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Determination of Hibernation Site in the Ladybird Beetle, *Harmonia axyridis* PALLAS (Coleoptera, Coccinellidae)

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Abstract Adults of *Harmonia axyridis* migrate in late autumn and form aggregation for hibernation. Some aggregation sites in and around Kyoto, Japan, were investigated. In most cases, they were connected with whitish or light-colored objects situated at the hill top, the hill valley and the base of mountain. In order to test whether *H. axyridis* is attracted visually to whitish object or not, white, black, red, yellow and green boards were set up near one of the aggregation sites. Most of beetles in migration were attracted to and landed on the white board. Such a tendency may play an important role in the formation of aggregation.

Introduction

Adults of *Harmonia axyridis* PALLAS migrate in late autumn from the feeding habitat to the hibernation site in Japan and then pass the winter in a mass (TANIGISHI, 1976). It has been said that the aggregation sites are found in the same place every year.

There are many reports on migration and aggregation in adult coccinellids (EWING, 1913; DOUGLASS, 1930; THRONE, 1935; SHERMAN, 1938; STEWART *et al.*, 1967; MCMULLEN, 1967; HODEK, 1973). HAGEN (1962) proposed that the two apparently different types of aggregation should be called "hypsotactic" and "climatotactic". The "hypsotactic" aggregations are those connected with prominent isolated objects usually present in relatively dry situation, whereas the "climatotactic" aggregations are found mostly in moist situation and are not associated with isolated objects or silhouettes.

The aggregation in *H. axyridis* has been not investigated in detail beyond the short description that the east Siberian *H. axyridis* seemed to be the same type as *Semiadalia undecimnotata*, the typical species of "hypsotactic" aggregation (see HODEK, 1973). This paper describes the characteristic of the aggregation sites in *H. axyridis* and mechanism of aggregation forming will be also discussed, being based on the field experiment using color boards.

Materials and Methods

Five areas in and around Kyoto, Japan were investigated at random and 14

Fig. 1. Arrangement of five boards in field experiment at the slope of Mt. Shiroyama. W: White, B: black, R: red, G: green, Y: yellow; each made of a painted plywood (91×182 cm). The large rock behind color boards is one of the aggregation sites of *H. axyridis*.

aggregation sites of *H. axyridis* were found. The characteristics, for example the surrounding feature and the material, of each aggregation site were recorded.

In late autumn of 1983, the field observation and experiment were made near one of the aggregation sites that had been found in the previous year, a large rock at the top of Mt. Shiroyama in Kameoka, Kyoto. The change in the number of flying beetles was roughly observed in relation to the weather, the temperature and the time. Further the color-board experiment was carried out in order to examine whether beetles in migration were attracted to specific color or not. White, black, red, yellow and green boards of the same size (91×182 cm), each made of a painted plywood, were set up on the slope, facing the direction from which beetles came flying. Five boards were arranged in two rows (Fig. 1), the distance of which was about 10 m. Although the daily change in the arrangement of five boards was not made throughout the experiment, they were regarded as visible almost equally for beetles' eyes because they were situated in the migration route of beetles. Under this experimental condition, the number of beetles which landed on each color board was counted from 12: 00 to 15: 00.

