Initial Attack of the Minute Pine Bark Beetle, *Cryphalus fulvus* Niijima (Coleoptera : Scolytidae) *

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Abstract : Detection of healthy or weakened pine hosts from a distance by the minute pine bark beetle, *Cryphalus fulvus,* through olfaction was investigated in a pine stand. Beetles were flying usually at a height of about 4 m above ground level in and out of stand. There was no significant difference between landing rates, monitored by traps, of beetles on weakened trees and controls. Pioneer beetles were able to attack only weakened trees reduced resin pressure. Thus, selection of suitable breeding material must occur while pioneer beetles are in contact with tree after landing.

Introduction

The initial phase in the attack process of the minute pine bark beetle, *Cryphalus fulvus* NIIJIMA, is the period during which host selection, that is, landing and gallery initiation on the suitable pine tree takes place by the female "pioneer" beetles. Generally, visual and/or olfactory cues (host odors) have been reported as the factors influencing the landing rates of many bark beetles. Certain species, for example, tend to orient their landing to vertical objects (BILLINGS et al., 1976). In some cases, the landings appear to occur at random over the vertically distributed surface area on host and/or non-host trees (BORDEN et al., 1968 ; WOOD, 1972 ; HYNUM & BERRYMAN, 1980; MOECK et al., 1981). Olfactory cues seem to be the primary attraction for many scolytid species of *Ips* and *Dendroctonus* (RENWICK & VITÉ, 1970; WOOD, 1982). In addition, gustatory cues can play an important role in the attack behaviors of some species after random landing, and various tree chemicals were found to stimulate or inhibit gallery initiation (GILBERT et al., 1976 ; BAKER & NORRIS, 1968).

On the other hand, characteristics of the resin system in conifers, with properties of resin composition (HODGES et al., 1979), resin pressure (BOURDEAU & SCHOPMEYER, 1958 ; VITÉ & WOOD, 1961), total flow (HODGES et al., 1979), flow rate (MASON, 1971), and crystallization rate (HODGES et al., 1979), can function to provide the host resistance against the beetle attack.

It is said that the minute pine bark beetles may land on the pine trees at random, successfully infesting only those trees that are weakened physically or physiologically, and also by the attack of other boring insects, because suchlike secondary (non-tree-killing) species do not encounter the same host resistance mechanisms, e. g. resinosis as do the primary (tree-killing) species (WOOD, 1982). However, YASUNAGA et al. (1962) reported that the minute pine bark beetle and pine shoot beetle,

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Tomicus piniperda (L.), were attracted to benzoic acid from the red-pine bark in the laboratory experiment. A question addressed is whether the beetles land at random or in response to host odors in the field. In this paper the landing and invasion behaviors of pioneer beetles in order to define the initial attack process on living healthy trees and artificially damaged trees were investigated.

Methods and Materials

Field studies were conducted in the Experimental Forest of Kyoto Prefectural University, Ohe, Kyoto, during the period May—October, 1975. Twelve trees of the Japanese red-pine, *Pinus densiflora* SIED. et ZUCC., about 7 m high and about 11 cm in diameter at breast height, growing at ridge in a plantation, were selected as models to represent the degree of damage and also as control. Four trees were cut off all the branches and inflicted an incised wound reached to the inner bark by saw at base of each trunk on 27 May, 9 and 26 June, and 24 July, respectively. Four other trees were cut off one-half of whole branches(every other branch) and also wounded as written above on the same day. These will hereafter be termed model-trees "severely damaged" for the former and "slightly damaged" for the latter.

The resin pressure was measured at heights of 2, 4 and 6 m of trunk above ground level every about seven days from 13:00 to 15:00 PM. The beetles responded to each tree were captured by the sticky traps(50x50 cm of transparent plastic board). Three traps were placed on each study tree southwardly at heights of 2, 4 and 6 m of trunk above ground level. On the basis of this trapping it is assumed that beetles caught in traps were trying to land. The number of boring pioneers was counted by a trail of brownish boring dust on the outer bark according to directions.

In the second experiment, each two severely damaged model-trees growing along edge of plantation and in stand were investigated in September as in the previous one, although all of the new borers were crashed to death by the point of forceps every day to prevent the emission of aggregation pheromone.

