Report

A report on four dance performances of two worker honeybees visiting the feeding station regularly within 105 m from the hive

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Abstract

Four dance performances *(round dancing; transition dancing; shaking; tremble dancing)* were observed within an observation hive in the autumn of 2000. Our observations were continued during 11 days after November 6 (Day 1). Only 2 honeybees (Nos. 862 and 874) followed to the feeders of 0-13 m from the hive. After Day 3, only No.874 visited the feeder of 15-105 m. Several recruits visited on the feeder with diluted honey on Days 1-2. No recruit flew at all, however, about the feeder with 0.5M-sucrose solution and without scent after Day 3. This may also be related to the fact that it had been cold since Day 3. Two dancers performed 4 dances except for *waggle dancing*. No.874 performed *transition dancing* even at the 105-m feeder. This may be related to the necessity of passing through 2 doors of the Mesh House, where No.874 always hesitated to enter. *Shaking* and *tremble dancing* were often observed on cold days, and/or in unsuccessful flights and in the start or end of the flights on warm days. It was discussed that *shaking* may be related to a sort of frustration, and *tremble dancing* was a 'unripe' dance performance. Discussion also concerns the psychological barrier, the sunlight, the scent, the low temperature and the worker's age, as points to be considered hereafter.

Key words: round dancing, transition dancing, tremble dancing, shaking, psychological barrier

Introduction

Although Wenner and Wells (1990) rejected the result of the mechanical dancer model by Michelsen et al. (1989) which contained serious incompleteness, Michelsen et al. (1992) showed that both wagging run and sound can be informed partially as the master components of the dance, not taking into account the six problems listed by Wenner and Wells (1990: 370-371). The above "partially" means that some honeybee workers can communicate the object information to only a few of their nestmates. The communicating manner of the object information seemed to be very different from the standard manner described by von Frisch (1967).

Wenner and Wells (1990) showed us various anomalies, and Ohtani (2000) also recently reported some anomalous results, compared with the standard of von Frisch. We recognized some great problems to be hidden in the dance performances. It may be necessary that some experimental trials on the dance performance are reported in as much detail as possible with unsuccessful circumstances and the movements of scented objects (e.g., observers themselves, observers' lunches, the feeder's food etc.).

Kirchner et al. (1988) indicated that the dance performances such as the round dance provide information about direction, being different from von Frisch's standard. Ohtani (2000) reported transition dances between the round dance and the wagging dance, based on the detailed definition of the transition dances which has been little reported up to the present.

This report is published as raw data in 2000, in progress towards more definite results in future, focusing on the transition dances.

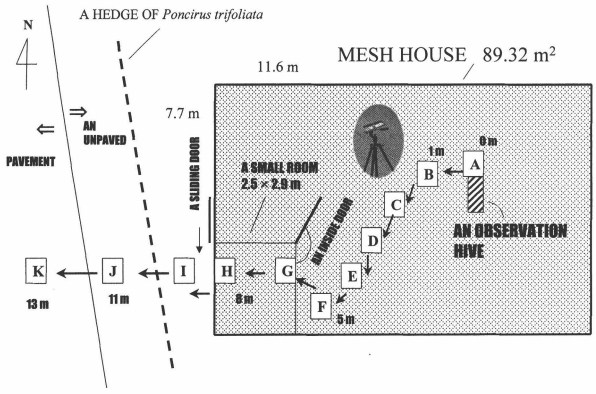


Fig.1. The A-K points of the movable feeder in the Mesh House (11.6×7.7 m). All foragers must pass through the 2 doors of the small room.

Materials and Methods

The Mesh House

After the trial in 1999 (Ohtani, 2000), we wished to make observations in a broader field to carry out further experiments on the dance performance of honeybees. We found the Mesh House (7.7×11.6 m; Fig.1) which is a greenhouse with no glass but meshed walls and roof. As we also wished to know the age of the dancers, we produced a small colony with all marked bees for observation.

When the electric heater of the old observation hive was switched on, the marked bees within the hive, always and suddenly became agitated, probably due to electromagnetic waves from the electric heating element. Then, we made a new observation hive which was placed on a metal vessel filled with water, the temperature of which was controlled by an electric heater.

