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The Distribution of Shot-Hole Borer, *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae), Across Tea-Growing Areas in Sri Lanka: A Reassessment

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ABSTRACT

Shot-hole borer (SHB), *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae), is the most serious pest of tea in Sri Lanka. It has become a problem in tea grown in the range 150 - 1400 m above sea level, but it is found outside this range as well. A survey was carried out to ascertain the current status of the infestation levels across tea-growing areas. The results reveal that there is an ascending and descending gradation of damage across an altitudinal range from almost near sea level to about 1400 m.

The damage is highly variable in the range from near sea level to about 600 m. Consistent and high infestation levels are seen in the range 600 – 1200 m, but variation is observed above 1200 m.

These results suggest that 1400 m may be taken as the upper limit of the present distribution of shot-hole borer and the damage caused by it. The infestation levels within major tea-growing regions are discussed.

Key words: damage, altitude, distribution, tea, *Xyleborus*

INTRODUCTION

The shot-hole borer, *Xyleborus fornicatus* Eichh., was first encountered at Craighead Estate, Nawalapitiya (Gadd, 1947; Austin, 1956), and since then various control measures have been suggested to curtail the damage caused by this serious perennial pest. It is still rated as an important pest of tea, warranting expensive management strategies.

The pest has gained a foothold in almost all the tea-growing areas, and there is growing concern that the pest is now on the verge of expanding its present range of distribution to areas previously free of the problem, and becoming a threat to plantations in those areas.

As the density and extent of pest populations are strongly influenced by variations in temperature and other climatic variables, they are likely to be the first to exhibit some modification in response to climate change (Sutherst, 1995). A possible scenario under the phenomenon of global warming would therefore be the range extension of major pests like shot-hole borer (Danthanarayana, 2003).

A survey, covering tea plantations or estates in all the tea-growing areas, has been carried out in order to determine the present distribution and abundance (in terms of the level of infestation) of shot-hole borer in the tea-growing areas. The results of the survey are presented here in terms of the level of infestation in all major tea-growing areas, which could be used as baseline information for future work.

The population levels of shot-hole borer are known to vary with time (Cranham, 1963; Calnaido and Thirugnasundaran, 1966; Sivapalan, 1977), but the damage it causes is cumulative over the pruning-cycle, and the damage parameters can give an adequate representation of the current situation of the problem.

MATERIALS AND METHODS

The sampling location is the estate, and all the estates in a given region have been sampled. A particular region might consist of one or more districts, and many estates might be contained within districts (Table 1).

Table 1. The number of estates sampled in major tea-growing districts (see also Fig. 1)

Districts that grow tea	Major tea growing regions Sampled	Number of estates
Badulla	Mid country dry zone	62
Kandy/Matale/Kegalle	Mid country wet zone	55
Ratnapura/Kalutara/Colombo	Low country I	68
Matara	Low country II	14
Galle	Low country III	13
Nuwera Eliya	Up country	50

At each sampling site or estate, 100 primary branches or stems of, 30 cm in length were removed from randomly-selected bushes (one per bush), covering an extent of a hectare. To get a more detailed assessment, this method has been adapted by (Vitarana 2003) and replaces the standard-unit method described previously (Judenko, 1958; Anon, 1972, 1985).

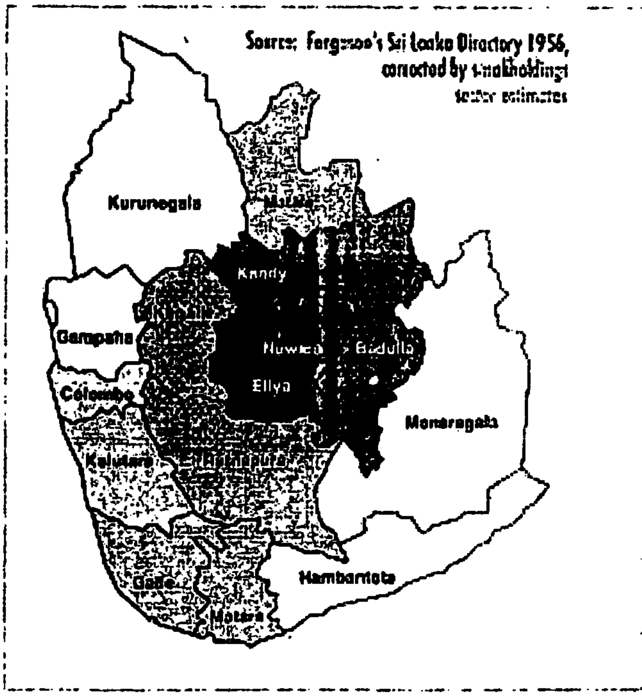


Figure 1: Districts that grow tea (shaded only) in Sri Lanka. The major regions for which the districts come under are Low country – I (Ratnapura, Kalutara and Colombo), Low country – II (Matara), Low country - III (Galle), Mid country wet zone (Kandy, Matale and Kegalle) and Mid country dry zone (Badulla) and Up country (Nuwera Eliya) (source: indicated in the figure)

Fields of TRI 2025, the commonly-grown tea Cultivars, which were due for pruning were selected for sampling, based on information provided by growers, especially in relation to those fields known to have suffered previous shot-hole borer attacks.