Results

1. Relation between change of resin pressures and number of beetles responded

Resin pressure

Resin pressures of the healthy trees varied from 3.2 to 7.6 kg/cm^2 according to tree and even from season to season, but were almost constant during the experimental period in each tree(Fig. 1A). On the other hand, the resin pressure in the severely damaged model-trees was reduced more sharply than in the slightly damaged ones, and was not measured at all about 15 to 40 days after treatment(Fig. 1C). In the slightly damaged model-trees its perfect reduction occurred about 50 to 80 days later(Fig. 1B).

Number of beetles landed on traps

The numbers of the minute pine bark beetles landed on the sticky traps placed at three different heights of control tree are shown in Fig. 2. Beetles seemed to be composed of most of the first and second generations and smallest part of the third generation (see Appendix). The numbers of beetles caught were almost constant in each level from June to mid August, of which a comparatively large proportion was at height of 4 m above ground level. After then they decreased gradually in numbers.

The mean number of pre-aggregation landing beetles per 2,500 cm^2/week were 9.72 on the severely damaged model-trees, 9.33 on the slightly damaged ones and 11.03 on controls. There were no significant differences among them. This indicates that the minute pine bark beetles were unable to

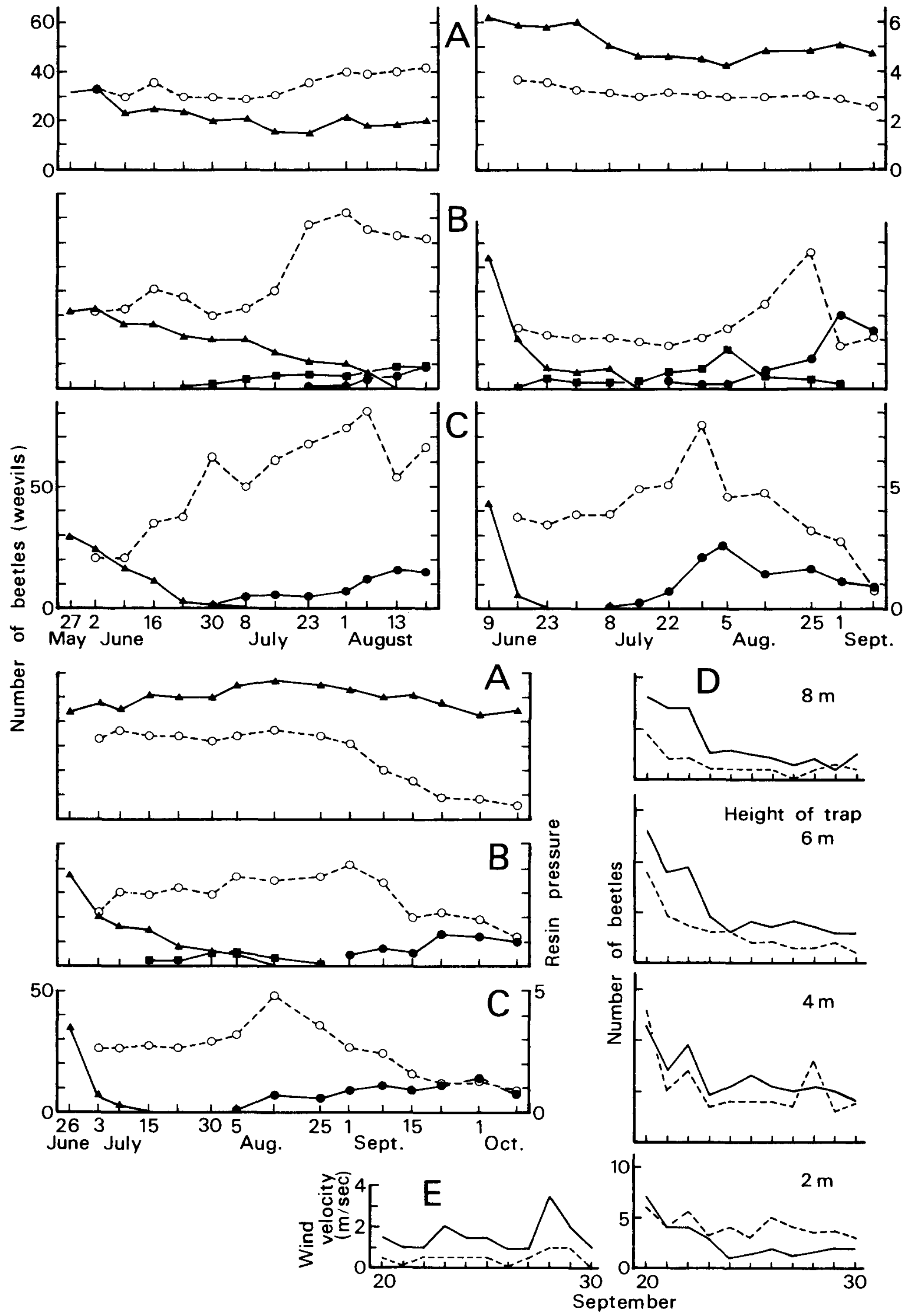

Fig. 1. Relation between numbers of the minute pine bark beetles and pine bark weevils attacking the healthy (A), slightly damaged (B) and severely damaged (C) red pine trees and changes of resin pressures, and relation between landing rates on traps placed on tree trunk (D) and wind velocity (E) within and outside of a stand.