Results and Discussion

The sketch maps of five areas which had been investigated and the location

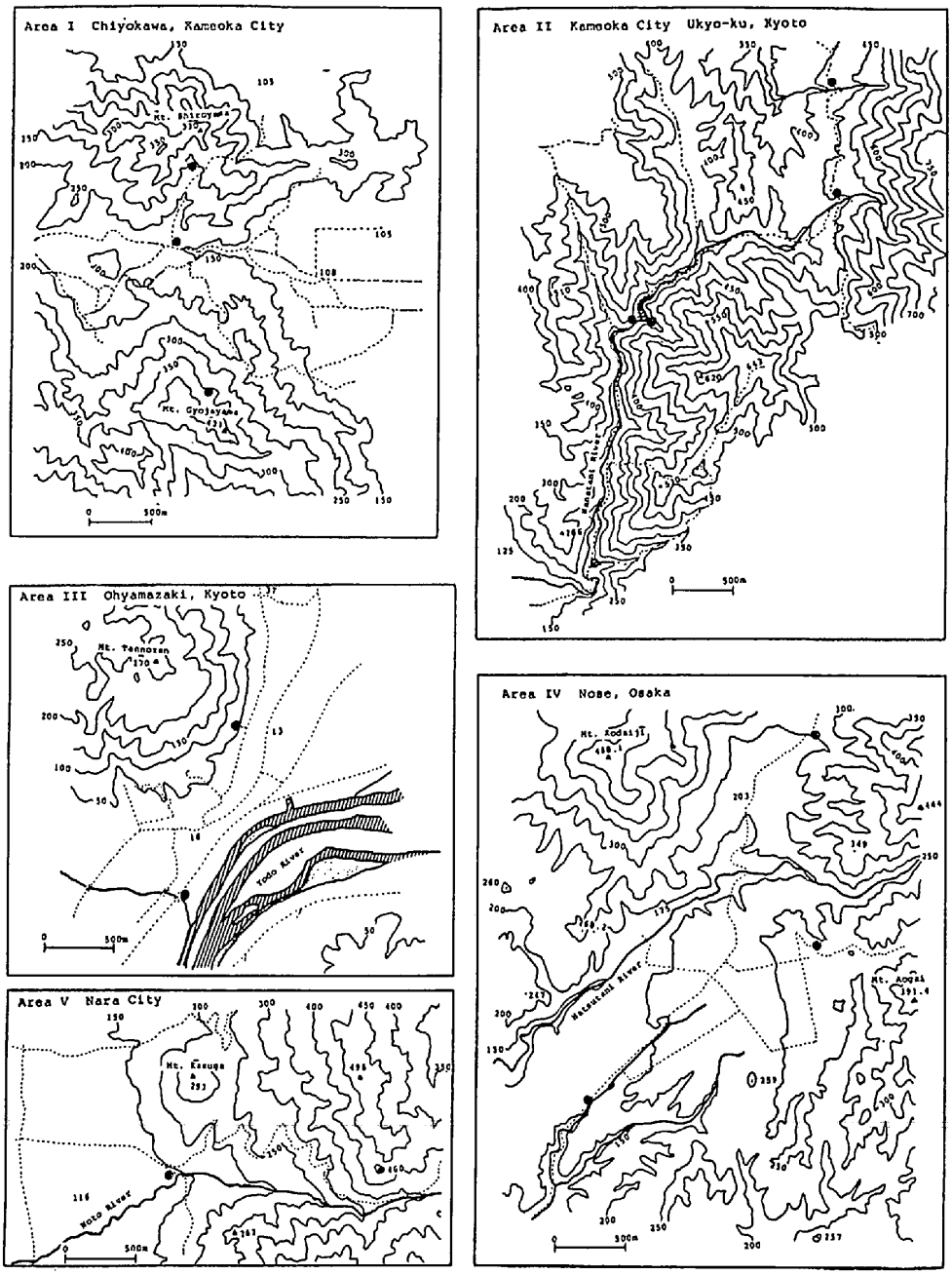

Fig. 2. Sketch maps of the investigated areas. A solid circle indicates the location of each aggregation site. Solid line represents the contour of every 50 m and broken line shows the road or path. The upper side of each maps corresponds to the north direction.

of each aggregation site of *H. axyridis* are shown in Fig. 2. In most cases, the aggregation site was situated at the elevated ground along the hill valley. The feature seemed to show that the air current converged on the site. *H. axyridis* was observed to come flying from the south at Mt. Shiroyama in the area I (Fig. 2). Other insects, such as red dragonfly, *Sympetrum frequens*, reduviid and coreid bug

Table 1. Type of aggregation site of *H. axyridis*.

	Frequency
Crack in a rock	4
Gatepost made of granite	2
Stone garden lantern	1
Bridge made of granite	1
Fence made of granite	1
White painted signboard	2
Concrete pole	1
Inside of a wooden hut	1
Underside of fallen leaves behind a hut	1
Total	14

and dronefly, *Megaspis zonata*, were also observed to assemble from the same direction. Although there is both approval and disapproval of the assumption whether coccinellid beetles in migration utilize air currents or not (HODEK, 1973), the migration route of *H. axyridis* seemed to be approximately determined according to the air current along the valley.