Samples were collected, labeled and brought to the laboratory in polythene bags. The bags were split open and the following details recorded.

1. Number of infested stems: Regardless of whether a stem has just one gallery or a number of galleries, it is considered as a single infested stem.

2. Number of galleries: the total of open and healed galleries in each stem of a sample. Open galleries are those open externally. Healed galleries have external openings, which are healed but are intact internally.

Computation of damage parameters

Based on the recorded data, the following parameters were computed for each sampling site.

1. Percentage of infested stems = number of infested or galleried stems/total no. of stems x 100

2. Average number of galleries per stem = total number of galleries (open + healed) / total number of stems (n = 100 x 30-cm lengths).

RESULTS

The distribution of shot-hole borer damage over tea-growing areas is presented in terms of two damage parameters: (1) the percentage of infested stems, and (2) the average number of galleries per stem (30-cm lengths).

1. Distribution of damage levels within the mid-country dry zone (the Badulla District)

In the mid-country dry zone (the Uva), more than 77% of the estates had the highest infestation levels (91-100%), as expressed by the percentage of infested stems in the sample. Eleven percent of the estates were in the second-highest category of 81-90%. Three percent of the estates showed infestation levels below 10%, and 2% of the estates, which represent those in the higher elevations within the region, showed infestation levels of 31-40% and 61-70% (Fig. 2 c).

On the other hand, the average number of galleries per stem showed a pattern somewhat akin to a normal distribution, with a mode at the 4.1-5.0 category (Fig. 3 b). A significant observation is that the instances where extremely high numbers of galleries are observed in the 30-cm stems were in the range of 7-9 galleries on average (Fig. 3 b).

2. Distribution of damage levels within the mid-country wet zone (the Kandy, Matale and Kegalle Districts)

The distribution of the damage parameter (percentage infested stems) showed a positively-skewed distribution, where 64% of the estates showed infestation levels of 91-100%. Twenty-four percent of the estates showed infestation levels of 81-90%. Seven percent of estates were in the range of 71-80%. Similar to the situation in the mid country dry zone, the other categories are not well represented by estates in this region, except that a low percentage (5%) of the estates had infestation levels in the lowest category, 0-10% (Fig. 2 b).

