THE CAUSAL AGENT OF BENGUET PINE DETERIORATION IN THE PHILIPPINES

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Introduction

In the Philippines, the Benguet pine, *Pinus kesiya* Royle ex. Gordon is distributed in central and northern Luzon, and its pure forest stands extend over large areas especially at high elevations. The pine forests are particularly important not only in supplying raw material for the large lumber and pulp and paper industries, but also in controlling water run-off or erosion in mountain areas.

Since about 1958, spotty lesions affecting scattered groups of Benguet pine trees have been observed throughout these areas. Although these were always associated with infestation by the six-spined engraver, *Ips calligraphus* (Germer), the presence of other infectious agents inducing pine deterioration or beetle attacks was considered because the engraver beetle was thought to be merely a secondary pest. Through the research cooperation programs carried out between the Tropical Agriculture Research Center and the University of the Philippines at Los Banos, a joint research project was initiated in 1976 to study the etiology of Benguet pine deterioration. Phytopathogenic fungi or nematodes isolated from dead pine trees were examined in 1976 and 1977, but causal agents could not be detected. The results of the observations suggested that only *Ips* beetles seemed to play an important role in the destruction of pine trees. The factors responsible for the enhancement of the activity of engraver beetles and for heavy infestations remained unknown.

In 1978, the author and his colleague had the opportunity to participate in the research project and to clarify not only the biology of *I. calligraphus* but also the population behavior of this beetle in association with the pine deterioration. This report summarizes the results obtained from these surveys and investigations which were conducted from January 12 to March 11, 1978. The detailed report will be published in PTEROCARPUS, the Philippine Science Journal of Forestry.

Biology of *I. calligraphus*

I. calligraphus is widely distributed in southeastern Canada, throughout most of the United States, from Mexico to Honduras and in some Caribbean islands. The specimens were first collected from Benguet pine trees in Baguio and its vicinity in Benguet in 1956 and now throughout central and northern Luzon. This beetle probably breeds in most species of pines within its range.

1 Gallery system, brood size and sex ratio

I. calligraphus is polygamous. The male attacks first, bores an entrance hole through the outer bark and constructs a small irregular nuptial chamber in the phloem. Usually females follow and join the male before the nuptial chamber is completed. After mating, females begin to exacavate egg galleries which radiate from the nuptial chamber and eventually run parallel to the grain of the wood. The number of egg galleries per nuptial chamber range from 2 to 6 with an average of 4. The females deposit eggs individually in small niches cut into both sides of the gallery wall at irregular intervals.

As in other species of *Ips*, the number of eggs deposited in one gallery depends on the gallery length which is greatly influenced by the attack density, namely, the number of egg galleries per

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unit area. The bark samples examined indicated that the number of egg galleries per 0.1 m² ranged from 33.0 to 119.0 and the average length of egg galleries apparently decreased as their number increased (Fig. 1-A). It could also be demonstrated that the number of galleries devoid of egg niches increased with the attack density and consequently the number of galleries with egg niches were below 60 per 0.1 m² approximately (Fig. 1-B and C). This suggests that the females regulated their oviposition and would not deposit eggs above a certain density in order to prevent their progeny population from destruction consecutive to overcrowding.

