

SHOT-HOLE BORER DAMAGE AND TEA YIELDS

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In a previous article the writer (Gadd 1943) asked the question: "Does manuring reduce the damage caused by Shot-hole borer?" and presented data from a manurial experiment in the Passara district indicating that the answer was in the negative. The experiment there described was continued for a third year, and the data collected during that further period October, 1942 to September, 1943 are now presented for discussion. (Table 1.)

Manures were applied in March, 1943 at the same rate as previously.

sists of a main branch together with all the twiggy growth it carries. The first collection was made on January 31st, 1942, when the tea was 16 months old from last pruning. On that date 2,689 broken branches were collected from the whole experimental area (3.2 acres). Thereafter the broken branches were collected weekly for 83 weeks until September 2nd, 1943, when the experiment ceased at the end of a 3-year plucking cycle. Records of these collections are given in a simplified form as Fig. 1. In February, 1942, 4,821 broken branches were collected from the 3.2 acres

TABLE I

Yield and number of broken branches during the third year from pruning and for the whole cycle, from 3.2 acres

Treatment	Yield in lb.		Broken Branches	
	3rd year	Total	3rd year	Total
O	... 226.36	658.64	1898	8,249
N	... 297.15	824.56	2,334	10,318
P	... 243.13	691.95	2,228	8,900
NP	... 283.84	734.04	2,203	10,611
K	... 301.32	841.60	2,697	11,364
NK	... 286.33	789.93	2,187	9,619
PK	... 210.67	626.23	1,910	8,425
NPK	... 270.44	753.81	2,317	9,528
Total	2,119.24	5,970.76	17,774	77,014

During the course of the experiment the damage caused by shot-hole borer was estimated by counting the number of branches broken in each plot after each pluck, i.e., at weekly intervals. What is here termed a "broken branch" refers to that part of the woody frame which comes away when a branch is broken; each con-

after four plucks in that month. By a simple calculation a value of 377 is obtained for the mean number of breakages per acre per week for the month of February, 1942. Other values were obtained similarly for the other months of the experiment and they are shown graphically in Fig. 1. It will be seen that the mean weekly number

of breakages increased steadily until June, 1942 when a peak, 765 breaks per acre was reached. Afterwards, the number of breakages decreased until March, 1943 and then remained fairly constant at a low level of about 80 breaks per acre per week until

Damage was at a maximum in June, 1942 (765 breaks per week per acre) and near a minimum in June, 1943 (82 breaks). Are we to interpret those observations to mean that shot-hole borer beetles were less numerous in the district in June, 1943 than in 1942? General observations give no