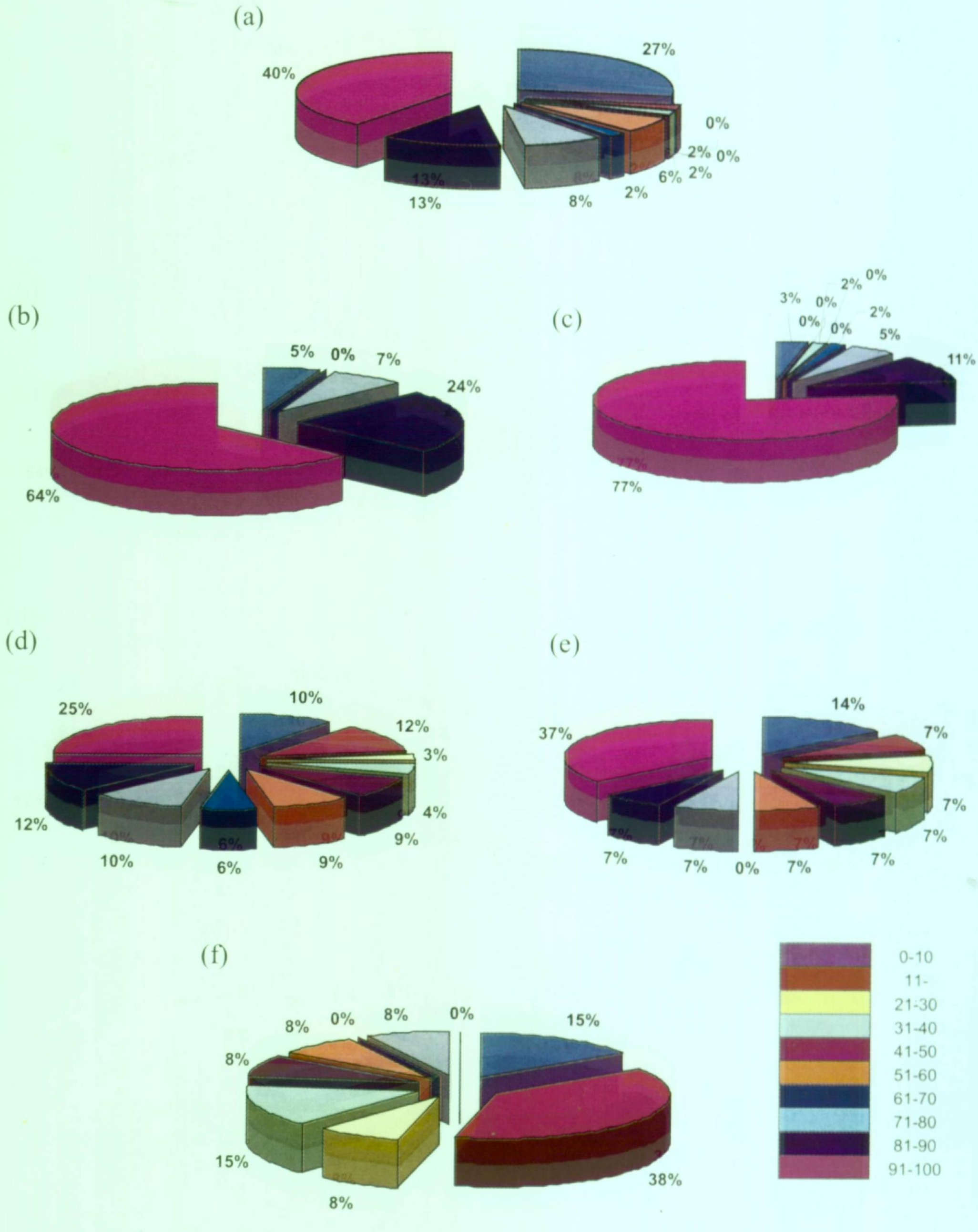


Figure 2: The percentage distribution of the damage as expressed by the percentage infested stems in the sample in (a) Up country (b) Mid country wet zone (c) Mid country dry zone (d) Low country (I) (e) Low country (II) and (f) Low country (III).

The distribution of the damage parameter, the average number of galleries per stem, showed a trend somewhat akin to the normal distribution with a mode at the category 4.1-5.0 (Fig. 3 c). This was followed by the category 3.1-4.0 with a very similar mode.

The distribution and the intensity of damage, both in terms of the damage parameters, suggest the presence of severe infestation in the mid-country wet zone, which is very similar to what is observed in the mid-country dry zone.

3. Distribution of damage levels within the up-country (the Nuwara Eliya District)

In the up-country region, the distribution pattern shows a somewhat different trend. This is due in part to the attitudinal effects within the region; this is discussed later.

Forty percent of the estates showed infestation levels of 91-100%, with 27% in the lowest category of 0-10%. Thirteen percent of the estates were in the range 81-90%, followed by 6% in the 51-60% range (Fig. 2 a).

On the other hand, the average number of galleries, across the scale, is well represented by estates with a mode in the lowest category of 0-1.0 (Fig. 3 a). The next highest representation is in the category of 5.1-6.0. All, except the last two categories of 8.1-9.0 and of 9.1-10.0, are represented by estates with 4 -17%.

4. Distribution of damage levels within the low country (I) (Ratnapura, Kalutara and Colombo Districts)

All categories of the damage parameter (percentage infested stems) are well represented by data, similar to that of the up-country data. There are two modes that can be recognized in the distribution. Ten percent and 12% of the estates are at the lowest two categories of 0-10% and 11-20%, respectively, while 12% and 25% of the estates are at the highest two categories of 81-90% and 91-100%, respectively (Fig. 2 d).

The average number of galleries per stem, on the other hand, shows a negatively-skewed distribution across the scale of 0-10.0 (Fig. 3 d). Forty-one percent of the estates were in the lowest category of 0-1.0 followed by a gradual decrease along the categories. The categories, 7.1–8.0 and 9.1-10.0, are not represented.

