

# DOES MANURING REDUCE THE DAMAGE CAUSED BY SHOT-HOLE BORER?

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In 1903 Green <sup>(2)</sup> writing on the control of Shot-hole borer in tea, stated: "Our object should be to induce by suitable pruning and cultivation such a vigorous condition that the damage is automatically and continuously repaired." That statement still fairly represents prevailing opinion today. The aim of every planter is to induce and maintain a vigorous condition in his tea bushes, if for no other reason than that the size of his crop largely depends upon his success in that direction; careful pruning and good cultivation are amongst the methods employed. As an agricultural policy Green's advice is eminently sound. The advice, however, was not given merely as a general agricultural policy but as a specific method of reducing the damage caused by shot-hole borer. If the damage is automatically and

continuously repaired by bushes in a vigorous condition, it should follow that visible damage will be least in those areas where the bushes' vigour is greatest, and *vice versa*. The experiment to be described is designed to test that inference, which for so long, has been generally accepted without proof.

It will be obvious that if vigour and damage are to be compared, methods for measuring each must be devised. Vigour will be reflected in yield; the more vigorous bushes may be expected to give the greatest harvest, if other factors, like type of plucking, are kept constant. The crop harvested from individual plots can be determined with considerable accuracy, and such figures may be accepted as a fair measure of bush vigour, or of soil fertility inducing vigour.

TABLE 1.  
Experimental Results.

Treatment	Yield lb.	Broken branches in hundreds	Galleries per 100 broken branches	Healed galleries %
O	432.28	63.51	176.7	20.21
N	527.41	79.84	180.6	16.78
P	448.82	66.72	186.9	19.12
NP	500.20	84.08	200.9	23.68
K	540.28	86.67	204.8	18.36
NK	503.60	74.32	179.0	17.55
PK	415.56	65.15	190.4	16.41
NPK	483.37	72.11	181.8	19.06
Total	3,851.52	592.40	1,501.1	—
Mean	481.44	74.05	187.6	18.90

The primary damage caused by shot-hole borer is the formation of galleries in the stems. If that were all, the boring beetle could be regarded as a minor pest, but unfortunately, the damage does not end with the boring of galleries. The presence of galleries weakens the stems and they tend to break in high winds and during plucking; the fracture always occurs at a gallery. The loss of leaf-bearing branches must cause a loss of crop; that is probably the greatest damage resulting from shot-hole borer attacks. It is not the only damage as, during pruning, branches are apt to break at unexpected places, and after pruning, diebacks are likely to be prevalent because of injury to buds. Also, there are grounds for suspicion that wood rot is increased in the frame following the boring by

beetles. Nevertheless, the breakage of branches is the principal damage occurring during the plucking season, so a count of the number of broken branches affords a fair measure of the damage from borer attack. In this experiment the number of broken branches is used as a measure of the damage done.

In previous work <sup>(3)(4)(5)</sup> Jepson attempted to determine the effect of manuring on the incidence and control of shot-hole borer. In that work no account was taken of the yields obtained from the experimental plots, nor was any direct measure made of the damage done. Galleries were counted and classified; estimates were made of the beetle population in every plot, and conclusions were drawn from such observations. In this

experiment, the angle of approach to the problem is entirely different, and although observations similar to those made by Jepson were taken, they are regarded as of secondary importance. The measure of bush vigour is yield, and that of damage is the number of broken branches. The problem is to determine how improved vigour, *i.e.*, increased yield, affects the amount of damage as measured by the number of broken branches.

The experiment was designed and laid out by Dr. T. Eden with the object of determining the effect of manurial treatments on the yield of tea in a shot-hole borer infested area of the Passara district, at an elevation of 3,300 feet (approximately) above sea level. It consists of 4 blocks each divided into 8 plots of approximately one-tenth acre in extent. Eight manurial treatments were applied, so that each treatment occurred in every block; the blocks are replicates so far as treatment is concerned. The treatments were (1) no manure, (2) nitrogen alone at the rate of 40 lb. per acre, per annum, (3) potash alone at 40 lb. per acre, (4) phosphate alone at 30 lb. per acre, (5) nitrogen and potash together (6) nitrogen and phosphate, (7) potash and phosphate and (8) a complete mixture of nitrogen, potash and phosphate. Where more than one element was used the quantity of each was the same as that applied alone in treatments (2), (3) and (4). The letters O, N, P, and K. will be used to designate no manure, nitrogen, phosphate and potash treatments respectively in tables and figures.