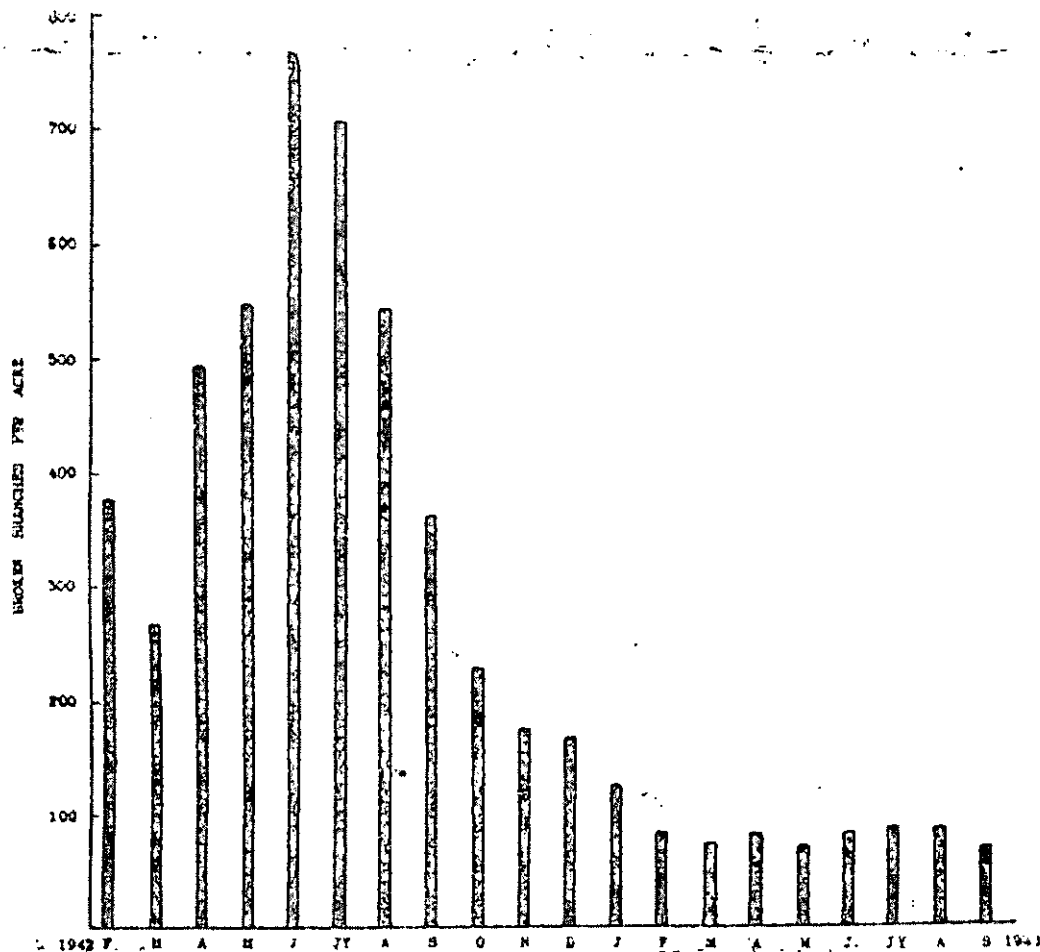


Fig. 1.—The mean number of broken branches per acre collected weekly, after plucking during the period February, 1942 to September, 1943. A three-year plucking cycle terminated in September, 1943.

the end of the experiment. The maximum damage therefore occurred during the second year from pruning which ended in September, 1942.

support for such an interpretation, as throughout the district shot-hole borer damage in 1943 was much the same as in 1942.

The writer (Gadd 1941 pp. 135-137) first drew attention to the fact that shot-hole borer attack, although it may not cease entirely, is very materially reduced during the third year from pruning. His evidence was based largely upon an analysis of data collected by Jepson (Jepson and Gadd 1925) over a pruning cycle September, 1920 to November, 1923. Later, (Gadd 1942 p. 32) data from a plucking experiment during the period December, 1938 to December, 1941 indicated a similar conclusion. When, therefore, the data collected during the present experiment showed that insect damage had begun to decrease towards the end of the second year from pruning, it was considered advisable to extend the experiment for a third year, if for no other reason than to ascertain whether the decrease would continue as expected. It has already been shown that the amount of damage continued to decrease during the first half and then remained at a low level during the second half of the third year from pruning. The decrease in shot-hole borer damage in the experimental area during 1943 must therefore be attributed to the bushes being in their third year from pruning; and *not* to the weather or other external conditions being unfavourable for the beetles.

The loss of branches from tea bushes in plucking must result in a loss of crop, and although such loss cannot be estimated it is probable that it is roughly proportional to the number of branches lost through breakage. During the whole 3-year cycle 77,014 broken branches were collected and removed from the whole area. That number is equivalent to 24,067 per acre or 7.4 branches per bush. During the third year 17,774, (*i.e.*, 555 per acre) branches were broken as compared with 59,240, (*i.e.*, 1,851 per acre) previously, though mainly in the second year. Breakages in the third year were less than one-third of the number broken in the second year. During the

last six months of the cycle, March to August, 1943, the mean number of broken branches per pluck per acre was 82 as compared with 558 during the same months of the previous year; the loss in crop during the last six months of the cycle resulting from shot-hole borer attack was therefore only about one-seventh of that occurring in the later half of the second year.