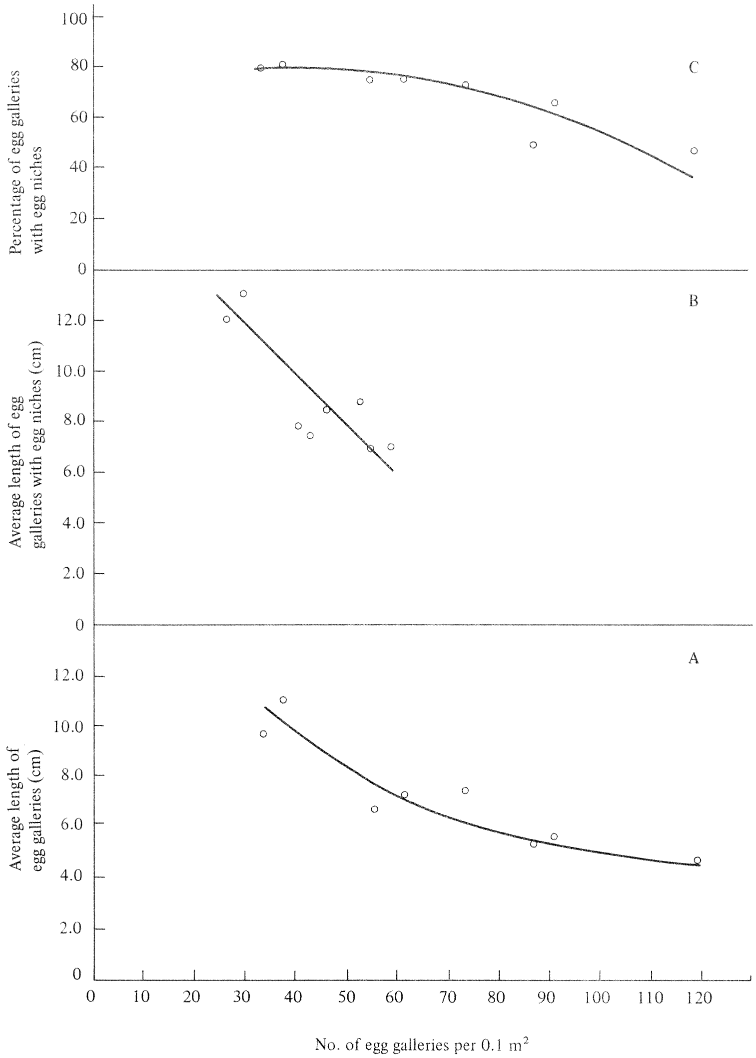

Fig. 1 Relationship between length of egg galleries and attack density of *I. calligraphus*.
A: Obtained from all galleries constructed.
B: Obtained from galleries with egg niches (Excluding galleries without egg niches).
C: Percentage of egg galleries with egg niches.

The number of egg niches plotted against the gallery length appeared to fit a linear relationship and no significant differences were found among the samples taken from various trees. The data were therefore grouped to calculate a mean of 2.5 egg niches per cm gallery. Actual fecundity was not determined because most of the parent adults seemed to emerge to resume the attack and establish a second brood. In laboratory rearing such phenomena were found to take place about 20 days after the initial attack. The progeny production ratio was relatively high and showed a downward trend as the attack density became higher as a result of intraspecific competition for limited food.

A ratio of 1.03 female to 1 male was recorded from 302 newly emerged adults. As apparent from the gallery system, however, the ratio between attacking females and males was approximately 4:1. The higher differential loss of males before reproduction may be caused by unsuccessful initial attacks by males.

2 Seasonal development and attack period

The infestation of *I. calligraphus* is reported to occur in Benguet from February to June, from the beginning of the dry season to the start of the rainy season. Heavily infested trees containing all stages of insects were observed even in January, indicating that the beetle attacks on green trees already took place in December of the preceding year.

Rearing experiments at Los Banos revealed that the time required to complete a generation was 15-17 days. The callow adults, however, needed some 10 more days to emerge from the logs in which they developed, so that it took about 25 days from the attack of parents to the emergence of progeny. From the observations made on bait logs set in the field, this period seemed to extend for another 10 days or so in Benguet where the temperature was much lower than at Los Banos. In the southern United States, *I. calligraphus* required approximately 25 days to complete a generation in summer, and at least 4 generations were observed throughout the season. Attacks were seen almost continuously from April to September in this case, but from March to December in certain years at lower elevations. Judging from these records and our observations it can be said that in the Philippines the engraver may continue its development and reproduction without hibernating and have 10 or more generations a year. Since no information has been obtained on the development from July to December, further investigations will be needed to confirm the number of seasonal generations.

3 Mode of attack

I. calligraphus prefers recently killed trees and slash, but is capable of breeding in trunks and limbs of apparently healthy trees. In all places surveyed in Benguet, the beetles attacked the main trunk predominantly but were also found in the branches. The infestation was observed from the base to the top of the trees, but most frequently on the middle and lower boles. In some of the trees which had suffered from forest fire, however, no attacks or only yellow pitch tubes were found on the lower bole while heavy infestation was observed in the upper bole. This is a characteristic phenomenon in the beetle infestation on Benguet pine trees.

During the attack, the adults usually feed on the fresh phloem material as they bore tunnels. However, mass attacks for feeding alone are sometimes found especially in saplings and small poles. The destruction of young naturally regenerated trees illustrates this phenomenon. Mass attacks for feeding are presumably enhanced when the inner bark and sapwood surfaces are quickly exhausted by feeding of many callow adults, leading to a shortage of food under the bark in which they have developed.

The trees infested with *I. calligraphus* frequently harbored a scolytid beetle, *Cyrtogenius* sp. This species is supposed to be a native one and only a secondary pest. Some of the infested trees also harbored a small number of cerambycid beetles in the lower bole.

Beetle infestation and pine deterioration

1 Character of infestation

Since about 1958, as mentioned before, dead pine trees associated with infestation of *I. calligraphus* have been observed in scattered groups. According to the observations made by foresters, the infested areas would often expand unless dead trees were cleared away. This suggests that the beetles continue to attack nearby uninfested trees until their population density decreases probably due to limitation of the suitable host material in a given area and intra- and interspecific competition for food.

In the surveys conducted in 1978, many newly killed pine trees with red or brownish foliage were observed in groups throughout Benguet province. In all places, damage was more severe on the southern slope of mountains or ridges, and most of the stands damaged had partially suffered from forest fires. All the dead trees were recognized to be heavily infested with *I. calligraphus*. The beetles seemed to attack the green healthy trees and their attacks apparently spread from the edge into deep in the forests. As the progeny production ratio of *Ips* was still high and the population density remained at high level, the beetle infestation could expand in these areas.

