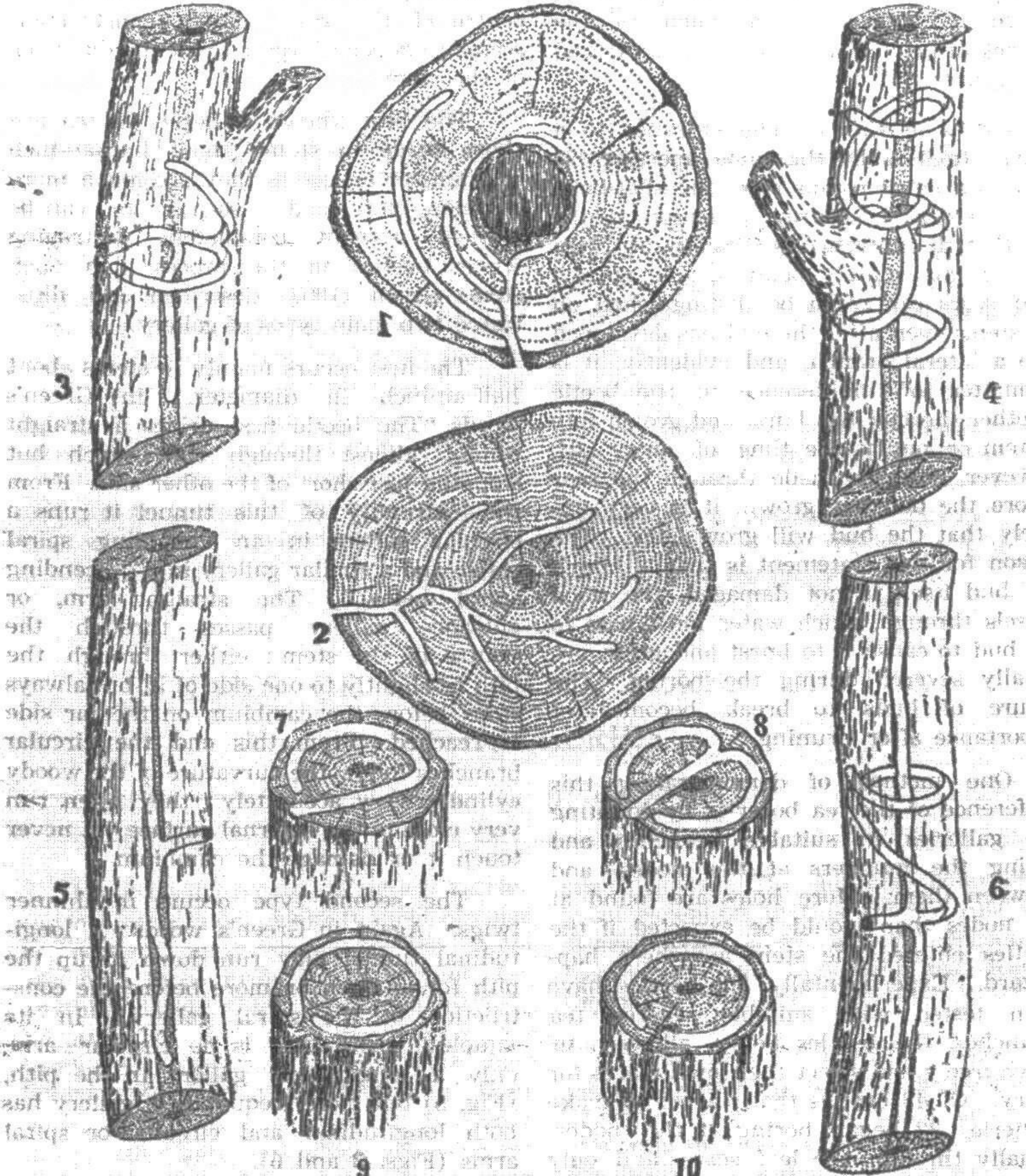

PLATE I

Galleries made by Shot-hole Borer (*Xyleborus fornicatus*)

1. In castor stem. 2. In large tea stem. 3—6. Longitudinal and spiral galleries in smaller tea stems. 7—10. Galleries at fractured ends of branches.