Some idea of the extent of the damage may be obtained from Table 2 in which the weights of all broken branches collected on ten occasions are given, together with diameter measurements of the branches at the breaks.

The broken branches were weighed fresh, immediately after collection. In order that the results may be comparable the mean weights per 100 branches for each occasion are given in the last column of Table 2. The mean weights varied somewhat from time to time as might be expected; on the average the branches were somewhat heavier in 1942 than in 1943. The average from all occasions was 5.27 lb. per 100 branches and by applying that value to all the branches collected during the experiment (77,014) it may be calculated that 1,268 lb. of branches were removed from each acre during the 3-year plucking cycle. The prunings from clean pruned bushes on St. Coombs (where shot-hole borer does not occur) at the end of a 3-year cycle weigh, on the average, 8,000 lb. per acre (dry weight) from which a rough picture of the extent of the damage may be visualised.

Diameter measurements of broken branches at the fracture were taken with a gauge. A branch which would not slip into the slot of the gauge 3-sixteenths-of-an-inch wide but would enter the next larger slot was recorded as 4-sixteenths; its true diameter of course might be anything between 3 and 4 sixteenths-of-an-

inch. The necessary correction was therefore made when calculating the mean diameters given in Table 2. During 1943 the broken branches were but slightly thicker than in 1942 (0.25 in. as compared with 0.23 in.) This difference, though small,

every broken branch had a gallery at the fracture. The percentages of such galleries as were occupied by beetles, pupae, larvae or eggs are given in Table 3. It will be seen that the percentage of occupied galleries fell from 10.9 in Septem-

TABLE 2
Weight and diameter at the fracture of broken branches on 10 occasions.

Collection No.	Date	No. of Branches	Weight lb.	Mean diameter in sixteenths-of-an-inch.										Mean diameter inches	Mean weight per 100 branches lb.
				3	4	5	6	7	8	9	10				
1942															
1	January 31	2,689*	169.78	233	256	223	100	13	5	0	1	0.24	6.31		
17	May 22	1,722	90.74	777	536	313	84	12	—	—	—	0.21	5.27		
32	September 4	1,162	52.64	390	327	287	134	18	4	2	—	0.23	4.53		
36	October 2	643	31.92	188	191	160	87	16	1	—	—	0.24	4.96		
40	October 30	705	30.40	186	195	191	107	23	2	1	—	0.25	4.31		
Total		6,921	375.57	1,774	1,505	1,174	512	82	12	3	1	0.23	5.43		
1943															
64	April 13	257	11.22	28	52	90	68	18	1	—	—	0.28	4.37		
70	May 27	216	12.60	41	63	65	40	7	—	—	—	0.25	5.83		
74	June 25	260	9.71	56	116	61	23	4	—	—	—	0.23	3.73		
78	July 22	328	13.72	92	103	88	41	4	—	—	—	0.23	4.18		
82	August 19	258	11.78	38	81	80	50	9	—	—	—	0.26	4.57		
Total		1,319	59.03	255	415	384	222	42	1	—	—	0.25	4.48		
Grand Total		8,240	434.51	2,029	1,920	1,558	734	124	13	3	1	0.23	5.27		

* The diameters of only 831 were measured.

is probably real as the table shows that in 1942 the 3-sixteenth inch class was the largest, whereas in 1943 there were more branches in the 4 and 5-sixteenth inch classes than in the 3-sixteenth inch class.

On eight occasions, enumerated in Table 3 the broken branches were studied in greater detail. Every gallery was examined and classified as occupied or empty; the contents of the occupied galleries were counted. As all breakages had occurred at the sites of galleries

ber. 1942 to 1.9 in April, 1943. This was a period during which the number of breakages in the plots was decreasing.