The inside situation of the Mesh House was almost equivalent to outdoors. All furniture and implements were exposed to the wind, rain and sun, which often caused problems. Also, the intrusion of ants (*Lasius niger* or *Formica japonica*) caused a great fuss among the marked bees. Therefore, for the purpose of preventing ants, sticky ribbons were put on the legs of the desk on which the observation hive was placed. Many unexpected problems prevented us from carrying out spring and summer observations within the virtually outdoor Mesh House.

Used colonies and an observation hive

Usual Italian colonies (*Apis mellifera ligustica*) were purchased from API Company Limited in Nagoya City on October 24, and soon started the marking of newly emerged workers.

Our observation hive was placed (Photo 1) in the center of the Mesh House at the Gene Farm of the Museum of Nature and Human Activities, Hyogo (Fig.2; cf. Photo 5) in Sanda City (Hyogo Pref.). In total 1388 marked bees were introduced into the observation hive during 12 days (100, 200, 258, 280, 135, 0, 59, 129, 109, 57, 0 and 61 bees on respective days from October 24 to November 4). Since each newly emerged worker had finished molting on the previous day in the cell, a fresh bee was regarded as 1 day old, and was marked with a numbered paper disk or a color-spotted paper disk (Photos 2 & 3). A newly emerged queen was introduced in the observation hive on October 27 (Photo 3). When the oldest marked bees reached 14 days old on November 6 (Day 1), a feeding station was set up at the hive entrance (see, A of Fig.1), and our observations commenced. The feeding station was gradually moved further away (cf. Figs.1 & 2).

Observers and the contents of feeder

Two observers (Mr. Koga and I) were assigned to the feeding station and the observation hive. We communicated with transceivers. Sometimes we changed places. A new observer helped us on Day 10, and 2 helpers joined the last observation on Day 11.

The food contained in the feeder was diluted honey (honey : water = 1 : 1) at first, and was changed to 2M-sucrose solution at 15:00 on Day 2, and changed again to 0.5M-sucrose solution on Day 3. This weak solution kept, without scent, was then used to the last day.

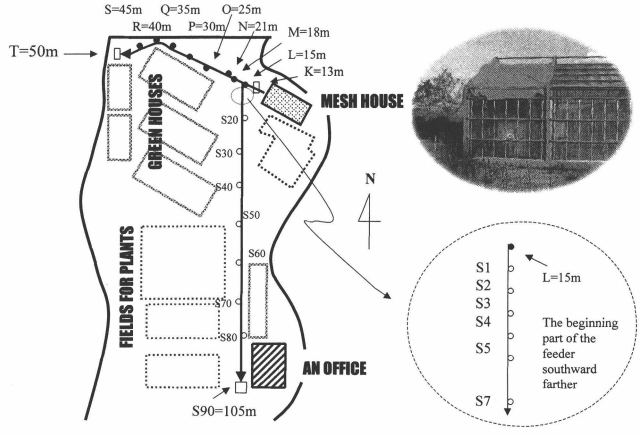


Fig.2. The experimental field in the Gene Farm of our Museum. Small circles on a line mark the location points of the movable feeder moved farther to northwest (black circles) and south (white circles).

Table 1. Behavior patterns defined by position (p) and movements (m) of main body parts, followed after Ohtani (1994) except for Lm7 (*wagging motion*) defined in the text. Gothic unmbers mean characterizing the behavior pattern.