The plots were pruned on September 2nd, 1940. Plucking started on December 13th, 1940, and was continued at weekly intervals; the crop from each plot was weighed, and recorded separately. Manures were applied on March 5th, 1941.

and again on April 2nd, 1942. The first collection of broken branches was not made till January 31st, 1942, when 2,689 broken branches were removed from the entire area (3.2 acres). This collection included all branches broken since the plots were pruned. Further collections were made weekly after each plucking when the number from each plot was recorded. Yield and breakage records are being continued during the third year, but the data here discussed refer to the first two years from pruning only, up to and including the records of October 2nd, 1942. Reasons for extending the second year from pruning beyond the correct date, September 2nd, will be given later.

Although the areas selected for the experiment were as uniform as possible, it is certain that all the plots were not equally fertile, *i.e.*, they would not have given exactly equal yields if treated alike. But as eight different treatments were applied, some of which would improve soil fertility more than others, it is not surprising that the crop harvested from the individual plots differs markedly. The highest yield was 171.86 lb. and the lowest 89.88 lb.; other plots gave yields between these extremes. Similarly, the largest number of broken branches collected from any one plot was 2,531; this plot happened also to be the one which gave the highest yield. The smallest number was 1,334 and that was from a plot which gave only 90.15 lb., the lowest but one of all yields. It would be unwise to draw any conclusion from the few data yet given, but they do indicate that if there is any relationship between yield and the number of broken branches, it is *not* the one expected, namely that the smallest number of breakages would be found in most vigorous, highest yielding plots. But there are 32 plot results to be considered,

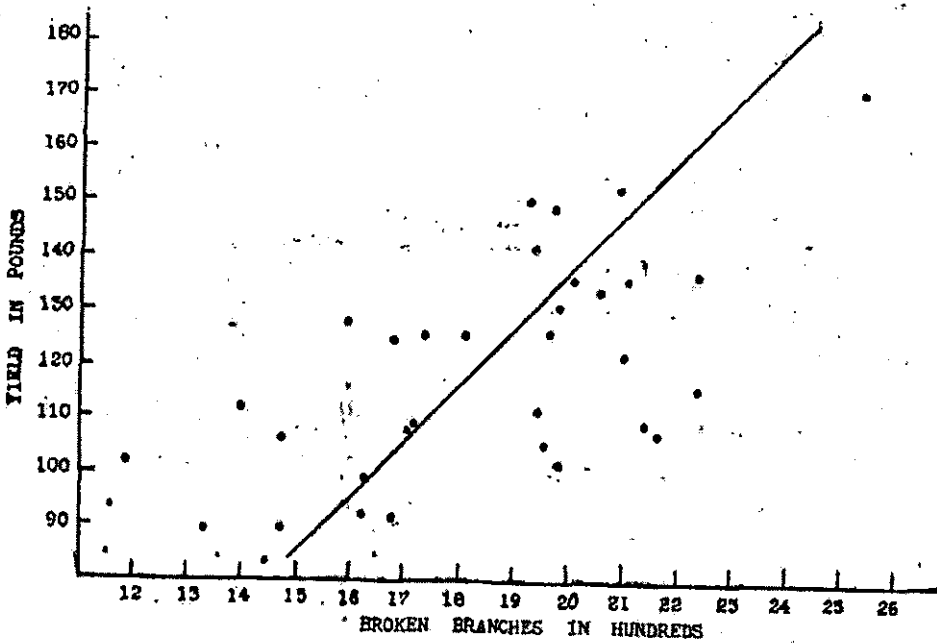


Figure 1.—Showing relationship between yield and number of broken branches in individual plots.