(Drawings by W. T. Fonseka.)

short of that gallery and never join it (Fig. 8). In fact, the beetle rarely (if ever) penetrates an existing gallery, no matter whether she or some other beetle made it. It is just as though she is aware of its existence and deliberately avoids penetrating it. (Figs. 7-10). Nor is the entrance gallery always driven through the middle of the stem. It often stops short soon after the wood is entered, and the beetle then turns either to the right or left and bores a circular gallery (Fig. 9), or the galleries may be spiral and more complex (Fig 4).

All tunnels are circular in section, and very uniform in diameter, just sufficiently large for the beetles to move easily along them. They are excavated by the female with her mandibles (jaws). The wood is cut into small strips about 0.6 mm. long and 0.2 mm. broad, *vide* Speyer, (1922), and the the fragments are thrown out of the gallery to form a small heap of wood dust below the entrance.

In thick castor branches the galleries of *X. fornicatus* follow the same plan in so far that they all start with a straight entrance gallery from which circular galleries following the curvature of the stem are made. (Fig 1). These are mainly in one plane and at varying distances from the pith; rarely are they close to the cambium. The circular galleries first made start from the entrance gallery but later ones may start from existing circular galleries and run at different levels. The galleries in thick tea stems, presumably made by the tea borer, are somewhat different in that the side branches are not circular and they "ramify in a branching manner" as described by Green. (Fig. 2).

Instinct.—The construction of a gallery is a remarkable engineering feat. The whole procedure is, of course, instinctive but what controls the instinct is a matter for conjecture. From what has been said earlier it may appear that the thickness of the branch in which the beetle is boring largely determines the type or shape of the gallery to be made, but that cannot be entirely true. It may be convenient for an observer to classify galleries according to the diameter of the branch in which they are found, but such classification does not imply that the beetle also is aware of branch size. That would require an intelligence which the beetle cannot possess.

What seems more probable is that the beetle is able to perceive very keenly small changes in some character of the tissues through which she is boring and her response to that stimulus is to align her body relative to the direction of that change, much as a moth aligns its body to light rays falling on it, and so when flying is compelled to move towards the light source.

Gallery Position.—The positioning of the gallery is a matter of considerable importance to the beetle. Green (1903) clearly indicated his opinion on the subject as follows: "The object appears to be to check the flow of sap without absolutely stopping it, as the death of the branch would defeat the ends of the insect. The eggs are deposited in these circular galleries and the developing grubs feed upon the exudation of sap on the walls of the galleries and upon the delicate mycelium of a fungus that almost invariably clothes them." The idea here is that the gallery must be sited in a region sufficiently wet for the sap to exude into it in small quantities for the benefit of the young.

On physiological grounds there is no likelihood of an appreciable flow of sap into galleries. When a tea branch is pruned the cut surface never bleeds freely, and the exudation of sap from the cut is hardly more than sufficient to wet the surface for a very brief period. A pruning cut severs all the water-conducting vessels, whereas a gallery severs, at most, a small fraction of them. Consequently exudation into a gallery is likely to be small and temporary.

Do galleries hinder the normal flow of sap, as Green suggested? Direct evidence on this point is very difficult to obtain. If, however, every gallery caused a hindrance to the sap flow, though each hindrance is too small individually to cause any visible sign of its existence, the cumulative effect of numerous galleries in a heavily infested branch would surely become evident, and cause a wilt of at least some of the leaves. Heavily infested branches, however, have never given any indication of water shortage under normal conditions, nor are attacked bushes particularly susceptible to drought.

Whether the young feed on sap exuding on to the gallery wall is not proven, but it is certain that they eat "the delicate mycelium" and spores of the ambrosia fungus which invariably lines the walls. So far as is known the ambrosia fungus forms the main, if not the sole food supply of the beetles and their young. That the galleries must be sited where the fungus will grow well is, therefore, a matter of vital importance. Failure of the fungus means death for the beetles. It seems probable, therefore, that the galleries are sited so that the fungus may be planted where it will grow best, in the most 'fertile' part of the stem. The fungus requires nutrients for growth and these are most readily obtainable in the region of the cambium, and possibly, in parts of the pith.

In the writer's opinion the positioning of galleries is dependent largely upon the requirements for satisfactory growth of the fungus, necessary as food. That necessity is most likely to lead to the development of an instinct by natural selection. Beetles without that instinct (or with it only slightly developed) are likely to make galleries in unsuitable places and so fail to raise their young.