A, B & C : Open circles, closed circles, closed squares and closed triangles refer to the numbers of beetles landed on traps, of beetles bored and of weevils bored, and mean value of resin pressures, respectively. D & E : Broken and straight lines refer to within and outside of a stand, respectively.

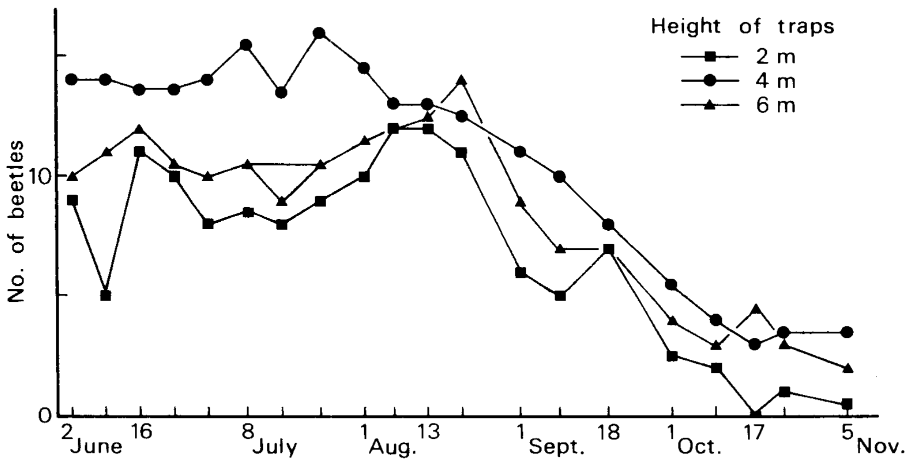

Fig. 2. Landing rates of the minute pine bark beetles on traps placed on the healthy pine tree trunk.

distinguish a suitable host-tree prior to landing.

The landing rates of beetles increased gradually after an invasion of the first pioneer female. The total number of landing beetles reached to the peak about 60(49—70) days after the treatment of severe damage and about 70(65—77) days after that of slight damage(Fig. 1). There was, however, no peak on the control trees. An increase in landing rates on the attacked trees may be the result of pheromone release by the pioneer females.

Attack pattern of beetles in relation to degree of damage

The minute pine bark beetles did not attack the healthy tree, but started to bore earlier the severely damaged model-trees that had been shown the remarkable reduction of resin pressure than the slightly damaged ones(Fig. 1). In the latter model-trees, the invasions of pine bark weevils, *Shirahoshizo* spp., or long-horned beetles were initiated prior to that of the minute pine bark beetles even if the trees were under a resin pressure of 2 kg/cm^2. The minute pine bark beetles were, therefore, able to invade those trees under a resin pressure of 0.1—1.2 kg/cm^2, although they attacked usually the trees under the absence of resin pressure.

The number of the minute pine bark beetles attacked the severely damaged model-trees in the first three weeks were very few as compared with that of landing beetles on the traps. In the next three weeks, however, its increase was as much as two to three times and about five times in the last three weeks. In the slightly damaged model-trees, a similar increasing tendency was seen at intervals of about two weeks.