Before considering any possible connection between these two observations it must be pointed out that as the galleries under consideration were broken, it is possible that some of their contents were spilled at the time the branches broke. If all the contents of a gallery were spilled the gallery would then be counted as empty, and the percentage of occupied

galleries would in consequence be decreased. Such accidents may give false values for the percentage occupied but they are hardly likely to affect the trend of successive values. Galleries in the broken branches other than those situated at the fractures were opened to determine their contents. The results are shown in Table 3 under the heading 'Galleries in Branch.' Again it may be seen that the percentage of occupied galleries gradually decreased until May, but later increased again. The trend of these results follow fairly closely those obtained from galleries at the fracture though the actual values are higher.

then be nil. The observed progressive fall in the percentage of occupied galleries to the low figure of 7.4 in the undamaged part of the branch must indicate a marked decrease in the number of new galleries being made. If so, the later rise in the percentage to 19.8 in July must indicate a renewal of the attack. This period of new invasion, April to July, 1943, corresponds roughly to the period of maximum attack in the previous year and so may be a seasonal effect. Judging from the number of breakages this late attack did relatively little damage.

TABLE 3
Galleries in Broken Branches

Collection No.	Date	Galleries at the fractures.			Galleries in Branch			Mean Content	Galleries per 100 branches	
		Total	Occupied	Occupied %	Total	Occupied	Occupied %			
1942										
32	September	4	1,162	127	10.9	10.16	278	27.4	2.3	87
36	October	2	643	56	8.7	606	113	18.6	2.9	94
40	October	30	705	43	6.1	595	104	17.5	2.8	84
1943										
64	April	13	257	5	1.9	308	25	8.1	3.3	120
70	May	27	216	23	10.6	121	9	7.4	1.0	56
74	June	25	260	30	11.5	111	18	16.2	4.0	43
78	July	22	328	40	12.2	175	35	19.8	2.5	53
82	August	19	258	34	13.2	155	29	18.7	3.8	60

Do these observations lend any support to the statement made earlier, that the diminution in the number of broken branches after June, 1942 was due to cessation of attack by the beetles? If attack ceased completely on a given date, no more new galleries would be made, but some of the existing galleries would contain beetles and their young. In the course of time these galleries would be vacated and eventually all would be empty. The percentage of occupied galleries would

The mean contents of the occupied galleries on eight occasions are also shown in Table 3. On May 27th, when the percentage of occupied galleries in the broken branches was at a minimum the mean content of the occupied galleries was 1.0. As the parent female remains in the galleries to tend the young the value 1.0 indicates that there were no young in any of the galleries examined at that time. That was the only occasion when neither eggs nor larvae nor pupae were found.

Individual galleries may contain as many as 30 or more young, but an average derived from a number of galleries chosen at random would never give a value as high as that. When studying the life history of the beetle it was found that galleries 36 to 49 days old, on the average, contained 12.6 young (Gadd 1941a); galleries younger than 36 days and older than 49 days had smaller mean contents. Galleries collected from the field are of very mixed ages and consequently vary greatly as regards their contents. At a time when galleries were increasing rapidly in number their mean contents (of 100 or more occupied galleries) ranged from 5.0 to 7.3 (Gadd 1942) and the writer is of the opinion that such values will be obtained only when conditions are favourable for the beetles. Under less favourable conditions the mean content of occupied galleries will tend to be lower.

The mean content of occupied galleries therefore depends upon two main factors (1) the mean age of the galleries and (2) the conditions within the gallery. It is impossible to ascertain the mean age of galleries collected at random from the field, so it may not be possible always to attribute a low mean content to the proper cause when the number of galleries examined is small. As in no instance do the values given in Table 3 exceed the value 4.0 it seems probable that the low values are indicative of somewhat unfavourable conditions in the galleries during the period September, 1942 to August, 1943.

The shot-hole borer beetles of tea spend practically the whole of their lives within galleries in living branches. In such a position they are well protected against enemies and against sudden changes of temperature and humidity brought about by the weather. It may not be obvious therefore why the beetles

cannot breed equally well throughout the year in a tropical climate. What then are the unfavourable conditions referred to above?