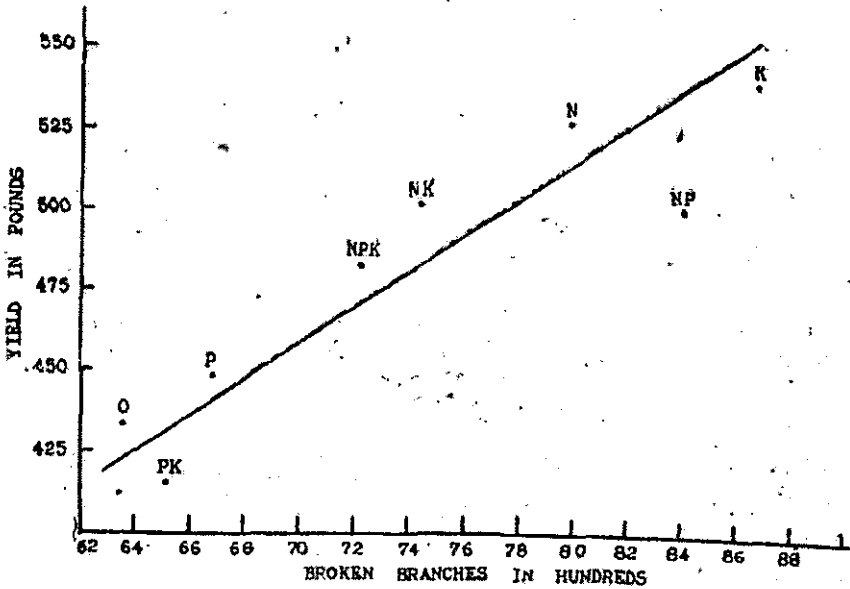


Figure 2.—Showing relationship between yield and breakages, plots being grouped by treatments.

A simple method of comparing all plot results is by expressing the data diagrammatically as in Fig. 1. There, each plot is represented by a dot and the position of the dot is determined by the yield and number of broken branches collected from that plot. The height of the dot, measured vertically and to the scale given on the vertical axis, represents the weight of crop harvested; its distance from the vertical axis, measured to scale horizontally, represents the number of broken branches collected from that plot. Every plot is represented in the diagram. At first inspection it may appear that the dots are scattered in a somewhat haphazard manner, but if one attempts to draw a straight line so that it will pass as close as possible to all dots it will start somewhere near the bottom left-hand corner and slope upwards towards the upper right-hand corner, much as the line given in the figure does. Of course numerous lines can be drawn by eye but they would not all be equally good. The one shown in the figure has been obtained by calculation and it has a definite meaning. It means that if all the dots representing plots were all on that line, not merely near it, every rise of 10 lb. in yield would be accompanied by an increase of 90 in the number of breakages. Any other sloping line can be interpreted in similar terms though each would represent a different number of breakages per increase in yield of 10 lb. The nearer all the dots are to the line the more importance can be attached to the values given by interpretation of the line. As in this instance few dots lie very close to the line and others are more or less distant from it, no great importance can be attached to the values stated above. Nevertheless, the diagram suggests that as the yield increases so does the number of breakages.

So far, particular treatments have not been taken into consideration. As there are four replications of each treatment, the data from plots treated alike may be added together. The totals so obtained are given in Table 1; each treatment result now applies to the area of 4 plots, viz. 0.4 acre. The results can be put into diagrammatic form as in Fig. 2, the letters above each dot indicate the treatment applied to the plots. From the diagram it will be immediately evident that the treatments giving the lowest yields (O, PK and P) have given the smallest number of broken branches, while treatments K, N, and NP giving the highest yields have also suffered the greatest damage. There is little difficulty in drawing a straight line such as the one shown so that it will pass close to all dots. But for the PK and NP results a still better fitting line might be drawn. The line given represents an increase of 180 breaks for every increase of 10 lb. in yield. There can be no doubt from these results that, in general, the larger number of broken branches has been removed from plots giving the higher yields.

The plots which received potash manures alone yielded the largest amount of crop. This does not mean that potash had the greatest effect on yield and breakages. The plots with no manure gave 432.28 lb., and those manured with potash alone gave 540.26. The difference, 108 lb., gives one estimate of the effect of the potash manure. Another, equally valid, is obtained by subtracting the yield of the plots manured with nitrogen only from those which received nitrogen and potash; the difference is - 23.81 lb. In the presence of nitrogen the potash appears to have a detrimental effect, reducing the yield by that amount. A third estimate can be obtained from the P and PK plots, and again the potash had a detrimental effect, viz. - 33.26 lb. For a fourth estimate the NP and NPK plots are used and again the

TABLE 2.

Effect of Nitrogenous, phosphate and potash manures on the yield and damage caused by shot-hole borer

	Yields in lb.				Broken Branches			
	With	Without	Increase	% Increase	With	Without	Increase	% Increase
Nitrogen	2,014.58	1836.94	177.64	9.7	31,035	28,205	2,830	10.0
Phosphate	1,847.95	2003.57	-155.62	-7.8	28,806	30,434	-1,628	-5.3
Potash	1942.81	1908.71	34.10	1.7	29,825	29,415	410	1.4
	Galleries per 400 branches				% Healed Galleries			
	With	Without	Diff.	% Diff.	With	Without	Diff.	
Nitrogen	742.3	758.8	-16.6	-2.2	19.27	18.52	.75	
Phosphate	760.0	741.1	18.9	2.6	19.57	18.22	1.35	
Potash	756.0	745.1	10.9	1.5	17.84	19.95	-2.11	

addition of potash or the presence of nitrogen and phosphate has resulted in a decreased yield, viz. -16.83 lb. Putting these estimates together the total effect of potash is shown to be an increase in yield of only 34.10 lb. It should be noted that all plot results have been used to obtain this value, half of them received potash and the other half did not, so that increase of 34.10 lb. has been obtained from an area of 1.6 acres. The effects of nitrogen and phosphate can be obtained in a similar way. The results affecting yields and breakages are given in Table 2.