5. Distribution of damage levels within the low country (II) (Matara district)

The distribution shows that the damage parameter (percentage infested stems) is concentrated in the lowest and highest categories, where 14% and 36% of the estates were in the lowest category of 0-10%, and the highest category of 91-100%, respectively. All the other categories, except 61-70% where no estate was represented, are represented by just one estate each (Fig. 2 e). The presence of damage levels at either

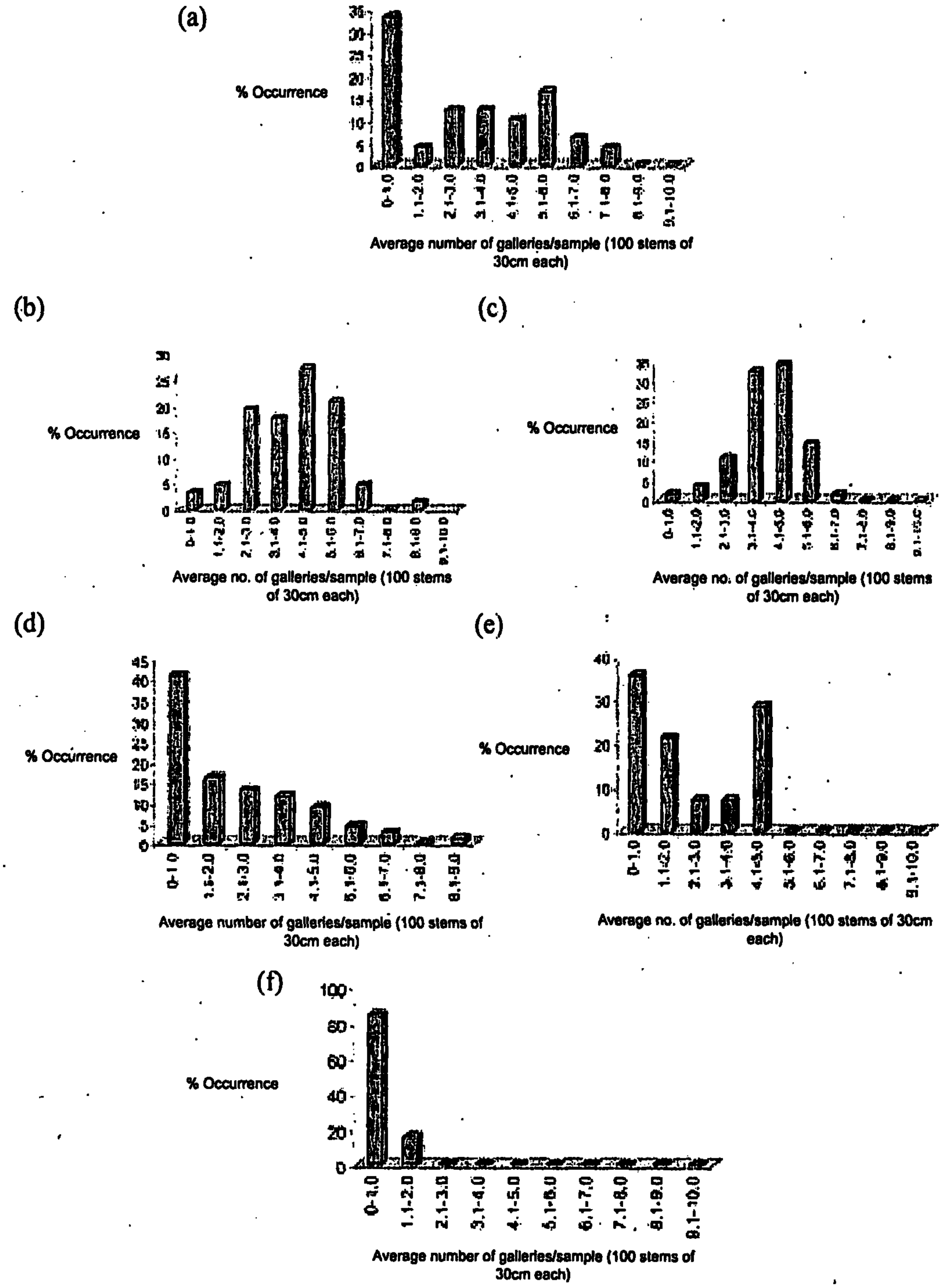


Figure 3: The % occurrence of the damage parameter, average number of galleries per stem in (a) up country, (b) mid country dry zone, (c) mid country wet zone, (d) low country I, (e) low country (II) and (f) low country (III).

extreme is the result of the difference in elevation within the region. The highest damage is reported from estates in elevations approaching 600 m.

The average number of galleries shows some unusual patterns, with the higher percentage (36%) of the estates having the galleries in the lowest range of 0-1.0, and 26% in the range of 4.1-5.0 (Fig. 3 e). This could also be a result of the effect of different elevations within the region.