A large number of entrance holes excavated into the tree trunk by the pioneers were found at a height of 3—5 m above ground level(Table 1). The weevils occupied predominantly a lower part of

Table 1. Mean total numbers of the minute pine bark beetles bored into the slightly and severely damaged pine trees.

Height of trunk*	0—1 m	—2	—3	—4	—5	—6
Slightly damaged tree	——	1.6	10.0	20.9	23.8	14.8
	(5.7)**	(15.5)	(14.3)	(2.0)		
Severely damaged tree	——	8.3	18.0	21.2	25.1	14.4

* Above ground level ; ** mean total number of the pine bark weevils.

trunk (1—3 m). The entrance holes of the minute pine bark beetles were found subequally in all directions, except for a low number on the south side of the severely damaged model-tree.

2. Flight and attack patterns in response to severely damaged model-trees in and out of a stand

Landing rates of the minute pine bark beetles within and out of a pine stand and mean wind velocity during the experimental period are shown in Fig. 1D, E. In the calmer conditions the beetles had been flying at a height of 2—4 m above ground level in a stand, while their usual flight-height in outside of stand was 4—6 m. When the wind velocity exceeded 3 m/sec, a change in flight dispersion occurred from the outside to the inside of a stand at level of 4 m.

Generally, beetles responded to the severely damaged trees in a stand in low numbers, and the entrance holes were distributed at a height of 1.5—5 m above ground level. On the contrary, they spread their distribution of entrance holes up to 7.5 m on the trees growing along edge of stand. Also, a great number of the entrance holes was observed clearly on the south to east side of both trees in and out of a stand.

Discussion

A role of the primary attraction, i.e. guided insect response host-produced volatiles, in the host selection behavior of the bark beetles has been demonstrated in many species of *Scolytus* and *Dendroctonus*, as well as the ambrosia beetles of *Trypodendron* and *Gnathotrichus*. Conversely, other field experiments in which cut host material as in all of the above studies or standing trees were used have failed to demonstrate the primary attraction for *Dendroctonus brevicomis* LECONTE (VITÉ & GARA, 1962 ; MOECK et al., 1981), *D. frontalis* ZIMM. (VITÉ & PITMAN, 1968), *D. ponderosae* HOPKINS (HYNUM & BERRYMAN, 1980 ; MOECK et al., 1981), *Ips avulsus* EICHH. and *grandicollis* EICHH. (VITÉ et al., 1964), *I. latidens* (LECONTE) (MOECK et al., 1981), *I. paraconfusus* LANIER (WOOD & VITÉ, 1961 ; MOECK et al., 1981) and *Gnathotrichus retusus* (LECONTE) (MOECK et al., 1981).

The results indicate that the minute pine bark beetles landed apparently at random on healthy and weakened pine trees, known to be suitable for infestation during the period of pre-aggregation flight, at a rate of about sixty beetles per tree per day, based on the mean landing rates to the surface area of a tree trunk with mean height (7 m) and diameter (7 cm). After landing, they will display capability to determine the gallery initiation. From the results it is clear that once a pioneer beetle bored in a weakened standing tree without resin pressure the aggregation landing of beetles (mass attack) is initiated on that tree, owing to the production of pheromone (SASAKAWA & NEGISHI, 1973 ; SASAKAWA et al., 1976). If the beetles land on healthy pine trees, they do not initiate galleries by the exudation of resin. We have experiences with such unavoidable cases, i.e. repeled or killed by resin at an early stage of attack, in the artificial introduction of virgin females into bait logs.

The flight-height of beetles above ground level and the effect of wind on flight were the same as those reported previously (SASAKAWA & NEGISHI, 1973 ; SASAKAWA et al., 1976).

APPENDIX

Number of generations of the minute pine bark beetle was investigated under natural condition, using the method of bait logs designed by SASAKAWA and KATAYAMA (1975) except that the density of entrance holes was 5 per 100 cm^2 of bark. Seasonal prevalence of occurrence in 1976 was shown in Fig. 3.