BEHAVIOR PATTERN	CODE	Antennae		Mandble		Glossa		Head		Wings		Metasoma			Forelegs		Midlegs		Hindlegs		SHAPE OF TURNING	NO. WAGGING	CODE	REFERENCES
		Ap	Am	Mp	Mm	Gp	Gm	Hp	Hm	Wp	Wm	Tp	Tm	Genm	Lp	Lm	Lp	Lm	Lp	Lm				
1) Dancing	*DA*																						*DA*	ohtani (2000)
1a) Round dancing	Da^r	–	1,2	1	–	1	–	1	–	1,2	–	1	–	1	–	4,9	–	4,9	–	4,9	circle	0	Da^r	von Frisch (1967); Ohtani (2000)
1b) Waggle dancing	Da^w	–	1,2	1	–	1	–	1	–	1,2	–	1	7	1	–	4,9	–	4,9,10	–	4,9,10	double half circle	4+	Da^w	von Frisch (1967); Ohtani (2000)
1c) transition dancing	Da^t																						Da^t	von Frisch (1967); Ohtani (2000)
without waggling	Da^{t0}	–	1,2	1	–	1	–	1	–	1,2	–	1	–	1	–	4,9	–	4,9	–	4,9	eight	0	Da^{t0}	von Frisch (1967); Ohtani (2000)
with 1 or 2 waggling	Da^{t1}	–	1,2	1	–	1	–	1	–	1,2	–	1	7	1	–	4,9	–	4,9,10	–	4,9,10	eight	1,2	Da^{t1}	von Frisch (1967); Ohtani (2000)
with 2 or 3 waggling	Da^{t2}	–	1,2	1	–	1	–	1	–	1,2	–	1	7	1	–	4,9	–	4,9,10	–	4,9,10	eight	2,3	Da^{t2}	von Frisch (1967); Ohtani (2000)
with over 3 waggling	Da^{t3}	–	1,2	1	–	1	–	1	–	1,2	–	1	7	1	–	4,9	–	4,9,10	–	4,9,10	eight	3+	Da^{t3}	von Frisch (1967); Ohtani (2000)
2) Tremblle dancing	*TD*																						*TD*	Seeley (1992)
2a) Tremble walking	Td^w	–	1,2	1	–	1	–	1	–	1,2	–	1	–	**1**	–	4	–	4,10	–	4,10	nothing	0	Td^w	Seeley (1992)
2b) Tremble running	Td^r	–	1,2	1	–	1	–	1	–	1,2	–	1	–	**1**	–	4	–	4,10	–	4,10	nothing	0	Td^r	ohtani (2000)
3) Shaking	*Sh*/w	–	1,2	1	–	1	–	1	–	1,2	–	1	**1**	–	7	4	1	4	1	4	nothing	0	*Sh*/w	Haydak (1929); Ohtani (1994)

Am1=*Tapping*: Repeated alternate touchings of some objects. Am2=*Exploring*: Repeated alternate touchings of substrate, sometimes without actual touching. Movement more slow and gentle than in Am1.
Mp1=*Closed* Gp1=*Folded* Hp1=*Disposed properly* Wp1=*Tightly folded* Wp2=*Folded* Tp1=*Disposed properly*
Tm1=*Dorsoventral motion:* Repeated motions from Tp2 to Tp3. Tp2=*Raised* Tp3=*Lowered* Tm7=See, text Genm1=*Trembling*: Quick, vibrant movements of various body part.
Lp1=*Contracted*: In contact with substate and body sides. Lp7=*Touched*: In contact with objects other than substrate. Lm4=*Walking*: Cooperative movements of 6 legs for advancing or stepping.
Lm9=*Turning*: Sudden turning back halfway advancing. Lm10=*Swinging*: Laterally quick-and-repeated movements of meso- and metasoma.

Results with short comments

1. Dance performances described by Ohtani (2000)

Ohtani (2000) named, coded, described and used the dance performance as shown in Table 1, in which the terms defined by Ohtani (1974) and Ohtani (1994) are used, except for Tm 7 defined here:

Tm (=movements in metasoma)

7. *Wagging motion:* Repeated small motions laterally and swiftly.

There is a note on Da^{t3} (*transition dancing* with over 3 wagging motions) to be mentioned here. We often observed a more vigorous type than usual Da^{t3}. The vigorous type is similar to Da^w (*waggle dancing*), but the waggling run is unsettled and more vigorous than Da^w. In the tables of this report, the vigorous type was represented with a black circle at the right end of the table-cell.

2. Behavior of foragers on Day 1 (November 6)

The feeding station was set up at the 0-m point (Fig.1, A) from the hive entrance at 12:00. After 6 min, No.956 (13 days old) fed at the feeder and returned to the hive. Other bees that visited were Nos. 874 (13 days old), 2093 (12 days old), 2119, 2336 (11 days old) and 11023 (10 days old). At 12:19, the feeder was moved leftward 1 m from A (Fig.1, B). Five foragers, Nos. 844, 862 (14 days old), 874, 956, 10435 (11 days old), visited the B-point, till the feeder was again moved, to leftward and further away at 12:21. Such description continued to the K-point (13 m), which is compactly shown in Table 2.