6. Distribution of damage levels within the low country (III) (Galle District)

The distribution pattern of the percentage infested stems in the low country (III) region indicates less damage, with 38% of the estates showing damage in the category of 11-20%. Fifteen percent were in the categories of 0-10% and of 31-40%; this was also observed in the distribution pattern. Eight percent is represented by just a single estate in the somewhat higher range of 71-80% (Fig. 2 f).

The damage parameter, average number of galleries per stem, showed a negatively-skewed distribution where all the data fell in the first two categories (Fig. 3 f). Eighty-five percent and 15% of the estates are in 0-1.0 and 1.1-2.0 categories, respectively.

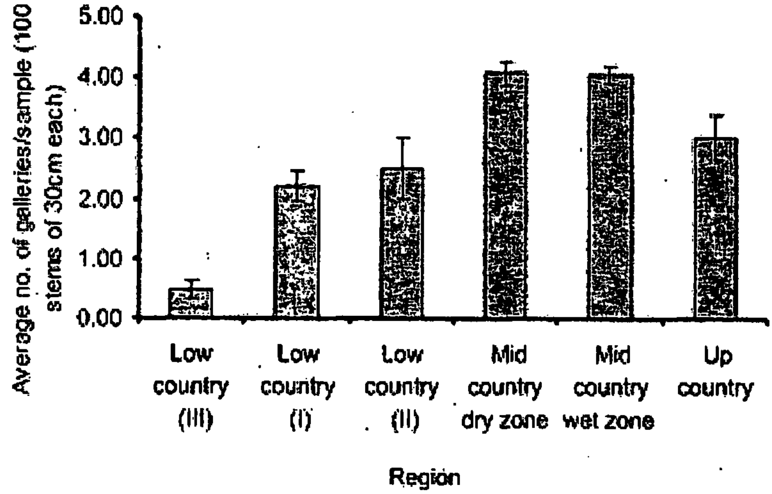
7. Distribution patterns across the major tea-growing regions

The distribution patterns across the entire range shows a definite trend, with estates in the Galle District (Low Country III) having the lowest damage levels in terms of both damage components (Figs. 3 a, b). The Ratnapura, Kalutara and Kegalle Districts (Low Country I) and the Matara district (Low Country III) show very similar levels of damage. The damage levels in both the mid-country dry zone (the Uva) and the mid-country wet zone indicate a similarity in terms of both damage components. The up-country has damage levels much similar to that in the low country (I) and (III). Figs. 3 a, b suggest that both parameters can be used to describe the damage levels of shot-hole borer. The two graphs follow exactly the same pattern in describing the data.

When data from all the low-country regions (I, II and III) were pooled, and the average infestation levels were presented, along with the mid-country dry and wet zones and the up-country, the major differences in the damage levels among these major regions become apparent (Fig. 5).

8. Distribution of damage across the tea-growing range in relation to elevation

The results reveal that there are ascending and descending gradations in infestation levels across the elevational range. There is a variation in infestation levels in the range from near sea level to 200 m, and also in the range 200 m to 400 m (Fig. 6).



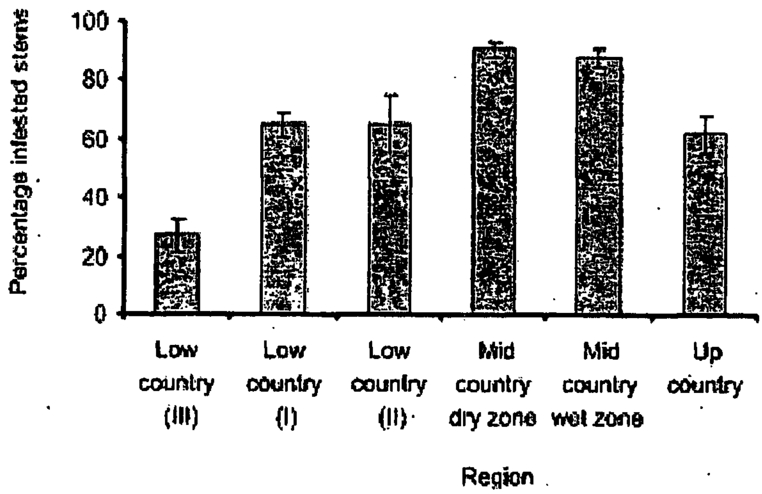


Figure 4: Pattern of the damage parameters, average number of galleries (a) and percentage infested stems (b) among different regions.