Exudation from Galleries.—Speyer (1922) was of the opinion that the exudation of sap into galleries is appreciable and that "Excess moisture in the wood during wet seasons drains out of the entrance hole in considerable quantities." Later in the same paper he states that the exudation is 'foul smelling.' Other observers give no support to Speyer's view that the gallery normally acts as a drainage channel. Exudations have occasionally been observed, but always under abnormal conditions. Rutherford (1914) commented on the exudation of a sour-smelling substance from galleries in which he found certain flies (Drosophilids). Jepson (1921) found galleries containing the flies and mentioned a 'putrid odour' but he made no reference to any fluid exudation. The writer has discussed these observations elsewhere (Gadd 1941a) and has put forward the view that the foul-smelling exudation is the result of a fermentation process which normally does not occur in galleries, and that the flies are attracted to it. He, therefore, regards the exudation as indicative of a 'diseased' condition of galleries.

Why Branches Break.—That borer infested tea branches should break is largely a matter of accident. The fracture is never solely due to the presence of a gallery: an external force must be applied to cause the branch to break. Whether a branch will break or not depends upon the following factors: (1) The diameter of the branch at the gallery (2) The type of gallery and (3) The pressure exerted to cause fracture.

One method of testing whether a tea bush is infested or not, is to sweep an arm over the bush so that pressure is exerted against the branches. This usually results in a number of fractures if the bush is infested; the greater the pressure the greater the number of breakages. Very strong winds and most cultural operations which bring the labourers in contact with the bushes cause a certain amount of damage in infested fields. Plucking is perhaps the most important operation because it occurs most frequently.

Numerous measurements of branch diameter at the fracture have been made. The writer has published elsewhere (Gadd 1944) measurements made in 1942 and 1943. On six occasions in 1942 more than 5,000 branches were measured; none were less than one-eighth inch or more than five-eighth inch in diameter. Thirty-five per cent of them were between 2 and 3 eighths and 30 per cent between 3 and 4 eighths of an inch. These figures tell little more than the expected, viz. that the thinnest branches break most readily. Although any one branch is relatively small the cumulative damage to the bushes is often extensive.

King (unpublished data) had measured the diameters of 662 branches broken during plucking, and the galleries at the fractures classified according to their type. The great majority of the branches were again between two and three eighths of an inch in diameter. More than one third of the galleries at the fracture were circular without a long entrance gallery, as shown in Fig 9. Others were simple galleries with long entrances (Figs. 7 or 8), or were of more complex type. All had circular arms running in one transverse plane and not one was of the simple longitudinal type. The circular gallery was sometimes the terminal loop of a spiral which had been made in one plane (Fig. 10).

Breakages also occur during pruning. Tea wood is very hard and considerable force is necessary to sever sound branches even with a sharp knife. A branch breaking during pruning usually breaks below the place the knife cut is started. Consequently the branches broken during pruning are much thicker at the fractures than are branches broken during plucking. The types of gallery at the fractures, however, are much the same.

Other things being equal, ease of fracture will depend upon the amount of undamaged wood left after a gallery has been made. On that basis, galleries with a long entrance and two circular arms should break somewhat more easily than those with circular arms only. The data under consideration, however, cannot be used to prove or disprove this point, because no data are available of the relative numbers of each type actually made, only galleries at the fracture being recorded.

The addition of new wood by new growth after a gallery is completed must tend to strengthen the branch and decrease its liability to break.

Healing of Galleries.—"It will usually be found that galleries in the lower parts of the stem are unoccupied and that the exit (or entrance) holes have become obliterated by growth of new wood which completely shuts off the perforations. This blocking of the exit hole is of frequent occurrence in vigorous wood, and usually — though not invariably — results in the death of the contained insects." This quotation is taken from Green's important account of the shot-hole borer of tea (1903). It contains one rather glaring contradiction. In the first sentence he speaks of the galleries being "unoccupied" and in the last of "the death of the contained insects." A later passage, however, makes evident his opinion that beetles can be trapped and killed in their own galleries. "I have repeatedly observed that a vigorous condition of the plants results in an obliteration of the earlier perforations and a tendency to choke out the insects that have more recently gained an entrance into the branches."