The aggregation sites, as shown in Table 1, were mostly connected with prominent objects contrasting with the background. Large rock, cracks of which were used for aggregation sites, was not so weathered for water to permeate and most of artificial stone structures where beetles aggregated were made of granite. These facts suggest that *H. axyridis* prefers relatively dry situation. The characteristics of the aggregation sites in *H. axyridis* seem to be coincident with that of "hypsotactic" aggregation defined by HAGEN (1962).

Migrating *H. axyridis* was observed in early November of 1983 at Mt. Shiroyama and the number of individuals reached the maximum on 10th and 11th of the month. Fine and warm (18–20°C) weather appeared as the best condition for migration of beetles. Beetles came flying while the sun shined the slope (11: 00–15: 00), but a temporary cloudy weather sometimes interrupted beetles' arrival,

Table 2 shows the number of beetles which landed on the color boards set up on the slope of Mt. Shiroyama during the migration period. Most of beetles were observed to be attracted to the white board from a distance of 3 m or so and landed on it. The yellow board attracted more beetles than black, green and red boards did, but the effect was significantly less than that of the white board ($P < 0.001$, by χ^2-test).

"Hypsotactic" aggregation has been supposed to be based on individuals' visual response to "peaks or posts" (HAGEN, 1962). Which property of "peaks or posts" is key stimulus causing hypsotactic aggregation? It has been said that aggregation sites of *H. axyridis* are mostly associated with whitish or light-colored objects (TANIGISHI, 1973). Actually such a tendency seemed to be shown in Table 1. According to the information from Mie University forest, Japan, where the insect trap using color-boards was furnished throughout the year, the white trap

Table 2. Total number of beetles which landed on each color board.

Date	Weather	Max. Temp. (°C)	Color of board					Total
			green	red	yellow	white	black	
Nov.								
1	Fine	19.1	0	0	1	0	0	1
2	Fine, cloudy at times	19.3	0	1	1	0	0	2
3	Fine, cloudy at times	19.1	1	0	7	14	0	22
4	Cloudy[1)]	17.9	—	—	—	—	—	—
5	Cloudy	18.6	0	0	0	3	0	3
6	Fine, cloudy at times	20.6	1	0	10	16	2	29
7	Fine, cloudy at times	18.1	0	0	0	0	0	0
8	Cloudy, fine at times	15.3	0	0	1	0	0	1
9	Cloudy, fine at times	18.3	1	3	5	6	0	15
10	Fine, cloudy later	20.8	11	21	45	360	17	454
11	Cloudy, fine later	19.8	27	35	69	280	13	424
Total			41	60	139	679	32	951

1) Field observation was not made.

used to catch many individuals of *H. axyridis* in the particular season, late autumn (Z. YAMASHITA, personal communication). My color-board experiment confirmed that *H. axyridis* in migration was attracted visually to and landed on whitish or light-colored objects.

Since beetles were observed to change direction to the white board from some distance, their landing was regarded as visual and active response. But how the white color is reflected in beetles' eyes? The white board was more attractive when the sun shined brightly and most of landing on other color boards were observed when the sun got behind the clouds. Taking this observation into consideration, it is possible that *H. axyridis* distinguishes the white board from others according to the brightness of color. That the yellow board was the second may support this explanation.

When the autumn is drawing to close, adults of *H. axyridis* leave the feeding habitat for the hibernation site. It seems that they are wafted by a breeze to the base of mountain, the hill valley or the hill top. Migrating beetles have a tendency to be attracted to the objects with high brightness. Such objects, whitish or light-colored for human eyes, must be noticeable in their migration route along the hill valley and regarded as the proper meeting sites for beetles. Whitish or light color may mean rather dry situation which is suitable for hibernation of beetles. Although it is desirable to research on the factors which further concentrate *H. axyridis* after landing on, a tendency to be attracted to and to land on the objects with high brightness is supposed to be important as the first step in their formation of aggregation.

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