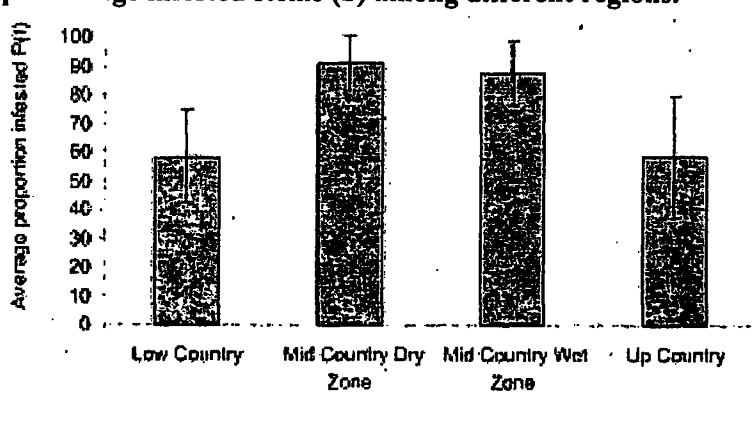


Figure 5: Pattern of the percentage infested stems among low, mid and up country regions

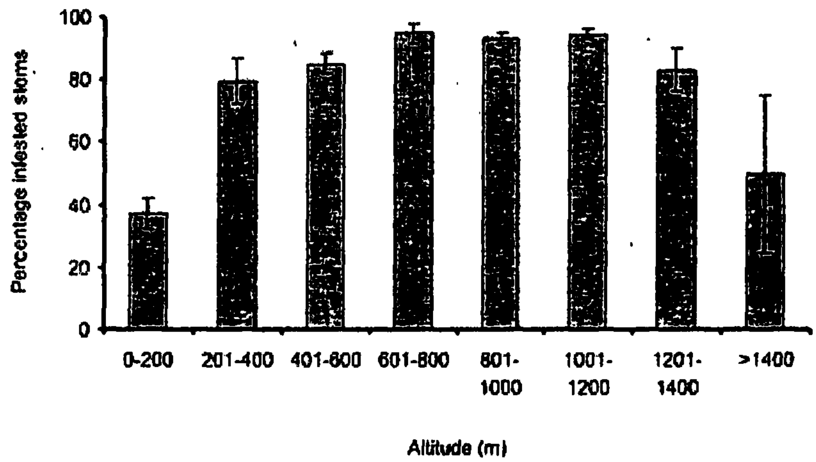


Figure 6 : Variation in infestation levels in relation to altitudinal range

The variation becomes less with increase in elevation to 600 m. Between 600 m and 1200 m, the damage levels are consistent, and this reflects the high levels of damage characteristic of the mid-elevations (in the wet and dry zones). From 1200 m upwards, variation in damage levels is seen again. This variation is less in the region 1200 – 1400 m, but a considerable variation occurs above 1400 m. This is because some of the estates in the higher elevations, but in the warmer, eastern sector of the country, have high damage.

The data from the up-country regions indicate the higher limit of shot-hole borer distribution. The damage is limited above 1400 m (Fig. 7). There were just one or two empty galleries in all the samples collected from plantations situated above 1400 m. There were no signs of brood development in the galleries, and the galleries were mostly incomplete.

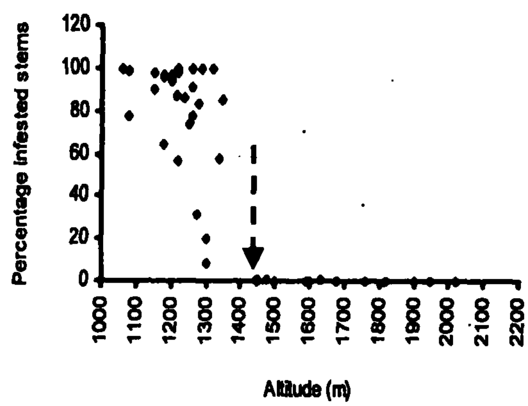


Figure 7: Upper limit of distribution of shot-hole borer (the data from the up country region is shown) (note the upper limit is around 1400m)

9. Distribution of damage across altitudes in relation to major infestation levels

The results indicate an interesting trend across the altitudinal range in the major categories of infestation (threshold levels, as defined by Sivapalan and Delucchi, 1975). Percentage infestation levels of >_60% increase rapidly with increase in elevation from 200 m, reach almost 100% around 600 m and then remain constant up to 1200 m (Fig. 8). The infestation levels decrease after 1200 m.