Comparisons of the effects of all three manures on yield and breakages are easily made from Table 2, and it is remarkable that whatever effect the manure has on yield, a similar and almost equal effect is observable in the number of breakages. From the table it will be seen that nitrogen, not potash, had the greatest effect in increasing the yield and also in increasing the breakages. These results leave no doubt whatever that the inducement of vigour as measured by yield does *not* lead

to a decrease in the damage caused by shot-hole borer. On the contrary, an increase in yield is accompanied by a corresponding increase in the number of breakages.

Obviously, the breaking of branches cannot of itself lead to an increase in crop; it must have the opposite effect. This becomes evident when the size and quantity of the broken branches are considered. All the branches collected on 5 occasions were weighed, and from the results given in Table 3, it will be seen that the mean weight of 100 branches was 5.77 lb. In all, 59,240 branches were collected from the area during the first two years from pruning, which is equivalent to 18,512.5 per acre, weighing 1,068.17 lb. As 6,000 lb. is a fair weight of prunings removed from an acre of tea during normal pruning operations, it becomes evident that approximately 17.8 per cent. of crop-bearing branches have been lost at some time or other during the two years. That loss may have reduced the cropping capacity of the bushes by as much as 8 or 9 per cent. That the breakage

of branches has caused some loss cannot be doubted. It seems strange, therefore, that the plots which lost most branches nevertheless gave the greatest crops.

The manurial treatments which improved soil fertility would cause an increase of the harvest, but what has here been measured as increase in yield due to treatment is not the true increase that would occur in the absence of shot-hole borer, but only what remains of it after the loss from increased borer damage has been deducted. This may well raise questions concerning the economics of manuring in shot-hole borer infested areas, but we shall not concern ourselves with that problem here. Instead, we may attempt to ascertain why manuring should result in an increase of insect injury.

Green appears to have based his recommendation, already quoted, on the fact that in some galleries "the mouth of the tunnel is invaded by an ingrowth from the vigorous cambial tissues." New wood is then formed, covering up the old wound, and the plant is able to carry on all its functions without interruption." Galleries with plugs in their entrances are now known as *healed* galleries, and it is generally understood that healed galleries are less liable to break than are open galleries, i.e., without plugged entrances. The mere presence of a plug in the gallery entrance is unlikely of itself to strengthen materially the branch at that place and so prevent it breaking. Something more than the healing of a visible wound is required.

So long as beetles are in occupation of a gallery they will keep the gallery entrance open if for no other reason than to facilitate emergence; but when a gallery is vacated the callus growth may block the entrance unhindered. For this reason healed galleries must, as a rule, be older than open galleries. So long as a branch is growing, new wood is laid down just

within the cambium, outside the circular gallery. This new wood strengthens the branch, and as a healed gallery is older, it would follow, other things being equal, that it has more young wood around it and the branch is in consequence stronger there than at a place where the gallery has been more recently bored. The branch therefore becomes less liable to break at a healed gallery as will be demonstrated later.

At the end of the second year, on September 4th, October 2nd and October 30th, 1942, all the broken branches were removed to the laboratory for detailed examination. The data collected have been amalgamated as though taken at one time, viz. on October 2nd, the mid-date of the three, and as being representative of conditions at that time. For that reason October 2nd was taken to be the end of the second year though one month late. The results of these examinations are given in Table I.

In all, 4,727 galleries, inclusive of those at the break were examined, and 897, i.e., 19 per cent. of them were healed. If every gallery were equally liable to break we should expect about 19 per cent. of the galleries at the fractures also to be healed. Actually, there were 2,510 broken branches, but only 156 or 6.2 per cent. had broken at healed galleries. The observed number of healed galleries at the fractures is much smaller than was expected if healed and open galleries are equally liable to break, so it becomes obvious that healed galleries are less liable to break than are open galleries. It would, however, be better to state the same fact in other words, namely, that the risk of a branch breaking at a shot-hole borer gallery decreases as the age of the gallery increases.