The beetle sometimes attacks a stem by boring a gallery and then vacates it before completion. This seems to happen most frequently when young stems are entered. Possibly the beetle finds the wood too sappy and the gallery too damp or the physical conditions unsatisfactory in other respects. The reason for the behaviour, however, is not known. When a gallery is completed satisfactorily the female plants a fungus (ambrosia) on its walls and her young later feed on the fungus. Much depends upon the growth of this fungus; if the growth is poor the food supply may be short and the size of the family is reduced accordingly. The fungus gets its food from the tea bush and is in fact dependent on the bush for all its requirements. A small change in the life processes of the bush, resulting from any cause, may therefore affect materially the growth of the fungus and indirectly the size of the beetle brood. When large families are raised the numerous females, when adult, emerge and make many new galleries for themselves; but when conditions are adverse the families are small; few females emerge and few new galleries are found.

On this hypothesis it would appear that during the early part of the second year from pruning, conditions are at an optimum for the beetles, the population increases rapidly and numerous branches break in consequence. Later an adverse change sets in and the beetle population is gradually reduced but does not disappear entirely. The beetles are there, but in relatively small numbers ready to take advantage of any favourable change of conditions. This gross change from favourable to unfavourable conditions is gradual,

and is undoubtedly associated with physiological and biochemical changes within the tea bush, possibly brought about by plucking. What those changes are cannot be defined at present but they probably react on the ambrosia fungus.

In the previous article in which the results of this experiment to the end of the second year from pruning were discussed, it was shown that the plots which gave the higher yields, in general suffered the greater damage from the boring beetles. This fact had not previously been demonstrated, so it may be well, before proceeding further, to ascertain whether the data collected during the third year demonstrates a similar correlation between yield and breakages.

In Fig. 2 are shown graphically the yields and number of broken branches collected from the different manurial plots during the third year from pruning. Each dot shows both the yield in lb. and the number of broken branches collected from four plots undergoing a particular manurial treatment indicated by a letter. The plots manured with potash alone (K) gave the highest yield, 301 lb., and the largest number of breakages, 842 (Table 1); they are represented by the dot K in the top right hand corner of the diagram. At the other extreme the plots receiving no manure, (O) and phosphate and potash together (PK) gave the lowest yields and also the smallest numbers of breakages. The dots O and PK are in the bottom left hand corner of the diagram. A straight line has been drawn to pass as near as possible to all eight dots in the diagram. It starts near the bottom left hand corner, passes through a point representing the mean of all results (265 lb. and 746 breaks) and continues towards the top right hand corner. Other lines might be drawn by eye but they would all start near the bottom left corner and pass towards the top right corner.

Such lines represent estimates of the effect of changes in one character (say yield) on the other (breakages). The line shown represents an increase by 62 breaks for every increase of 10 lb. in yield. The figure shows therefore that those plots which had the larger yields during the third year from pruning had also on the average the greater number of broken branches despite the fact that the general level of shot-hole borer attack had fallen considerably.

It will now be evident that the amount of damage occurring in a tea field as a result of shot-hole borer attack depends upon at least two factors: The first and more important is the age of the bush from pruning. The second is the degree of fertility of the field; its effect is relatively small as compared with the effect of age.

The fertility of an experimental plot is measured by the weight of crop harvested; the plot with the highest yield may be said to be the most fertile. Total fertility is made up of the initial fertility plus that added by way of manures. One of the problems in agricultural experimentation is to separate the effect of manuring from that resulting from initial fertility. Table 1 shows that 4 plots receiving potash manures only, yielded 301.32 lb. of tea during the third year, whereas 4 plots receiving no manure gave only 226.36 lb. The difference 74.96 is one estimate of the beneficial effect of potash manures on yield, but as shown in the previous article, 3 other estimates, equally valid, may be made. The truest picture is obtained by using all four estimates which brings every plot of the experiment into consideration. In this way the effects of nitrogen, phosphate and potash can be determined; such estimates are shown in Table 4, together with similar estimates of the manurial effects on breakages.