Other recent widespread damage was reported to have occurred in 1975, as a result of protracted drought in the dry season of the same year. Natural disturbances such as drought or forest fire are thought to frequently contribute to fluctuations in beetle populations and become the starting point for beetle outbreaks. Forest fires or burns damage main stem and surface roots and often defoliate groups of pine trees. Fires seem to be particularly harmful on sites where roots are close to the surface or where soil moisture is deficient. These weakened or damaged trees are subject to attacks of the beetles and bring about great increase in beetle population. Prolonged drought also weakens the trees seriously, especially on ridges or other dry sites with southern or western exposure and overstocked pure stands. Widespread severe damage observed in 1978 may have arisen as a result of the combined effect of fires and drought.

Logging operations also contribute to the increase of the beetle populations, because slash or cut logs left in the stands become their preferred breeding material. The hazard seems to be exemplified by the heavy beetle infestations on cut logs piled up at lumber mills, which were just brought from logging areas. This condition induces beetles to attack the residual trees whose physiological properties are temporarily disturbed by the change in environment.

2 Role of *I. calligraphus* in Pine Deterioration

Weakened or dying trees, cut logs, or slash may be considered the normal hosts of *I. calligraphus*. When these preferred host materials become exhausted, however, the engraver beetle attacks healthy green trees. In such a case, many attacking beetles are usually expelled or killed by copious resin flow but they often succeed in establishing their broods through high population density. This was confirmed by the field experiments indicating that healthy green trees were eventually killed by successive mass attacks of beetles which were originally attracted to trap logs set on the base of those trees. If the population density of beetles is low, on the other hand, most of the weakened trees can even survive without suffering from beetle attacks and regain their normal physiological condition in a season or so. Therefore, it can be said that the pine deterioration is closely related to the population density of *Ips* beetles.

Conclusions and control methods

Conclusions concerning Benguet pine deterioration can be summarized as follows:

(1) Natural and artificial disturbances weaken the pine trees. Among many related factors, forest fire and drought seem to be most important. Their influence on the physiological condition of trees depends not only on the intensity of the fire or the duration of the drought but also on the site conditions and forest composition.

(2) *Ips* beetles prefer and attack the weakened or recently killed trees where they markedly increase their population. The large populations of beetles then spread to nearby uninfested trees.

When the trees attacked are healthy and physiologically normal, the mortality of attacking beetles is very high and they require successive mass attacks to succeed in establishing their brood. As a result, the beetle population decreases rapidly and the infestation rapidly subsides.

(3) On the contrary, when weakened trees prevail throughout the stands, the beetle attacks to surrounding trees are repeated several times, resulting in severe volume losses of green trees. Even in this case, however, the progeny production ratio decreases with the increase in beetle population because of the high attack density and the consecutive intraspecific competition, so that the infestation seldom persists in a given area much longer than a year. In addition, the weakened trees usually recover their normal physiological condition in a season or so. This also hastens termination of the beetle infestation. In areas subject to repeated fire damage, however, the biotic equilibrium is disturbed again and consequently the beetle outbreaks may last for 2 or 3 years or more.

(4) General recommendations for controlling the engraver beetle consist of the use of infested trees before the broods start emerging, and of peeling and burning bark from logs or tree tops left in the stands. Much attention should be paid to the detection of beetle-infected trees because the broods may develop rapidly enough in the dry season to emerge shortly after crowns begin to fade.

Application of insecticides [0.5—1.0% Lindane = γ - BHC, or mixed emulsion of Sumithion (MEP) and ethylene dibromide (EDB)] can be used in place of burning. In stands where only few trees are infested, trap logs treated by insecticides are useful for killing the attracted beetles and reducing the population density.

The most important method for preventing beetle infestation is the control of forest fire along with the production of healthy trees through silvicultural practices such as salvage, improvement cutting, or thinning. An improvement in the reforestation system is also of importance. Mixed planting or reforestation with other tree species in the surrounding areas of pine forests may be one of the effective control methods.

Discussion

Yunus K. (Indonesia): Is *Ips calligraphus* also attacking other pine species?

Answer: Yes, this insect probably breeds in most species of pines within its range.

Choob K. (Thailand): Is it useful to apply insecticides to such insects which live under the bark? How about natural enemies?

Answer: As this insect is a cambium feeder, some chemical compounds can penetrate through the bark and kill the larvae developing under the bark. On the other hand, the use of natural enemies such as parasites or predators is difficult as *Ips* beetles live under the bark, thus being protected against attacks from natural enemies. Silvicultural control is therefore essential.

Sasaki, S. (Japan): Is this beetle associated with a fungus?

Answer: The beetles introduce a blue stained fungus into the trees they attack and almost all of the trees killed by the beetles were also infested by the fungus.

Kobayashi, F. (Japan): Although the fungus can be isolated from the *Ips*-infected trees and from the body of the beetles, its role remains uncertain.