The rate of decrease in the risk of breakage will depend, at least in part, upon the rate at which new wood is being formed. It has been assumed, perhaps rightly that

TABLE 3  
Number and Weight of Broken Branches

Collection	Date 1942	Branches No.	Weight lb.	Weight per 100 in lb.
1	January 31	2,689	169.78	6.31
2	February 7	1,183	81.51	6.89
17	May 22	1,722	90.74	5.27
32	September 4	1,162	52.66	4.53
36	October 2	643	31.92	4.96
Total Data		7,399	426.61	5.77.

the more vigorous a bush is, the more rapidly will new wood be formed and the risk of breakage be decreased. There appears therefore good logical grounds for Green's recommendation that the best way of decreasing damage by shot-hole borer is by improving the vigour of the bushes. Nevertheless, the results of this experiment suggest that there must be a fallacy in the argument somewhere.

What assumptions have been made, though unstated, in the argument? First, it is assumed that an improvement in the vigour of bushes will not make them more or less attractive to the beetle. If the bushes become more attractive, more galleries are made and the stems have more weak places in them. Increased damage would not then be surprising. Second, there is the assumption the wood laid down by a vigorous bush will be equally strong as that laid down more slowly by less vigorous specimens. If it is not, the greater number of breakages would occur in those plots with the weaker wood when the number of galleries

is the same in all plots. The observed results of this experiment could be explained (1) if the manurial treatment resulted in an increased attack by the beetles or (2) if some treatments made the branches more fragile.

We are now confronted with the questions (1) Were there more borer galleries in some plots than in others? and (2) Were the branches in some plots more fragile than in others? Neither of these questions can be answered with any certainty.

To count all the galleries in the experimental plots would be an impossible task. Jepson counted the galleries, *in situ*, of a number of bushes selected at random—an arduous task and one liable to considerable error. Another method<sup>(1)</sup> is to prune the selected bushes and count the galleries in the prunings. This has the advantage of increased accuracy as the presence of every gallery can be proved, but it has an obvious disadvantage in that it cannot be used in plots from which accurate yield figures are required. In this experiment, broken branches only

were examined on three occasions as already stated, and the galleries in them counted and classified.

A moment's consideration will show that the largest number of galleries is most likely to be found in the branches from the plot with most breakages, not because the galleries are most numerous in that plot but because there are more broken branches to search. This can be corrected by expressing the number of galleries as the number per 100 branches, as shown in Table 1. If such estimates are accepted as a fair measure of the number of galleries in each plot, it must be borne in mind when making comparisons, that all plots have the same number of branches per bush is assumed and nothing is known of the galleries in unbroken branches.

To facilitate comparisons, the effects of the manures on gallery numbers have been calculated in the same manner as for their effects on yield and breakages. The results are shown in Table 2 from which may be seen that the effects are very small, almost negligible, and the values show no obvious relationship to yields. We certainly cannot attribute the increased number of breakages in the higher yielding plots to an increased number of galleries in their branches. There may be markedly more galleries in some plots than others, but if so, this method of estimation does not detect the differences.

The fragility of branches, *i.e.*, their tendency to break, is also difficult to estimate directly. The percentage of galleries that have healed can be determined fairly accurately; the estimate does not depend upon the number of branches used but upon the total galleries counted. It has been assumed that the percentage

of healed galleries affords a measure of the rate of healing—the higher the percentage, the faster the galleries must be healing. As healed galleries are less liable to break than galleries with open entrances it should follow that by speeding up the healing process fewer breakages should result.

The percentages of healed galleries in the different plots have been examined to determine to what extent the manures have speeded up healing. The effect of manuring with nitrogen has been to increase the percentage of healing by less than one per cent., though its effect on breakages was to increase the number of broken branches by nearly 10 per cent. There is obviously no relationship between the number of fractured branches and the rate of healing or growth as measured by the percentage of galleries healed as may be seen from Table 2.

The results of the experiment may now be briefly summarised. The results show that the greatest number of broken branches are found in the plots giving the highest yields. Nitrogen caused the greatest increase in yield; it also caused the greatest increase in insect damage. These results are clear and beyond doubt. No satisfactory explanation however can be offered as to the way in which yield and breakages are linked together. The results are in conflict with prevailing opinion, but so far as the writer is aware, they are the first published records of yield and breakages resulting from shot-hole borer attack in comparable plots. Admittedly, confirmation is required from other experiments. This experiment is being continued during its third year from pruning and it is hoped that the results will throw further light on the problem.

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