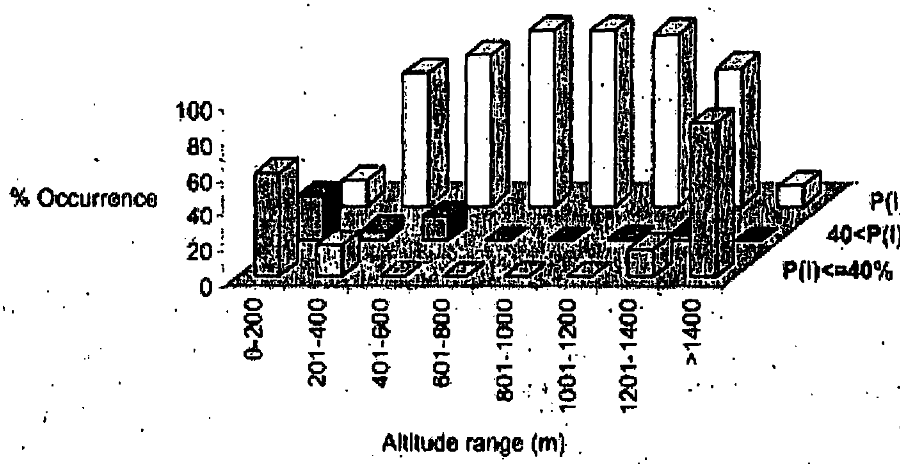


Figure 8 : Variation in major infestation levels in relation to altitude

Infestation levels, in the range of 40 to 60% are found only up to 600 m, nothing in this range being observed after 600 m. On the other hand, infestation levels of < 40% are found only at the two extremes of the altitudinal range: less than 400 m and more than 1200 m (Fig. 8). This trend also suggests the consistently higher damage in the elevation range of 600 – 1200 m.

An increase in infestation levels of < 40% after 1400 m indicates that estates have negligible or no damage above this limit. An increase in the higher infestation levels is also evident in the profiles of different major regions (Fig. 2).

DISCUSSION

The survey reported in this paper indicates the present status of the damage due to shot-hole borer across major tea-growing areas in Sri Lanka.

The damage levels are highly variable in the low-country region, and this variation is evident in the altitudinal range of 0 to 600 m. The damage levels seem to be constant in the range of 600 to 1200 m to which the mid-country region (the wet zone of the western slopes and the dry zone of eastern slopes) belongs.

The damage levels become variable after 1200 m, that is in the up-country region. The pest is active up to 1450 m, after which its activity is limited. The one or two galleries found in samples above 1450, which are incomplete and without any signs of brood, suggest that shot-hole borer is unable to colonize and breed successfully in areas above 1450 m where low temperatures prevail. Temperature has been shown to affect the life-cycle stages of the shot-hole borer (Gadd, 1949; Sivapalan and Shivanandarajah, 1977).

The results of this survey can be considered as an adequate representation of the present situation of the problem. The survey covered only the estates in the corporate sector, and hence the number of estates in the Matara and Galle districts (low country II and III) are as low as 13 in each. Sampling smallholder properties is suggested in order to get an adequate number of samples for elucidating the situation in this area.

Overall the results suggest that the infestation levels are extremely high and consistent, both in the wet and the dry zones of the mid-country. This is no surprise as the first record of shot-hole borer was made from an estate in the mid-country itself (Sivapalan, 1985). The very few estates in the mid-country dry zone region having a low level of infestation may have been due to the altitudinal effect within that region. These locations need repeated sampling.

The variation of infestation levels is quite obvious in the low-country region, specially in the Ratnapura, Kegalle and Colombo districts (low country I), as these districts cover a wide geographical area. As such, the tea in these districts experience climatic differences in the main, but there may also be other factors that cause differences in damage. The Galle district (low country III) has the least damage of all, and less variation is observed within the district. The Matara district (low country II) has damage levels higher than that in the Galle district plantations. Also, variation is seen owing to possible altitudinal effects within the region.

The major concern is whether shot-hole borer will expand its present range to previously undamaged areas, and therefore the upper limits of distribution are mostly discussed at present. Some authors have mentioned that shot-hole borer causes damage in the range of 150 to 1350 m, even though they can be found outside this range as well. There is no indication as to whether these limits have been obtained from surveys similar to the present one, or merely from observations. However, if those figures reflect the upper limits in similar periods of time, the present survey would suggest that shot-hole borer inflicts heavy damage well above the previously mentioned limits. There were instances where high infestation levels were observed at altitudes close to 1450 m.

The minimum number of stem galleries that corresponds to 100% infestation varies between different regions. The minimum values observed, given in decreasing order, are Nuwara Eliya district (up-country) 5.3 > Matara district (low country II) 4.7 >

Ratnapura/Kegalle/Kalutara districts (low country I) 4.5 > Badulla district (mid-country dry zone) 4.2 > Kandy/Matale districts (mid-country wet zone) 3.8.

This indicates that pest pressure is at its highest in the mid-country dry and wet zones, while it is at its lowest in the Nuwara Eliya (up-country) and Matara districts (low country).