Speyer (1922) is somewhat more definite. He states "When the vigour of the cambial layer is sufficient to heal over a tunnel in process of construction, containing a single female beetle, the insect may sometimes have time to leave the tunnel, but often is entrapped and being unable to turn round in the tunnel, so as to force the entrance with its mandibles dies within it." This statement implies that the entrance to a gallery may be sealed up even before the gallery is completed, before eggs can be laid and a family raised. Green may have meant the same thing when he referred to "insects that have *more recently* gained an entrance."

The suggestion is that beetles may be trapped alive within the galleries. But why young females only should be so entombed is not obvious. Speyer's explanation that "normally at any rate, injury to the tissue is sufficient to prevent healing so long as the insects are developing in the gallery" does not help materially, as he leaves unexplained what injuries young developing insects can produce that adults, capable of boring through wood, cannot make.

In the writer's opinion both Green and Speyer have misinterpreted their observations. Jepson (1920) made somewhat similar observations and indicated the main difficulty of interpretation. He wrote "Instances have been found where female beetles occurred dead and imprisoned in a gallery completely healed, or in an advanced process of healing, but there is no evidence to indicate whether death had occurred before, or after, healing had commenced." Neither Green nor Speyer claim to have seen living beetles in a healed gallery. A dead female is often found within a healed gallery, but as a parent female is reputed to die in her gallery after her young have departed, the presence of her body in a healed gallery should not occasion surprise.

A matter which must have a bearing on the question whether beetles can be trapped alive is the time normally required for a gallery to heal. Before discussing that problem it seems advisable to consider the process by which galleries are healed.

Healing.—Enveloping the woody cylinder of a stem is a thin delicate tissue termed the cambium which by active cell division forms wood cells on its inner and cortical cells on its outer surface. Increase of a stem's diameter is due entirely to the activity of the cambium. The entrance tunnel of a gallery runs right through the cambium. That is the only injury inflicted on the cambium; it is small and does no appreciable harm. The cambium continues to divide and the stem to increase in thickness slowly. In addition, the cambium attempts to heal its wound by lateral outgrowths of cells, usually termed "callus." The callus from opposite edges of the wound ultimately meet and fuse together, and so form a plug in the gallery entrance. The cambium reforms in this tissue and again becomes an unbroken cylinder. In this way the wound becomes completely healed and the entrance to the gallery is sealed off. The obliteration of gallery entrances is therefore the normal process of healing, and consequently those with plugged entrances are termed 'healed' galleries.

The callus which plugs the entrance is much softer than wood, and a female beetle should have little or no difficulty in keeping the gallery entrance open. The beetle normally ejects wood fragments, etc. from the gallery by pushing them out with the hind end of her body because she always faces inwards and cannot turn round. If she wishes, she can leave the gallery and so bring her mandibles into action to remove callus growth should that be necessary. Her body, particularly the thorax, is rough and might even be used as a rasp to remove callus at the entrance. Green even suggested that her rough body might be used in helping to excavate the tunnel. There does not, therefore, appear any reason why a beetle should be physically unable to prevent a slow growing, relatively soft tissue from blocking the gallery entrance as Speyer suggested.

Time for Healing.—Wounds on tea stems do not as a rule heal rapidly as compared with those of many other trees. Moreover there is a good deal of variation amongst tea bushes themselves as regards the rate at which their wounds will heal. It is not uncommon to find individual bushes with almost all their wounds partially healed while others immediately surrounding them give little evidence of healing. Such observations not only indicate that the rate of healing of gallery entrances varies from bush to bush, but they also throw doubt on the reliability of using healing as a measure of vigour.

Speyer's statement that a gallery entrance may become obliterated before the gallery can be completed suggests an extremely rapid rate of healing for tea, as a gallery may be made and eggs laid in so short a time as 10 days. Normally *vide* Speyer, entrances to galleries disappear almost entirely four months after pruning. This observation, however, must refer to galleries present in the frame at the time of pruning, but it clearly indicates that the plugging of galleries is not a rapid process.

King (1940) attempted to ascertain by direct observation the time elapsing between the formation and healing of galleries. His published data refer to 115 days' observation during which time only 16 per cent of the entrances (*i.e.*, 8 out of 49 galleries observed) healed. The shortest time observed was 36 days, but unfortunately no information is given regarding that gallery (and others), particularly to whether it was occupied by the beetle or her young when healed. Beetles will sometimes begin a gallery and then desert it before completion. Such galleries would be expected to heal most rapidly because of the absence of a beetle to keep the entrance open. The data, however, show that the normal time of healing exceeds 115 days (or 4 months). In another experiment 500 new galleries were observed for various lengths of time but only 4 were observed to heal. The closing of these galleries occurred when they were 45, 59, 62 and 65 days old, respectively. These galleries were dissected and found to be empty, the parent females and their families (if any) having gone, evidently before the entrance was closed.