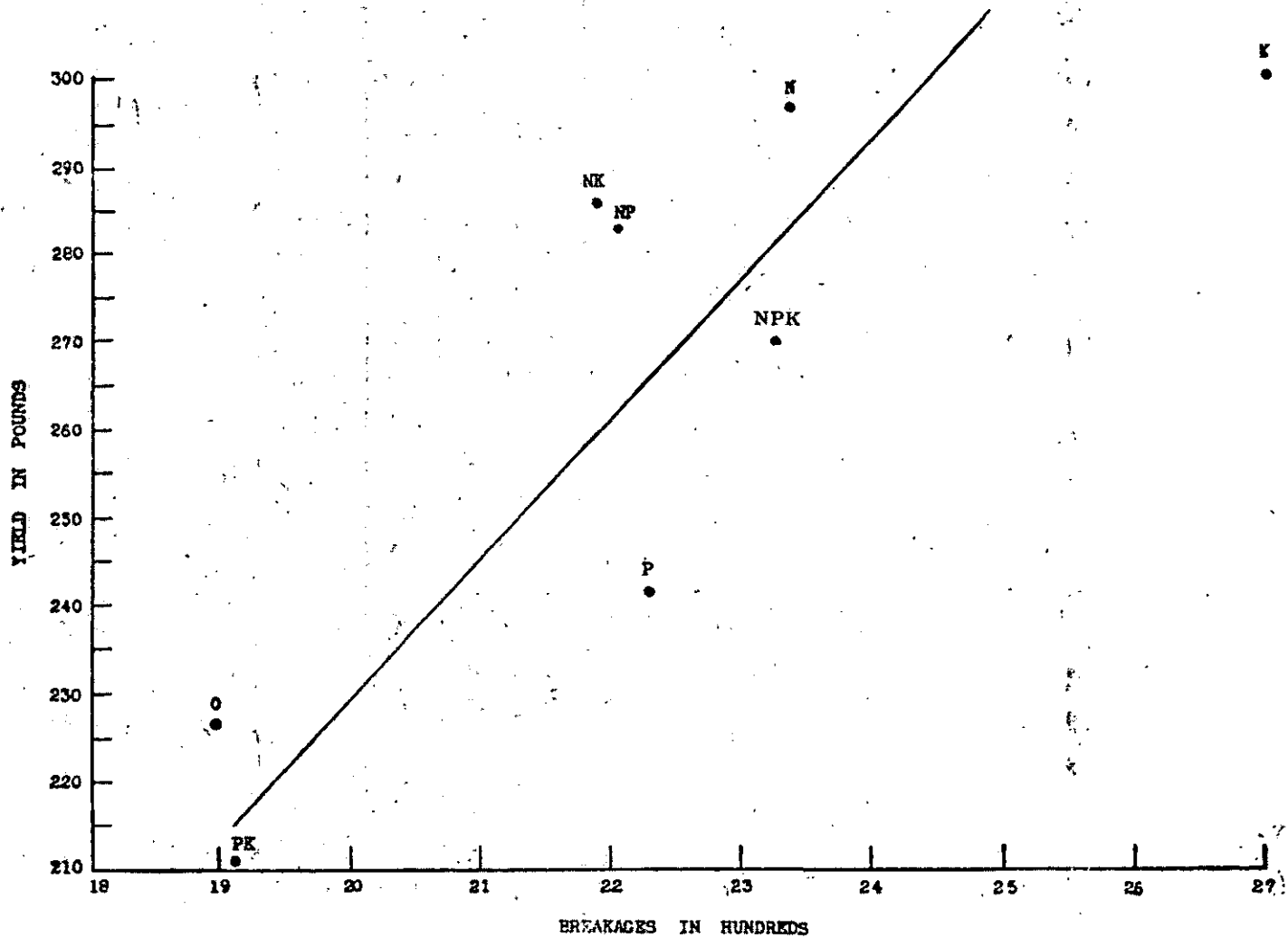


Fig. 2—Diagram showing the relationship between yield and number of broken branches during the third year of a plucking cycle.