Most of the adult beetles of overwintering generation emerged from the period 13 to 21 April. In

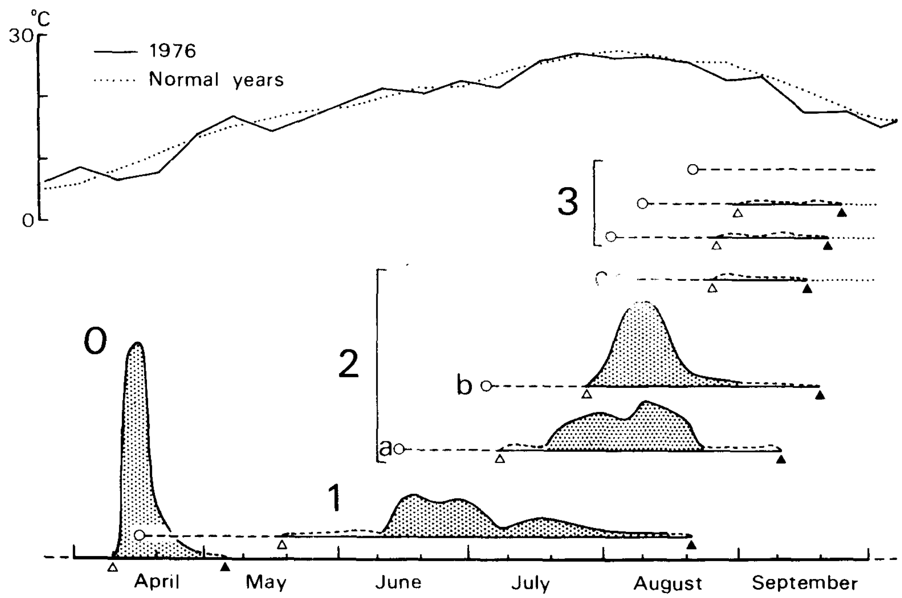

Fig. 3. Seasonal prevalence of occurrence of the minute pine bark beetle in Kyoto, 1976.
Open circles refer to the date of introduction of virgin females into pine logs : 16 April for the first generation ; 15 June, 5 July and 5 August for the second, and 3, 10 and 22 Aug. for the third, respectively. Open and closed triangles refer to the dates of first and last emergence of adults, respectively ; period of discontinuous adult emergence was shown by broken line. Numbers 0 to 3 refer to the overwintering, first, second and third generations, respectively.

the first generation, the adults emerged mostly during about two months from 11 June to 16 August. The date of 50% adult emergence occurred on the 72th day after monogamy began in a log. Adults of the second generation emerged during about one month from 20 July to 24 August in the first experimental case(2-a) and 28 July to 2 September in the second(2-b), and the dates of 50% adult emergences occurred on the 54th and 35th day after monogamy began, respectively. Mean temperature before the date of 50% adult emergence was 19.4℃ in the first generation, and 23.5℃ in the first experimental case of second generation and 26.6℃ in the second. In the case of 2-c, however, only about ten adult beetles emerged. A number of adults emerged in the first two cases of the third generation, but most of them entered into hibernation on account of low temperature in this year. Therefore, the minute pine bark beetle occurs three times per year at least in Kyoto.

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マツ類樹皮下穿孔虫キイロコキクイムシの初期攻撃

笹川満廣・河口洋一

要旨：パイオニア雌による寄主植物の選択，すなわち寄主体上への着陸と母孔の穿孔開始は，でたらめに行われるか，あるいは寄主が発散する揮発性物質（第一次誘引）に誘引されるかを明らかにする目的で，大枝演習林内のアカマツ植生地において一連の実験を行った。

1．雌雄は地上4 m前後の高度を飛翔する。ただし，林内よりも林縁における飛行高度のほうがやや高い。

2．粘着トラップに捕獲された総成虫個体数は，健全立木と激害型・微害型モデル立木とのあいだに有意差がみられなかった。すなわち，いずれの実験立木にも日当り約60匹が着陸するようで，パイオニアは健全木と衰弱木との識別ができない（ランダム着陸）。着陸後，穿孔開始の段階で樹脂圧の高い健全木では松脂のしん（滲）出によって穿孔が阻止される。それに反して，激害または微害型モデル立木では樹脂圧が皆無になったとき穿孔がみられる。ただし，シラホシゾウ類の既寄生があるときには樹脂圧が1.2 kg/cm²でも穿孔が可能であった。

3. したがって，本種のパイオニア雌は寄主に着陸後，その適否を判定し，穿孔を開始するといえる。おそらくその時点では化学刺激を感知するのであろう。