Table 2. The movable points of the feeder, where visited worker honeybees were counted on Day 1 (November 6, 2000).

POINT OF FEEDER[1)]	DISTANCE FROM HIVE ENTRANCE	START TIME (MIN OF DURATION)	INDIVIDUAL NO. OF A VISITED BEE (AGE)	TOTAL VSITORS
A	0 m	12:00 (19)	874(13), 956(13), 2093(12), 2119(11), 2336(11), 11023(10)	6
B	1 m	12:19 (17)	844(14), 862(14), 874(13), 956(13), 10435(11)	5
C	2 m	12:36 (8)	844(14), 862(14), 874(13), 956(13), 10435(11)	5
D	3 m	12:44 (4)	956(13), 10435(11)	2
E	4 m	12:48 (5)	874(13), 956(13), 2093(12)	3
F	5 m	12:53 (17)	874(13), 956(13), 2093(12), 2336(11) 10435(11)	5
・・・・・・・・・・ *the feeder closed during 20 min* ・・・・・・・・・・				
F	5 m	13:30 (14)	862(14), 874(13), 956(13), 2093(12), 2291(11), 2336(11) 10435(11)	7
G	6 m	13:44 (4)	862(14), 874(13), 956(13), 2291(11), 2336(11) 11023(10)	6
H	8 m	13:48 (10)	811(14), 862(14), 2093(12), 2336(11) 5453(13), 5504(13)	6
I	9 m	13:58 (30)	862(14), 874(13), 5343(14), 5504(13), 11000(10)	5
J	11 m	14:29 (15)	862(14), 874(13), 5354(14), 5453(13)	4
K	13 m	14:44 (90)	862(14), 874(13), 5350(14), 5354(14)	4

[1)] See, Fig.1, A-K.

In the middle of the experiment, the F-point feeder was closed for 20 min for another purpose (see, Table 2). Only 2 individuals (Nos. 862 and 874; cf. Photo 2) followed the feeder to the K-point (13 m) when our observations finished at 16:15.

The detailed observations to Nos. 874 and 862 were shown in Tables 3 and 4, respectively. No.874 repeated 18 round trips, but performed ***Da***^{r} (*round dancing*) and ***Da***^{t1} (*transition dancing* with 1 or 1.5 wagging motions) only after 2 returns from the trips to F-point (Table 3). On the other hand, No.862 performed 1 ***Da***^{r} and 14 ***Da***^{t1} in returning from 28 round trips (Table 4).

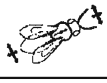
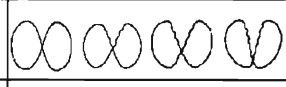
3. Nos. 862 and 874 at the1 3-m feeder on Day 2 (November 7)

It was a clear day from the early morning. In course of preparation, No.874 visited soon (within 1 min) at 9:45 when the feeder with diluted honey was placed at the K-point, 13 m from the hive entrance. We thought that it was sure to repeat the waggle dance of 1978 (the 14-m fixed feeder, cf. Ohtani, 2000). However, regrettably, No.874 did not perform ***Da***^{w} (*waggle dancing*) but the vigorous type of ***Da***^{t3} (*transition dancing* with over 3 wagging motions) even after many round trips (76 times !) (Table 5). Late starting No.862 also performed not ***Da***^{w} but ***Da***^{t3} in 50 round trips (Table 6). ***Sh*** (*shaking*) were observed in the 2nd trip from the last of No.874 and in the 2nd trip of No.862. ***Td***^{r} (*tremble running*) were also observed at the beginning or end of round trips (Tables 5 and 6).

No.874 seemed to be a little tired after the 47 th trip (13:54). Observers were also tired, and began to think about something to stimulate the circulation of blood for us and also for bees. After 1 hour, we thought of replacing the diluted honey as food into the 2M-sucrose solution without scent. We executed this idea, but it assumed to slightly perplex of No.874, that is, she performed frequent ***Sc***^{t} (*metasoma cleaning*) on the feeder and on the comb of the observation hive, and did not dance for a while.