Manurial experiments in areas free from shot-hole borer, such as St. Coombs, have always demonstrated a significant increase in crop as a result of nitrogenous manuring. In infested areas, such as the present experimental block, it has not been possible to demonstrate a similar response so clearly. In fact a significant response to nitrogen was demonstrated for the first time in this experimental block in 1943, during the third year of the cycle (Eden 1944). Incidentally this was the first time that this experimental area had been plucked over a 3-year period, previously the plots had been plucked on a 2-year cycle. The question naturally arises whether shot-hole borer was in any way responsible for the earlier failures to

of plots the observed increase of yield in the manured plots would have been greater. In the third year from pruning the insect damage in all plots was considerably less than in the previous year and the N. manured plots suffered only 3.5 per cent more damage than those receiving no nitrogen. Yields were maintained at a relatively high level and there was an increase of 15.9 per cent in the plots receiving nitrogen as compared with those receiving none. This larger increase proved to be of statistical significance. It seems probable therefore that the reduced amount of borer damage, both total and relative to the plots without nitrogen enabled a significant increase in yield to be demonstrated.

TABLE 4

Effect of Nitrogenous Phosphate and Potash Manures on the Yield and Damage caused by Shot-hole borer during the third year from pruning. Each result relates to 1.6 acres.

	Yield in lb.		Increase	%	Broken Branches			%
	With	Without			With	Without	Increase	
Nitrogen	1,137.76	981.48	156.28	15.9	9,041	8,733	308	3.5
Phosphate	1,008.08	1,111.16	-103.08	-9.3	8,658	9,116	-458	-5.0
Potash	1,068.76	1,050.48	18.28	1.7	9,111	8,663	448	5.2

demonstrate a significant response from manuring. Although this question cannot be answered with any certainty it seems probable that shot-hole borer was at least in part responsible.

At the end of the second year from pruning the plots receiving nitrogenous manure gave 9.7 per cent more crop, but at the same time suffered 10 per cent more damage than the plots receiving no nitrogen. The increase in crop proved too small to be of statistical significance. As shot-hole borer damage leads to loss in crop it seems fair to assume that had the 'damage' been equal in both series

A significant response in yield to nitrogenous manures was the only one expected. It may be seen from Table 4 that potash gave a small but statistically insignificant increase in yield and also in insect damage. Phosphates appear to have decreased borer attack slightly but they also depressed the yield somewhat. It is evident therefore that manuring has not proved of any value in controlling shot-hole borer attack. Any increase in crop following manuring has been accompanied by an increase in borer damage. Only when yield was depressed was there any decrease in borer damage.

The effect of manuring on borer damage is very small compared with the effect of the bush's age from pruning. At the end of the second year breakages during plucking are numerous so it is to be expected that if the bushes are pruned then, breaks during pruning will also be numerous. During the third year the beetle attack falls to a low level, few new galleries are made and consequently breakages during plucking are few. Undoubtedly the bushes benefit from the improved conditions and less damage is to be expected from pruning. The question arises whether the extension of the pruning cycle in shot-hole borer areas is sound economically.

The prolongation of a pruning cycle is usually decided upon after consideration of factors other than the mere prevalence of shot-hole borer. Each case has to be considered on its own merits and the question may well be asked "Did the prolongation of the pruning cycle in this instance prove to be economically sound?" That question can be answered definitely from

an examination of the yields. During the first two years (actually 25 months) the yield from the whole experimental area was 3,852 lb. or say an average of 1,926 lb. per year. In the third year (11 months) the yield was 2,119 lb. which exceeds the average for the first two years by 193 lb., i.e., by 60 lb. per acre. Obviously, an increased yield was obtained as a result of the prolongation of the pruning cycle in this instance, but it must not be assumed that similar benefits will accrue in all cases. These results suggest that the prolongation of the plucking cycle beyond two years may be advantageous in some shot-hole borer infested areas.

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