The writer has attempted to estimate the mean-time between gallery formation and healing by indirect methods. The first was based on Jepson's data (Gadd and Jepson 1926) and the second (Gadd 1941b) on data from another area collected during a plucking experiment. For details of the method used the original papers should be consulted. The first estimate gave from 3.2 to 4.3 months; the second was somewhat longer, viz. 20.1 weeks. These values are greater than the period which beetles and their young normally occupy galleries and indicate that entrances are not normally sealed off before the inmates leave the galleries.

These results give no support to the view that by rapid healing, beetles may be trapped within their galleries. They indicate a probability that the beetles can and do keep the entrances open as long as is necessary. Healing, therefore, has no direct value in the control of shot-hole borer by limiting the time a gallery can be occupied by a female and her family.

Healing and Breakage.—Green was never "sanguine of finding a radical cure for this pest." His advice was summed up in the words "Keep the tree in a vigorous condition and it will fight its own battles, provided it is relieved from constant reinfection." How can the bush fight its own battles if it is unable to trap and kill the beetles invading its tissues? Jepson (1920) suggested an answer. He drew attention to the fact that in some fields the percentage of healed galleries is very high and gave a figure of 96.6 per cent. He regarded gallery occlusion or healing as a process by which "severely damaged branches could be completely restored to their former sound condition, weakened branches becoming so strengthened that they could not be fractured at the point where the stem had been invaded." These observations markedly influenced the direction of his later work, particularly his attempts to ascertain the value of manures in the control of this pest.

Does healing so strengthen a branch that it will not break at the place where a borer has invaded it? It has already been shown that the ease of fracture depends largely upon the diameter of the branch and the shape of the gallery in the branch. It seems preferable to alter the question to "Does the healing of a gallery strengthen the branch and so diminish its liability to fracture?" The data given in Table I will supply an answer to this question.

During 1945 and 1946 broken branches were collected weekly from certain experimental plots, last pruned in September, 1943, in the Passara district. The branches were collected and counted weekly, and on occasions, the galleries at the fracture were classified as healed or open. On these occasions all other galleries in the broken branches were counted and similarly recorded. The data given in Table I refer

TABLE I

Healing and Branch Fracture

	Galleries examined			Galleries at fracture			Unbroken Galleries		
		Healed			Healed			Healed	
	Total	No.	%	Total	No.	%	Total	No.	%
1945									
March 14	993	208	20·9	451	29	6·4	542	179	33·0
April 4	1161	198	17·1	602	37	6·2	559	161	28·8
April 25	1168	295	25·2	508	52	10·2	660	243	36·8
Total	3322	701	21·1	1561	118	7·6	1761	583	33·1
1946									
March 13	784	575	73·3	281	181	64·4	503	394	78·3
April 3	664	447	67·3	234	132	56·4	430	315	73·3
April 24	370	274	74·1	132	85	64·4	238	189	79·4
Total	1818	1296	71·3	647	398	61·5	1171	898	76·7

to three such occasions at 3-week intervals in 1945 and similar observations at the nearest corresponding date in 1946. On the three occasions in 1945, over three thousand galleries were examined of which 21.1 per cent had healed entrances. If all galleries are equally liable to result in fractures, no matter whether the gallery is healed or not, we should expect to find about 21 per cent of the galleries at the fractures to be healed. Instead, only 7.6 per cent of the galleries at the fractured ends of the branches were healed, whereas of the galleries at places which did not break 33.1 per cent were healed. On each occasion the results were similar and the observed differences (from expectation) are too large and too consistent to be due solely to chance.

During the corresponding weeks in 1946 the breakages in the same area were smaller in number, 647 as compared with 1,561 in 1945, but the percentage of healed galleries was greater. In this period 71.3 per cent of the galleries were healed as compared with 21.1 per cent in 1945, and again fewer healed galleries occurred at the fractures than would be expected if healed and open galleries were equally likely to cause breakage. We must, therefore, conclude that although healed galleries remain liable to break, they are less likely to fracture than galleries with open entrances.