This indicates further that infestation levels of 100% are reached at an average of 3.8 galleries per stem in the mid-country wet zone, while to attain the same level 5.3 galleries/stem are required in the Nuwara Eliya district (up-country).

The high pest pressures observed in the mid-country wet zone, and also in the mid-country dry zone, makes these areas more suitable for studies in relation to screening tea cultivars for resistance or tolerance to shot-hole borer.

It is surprising to note that the average number of galleries a branch can have varies from 0 (no galleries) to as much as 8.3. A gallery average as high as 8.3 has not been reported before. The number of galleries that leads to the 100% infestation level varies from a minimum average of 3.5 to a maximum average of 8.3.

There were instances where some branches, from samples from badly affected areas, had more than 10 galleries along their entire length of 30 cm. It was possible to obtain such a high average of 8.3 in the present study because of the extended length of the sampling-unit size from 10 cm to 30 cm.

Cranham (1963) expressed the opinion that there could be a 'saturation density' of beetle galleries (1.5 galleries/10 cm pencil thick stem, which works out to 4.5 galleries/30 cm stem), which represents the upper limit (the carrying capacity) beyond which no colonization takes place. The upper limit of the saturation density seems to be governed by environmental variables, as well as by the health and vigour of the affected bushes. A rapid, heavy attack is thought to render the woody branches less favorable for colonization (not necessarily related to ageing of the branches), but limitation of space seems to have little influence on the number of galleries. This observation is in close agreement with the findings of Sivapalan (1975), who indicated that there was no, or poor, correlation between the number of brood galleries and the availability of space in terms of branch thickness and available length of wood. These findings point to the need for a thorough study for determining what exactly causes the decline of borer populations.

The number of galleries found in a branch is an important factor in considering the damage. It is the cumulative effect of the increasing number of galleries that determines the level of wood rot that sets in subsequently. Even though both damage components can be used to describe the infestation levels in a given area as both follow a similar trend (Fig. 3), the measure of percentage infested stems is not adequate to express the overall damage the plant will undergo in the following cycles.

Considering the fact that the average number of galleries a stem can carry varies even after reaching the 100% infestation level, it can be seen that the number could be anything in the range of 4.0 to 9.0 on average. The stems having such a large number of galleries may definitely affect the bush in subsequent cycles, because the larger the number of galleries a stem carry, the higher the possibility of a bush getting wood rot in subsequent cycles.

Fig. 9 gives a relationship between the average number of galleries and the percentage of infested stems. This shows that percentage infestation continue to stay at the 100% level on reaching the asymptote, irrespective of the increase in the number of galleries. This is a problem specially in the wet and the dry zones of the mid-country where heavy damage is observed.

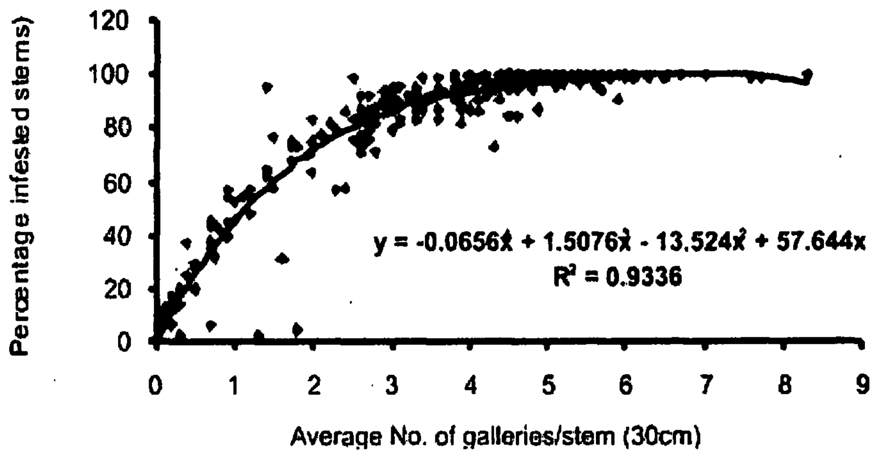


Figure 9 : The relationship between the two damage parameters of the combined data of all the regions. A polynomial function of 4th order fitted well to the data.

The present study confirms earlier observations that there is a variation in shot-hole borer activity across the altitude range of almost near sea level up to about 1450 m amsl in the tea growing areas. With the exception of a few estates having heavy damage above 1400 m, this can be considered as the upper limit of the distribution of shot-hole borer and the damage from it. There is ascending and descending gradations of the damage levels across this range. The distribution of shot-hole borer is therefore governed by altitude where the temperature is the main determinant.

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