Percentage of Healed Galleries.—Before leaving the data of Table I the question might be asked, Why was there a larger percentage of healed galleries in 1946, the third year from pruning, than in 1945, the second year from pruning? Was the process of healing speeded up during the third year? Or can other explanations be offered?

Jepson interpreted a high percentage of healed galleries as an indication that stimulation, or speeding up of the process had occurred. He wrote (Jepson 1920) "The greater percentage of healed galleries observed in the bushes which had been pruned, as compared with those which had been allowed to 'run up' appeared to indicate that this process of healing had been further stimulated by pruning." This line of reasoning prompted his work on the value of manures in shot-hole borer control. "If the process (healing) is not evident at all seasons but only following manuring, it will be important to discover the particular ingredient or element which assists the process."

There is, however, another interpretation of a high percentage of healed galleries which appears to have been overlooked. Let us suppose that for some reason or other, attack by beetles ceases altogether after a time. No new galleries would be formed, but the entrances of existing galleries would gradually become obliterated at the same rate as before the attack ceased. The percentage of healed galleries would consequently increase gradually to 100 when all entrances would be healed over. An increasing percentage of healed galleries may, therefore, mean a diminution or even a cessation of attack by the beetles. This question will be discussed in more detail when the measurement of attack is considered. For the present it is sufficient to show that the increased percentage of healed galleries in 1946 does not necessarily mean that healing was speeded up that year; it may, and in the writer's opinion does, suggest that the attack decreased, if it did not actually cease, in 1946, the third year from pruning.

Why Healed Galleries are less liable to Cause Breakages.—The mere presence of a callus plug in the entrance of a gallery cannot strengthen materially a branch at that point, so other reasons to account for the observed facts must be looked for. A gallery with an open entrance may be of recent formation and contain a beetle and her young. It may, however, be somewhat older; the brood may have departed. A healed gallery is generally older still. The fact that a gallery entrance is obliterated is, therefore, an indication of its relative age.

The presence of galleries does not prevent a stem from growing in length or increasing in diameter. Whether a gallery entrance is open or closed is immaterial, the stem continues to increase in girth owing to the formation of new wood on the exterior of its woody cylinder. Other things being equal a healed gallery, merely because it has existed for a longer time, will have more new wood formed outside the gallery than a more recently formed gallery with an open entrance will have. The new wood gives added strength to the branch. Consequently healed galleries are less likely to result in fractures than are open galleries. It would perhaps be better to express the same idea in words relating to age and not to healing. *Old* galleries are less likely to lead to branch breakage than young galleries, other things being equal.

Manures and Healing.—Other things are not equal if a gallery in a vigorous bush is compared with another in an ill-nourished slow-growing bush. The simplest way of increasing the vigour or rate of growth of a bush is by suitable manuring. Consequently it would appear that by suitable manuring the time during which a bored branch is likely to break can be diminished. That in turn might lead to a reduction in the number of breakages occurring in a given area. Jepson held this opinion. He wrote (Jepson and Gadd 1926, p. 10) "One way of meeting the difficulty (breakages during plucking and other operations) is, therefore, to so improve the vigour of the bush as to induce the rapid healing over the gallery entrance holes and to lessen the tendency of the branches to break." He collected data concerning the healing of galleries from controlled experiments, and the present writer analysed the results. I then wrote (p. 47) "These experiments show that nitrogen, potash and phosphoric acid all tend individually to promote the healing of galleries."

The question the experiments did not answer, because no data was collected affecting it was "Does the use of manures reduce the loss of branches?" It was generally assumed that where healing is accelerated a reduction in loss of branches must follow as a natural consequence, but the question was not tested by direct experiment till much later, and the answer was surprising. The numbers of broken branches collected from experimental plots in 1945-46 (Gadd 1943, 1944a and b) were greatest in the plots giving the heaviest crops. Nitrogen caused the greatest increase in yield; it also caused the greatest increase in insect damage.

The effect of manures on breakages will be discussed more fully later. This section may, therefore, be terminated with the statement that, although manures increase the growth rate of bushes and accelerate the rate of healing of galleries, they do not diminish the damage as measured by the numbers of broken branches. Damage may increase as a consequence of their use.

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