Several other foragers always visited the K-point feeder during the observation of Nos. 862 and 874 (Table 7). Five new-comers among a total of 11 visitors (including Nos. 862 & 874) came for the first time to the feeder and made trips regularly from 10:00 to 16:15. There were several new-comers in addition to the above regular visitors, but the observer of the feeder could not read their numbers in the

Table 3. Dance performances of a forager (No.874, 13 days old) visited the A-K points of the movable in the Gene Farm of Museum of Nature and Human Activities, Hyogo. All behaviors were observed in the observation hive within the Mesh House on November 6, 2000 (Day 1). There are observed cases (● or ◎) and non-observed cases (× or a blank).

BEHAVIOR	*shaking*[1]	*tremble dancig*[2]	*round dancing*	*transition dancing*[3]				*waggle dancing*	FEEDING	
CODE	***Sh***	***Td***^{r} ←***TD***→***Td***^{w}	***Da***^{r}	***Da***^{t0}	***Da***^{t1}	***Da***^{t2}	***Da***^{t3}	***Da***^{w}	PLACE	
TRIP									DISTANCE FROM HIVE POINT	(m)
1[4]			×	×	×	×	×	×	A	0
2			×	×	×	×	×	×	B	1
3			×	×	×	×	×	×	C	2
4			×	×	×	×	×	×	E	4
5			●						F	5
6			×	×	×	×	×	×	F	5
7			×	×	×	×	×	×	F	5
8			×	×	×	×	×	×	F	5
9			×	×	×	×	×	×	F	5
10					●				F	5
11			×	×	×	×	×	×	F	5
12			×	×	×	×	×	×	G	6
13		◎	×	×	×	×	×	×	I	9
14			×	×	×	×	×	×	I	9
15		◎	×	×	×	×	×	×	J	11
16			×	×	×	×	×	×	K	13
17		◎	×	×	×	×	×	×	K	13
18[5]			×	×	×	×	×	×	K	13

[1] Fletcher (1978) used 'vibratory dance', and Seeley (1995) prefered 'shaking signal'. The woodcut of shaking is copied from Hammann (1957).

[2] Seeley (1992) used tremble dance.The woodcut is a part of the figure by Seeley (1992).

[3] Von Frisch (1967) divided ***Da***^{t} into 4 sub-types as 4 woodcuts shown below. The woodcuts of ***Da***^{r} and ***Da***^{w} also from von Frisch (1967).

[4] The start time was 12:17. [5] The finish time was 16:12。

concentration of over 5 individuals.

4. *Tremble dancing* by No.874 on Days 3-5

Day 3 (November 8): As we could not observe *waggle dancing* in relation to the K-point feeding station, we decided to try moving the feeder to more distant station. The food on the feeder was the 0.5M-sucrose solution without scent. The wind rose, however, the clouds moved, and the air temperature gradually became lower (see, Fig.3). Probably due to such deterioration of weather, No.862 ceased to visit the feeder, and No.874 showed low activity (10 round trips) and did not perform ***DA*** (*dancing*) but ***TD*** (*tremble dancing*) as if it were another individual (Table 8a).

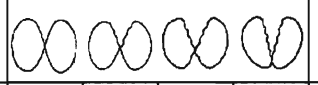
Most other foragers also ceased to visit, but Nos. 5453 and 2020 visited the feeder. No.5453 visited at 10:28 and 11:17. On the 2nd visit, No.5453 was slow to land on the feeder, and did not feed after landing, probably because of a new observer (a shift in work). No.2020 visited 8 times during 11:30 to 12:02, but did not feed but flew around the feeder. Nos. 2020 and 5453 seemed to smell the new observer, because they hovered briefly in front of the observer.

The feeder was moved to the M-point of 18 m via the L-point of 15 m from the K-point of 13 m.

Day 4 (November 9): The temperature was lower than on Day 3 (cf. Fig.3). Only No.874 performed ***TD*** (*tremble dancing*) and ***Sh*** (*shaking*) (Table 8b) in the low activity (9 trips) as Day 3. None of other foragers visited the feeder, which was moved to the N-point feeder of 21 m (See, Photo 4). No.862 never came back as a regular visitor.

Day 5 (November 10): The temperature of the early morning was the lowest recorded during this experiment (cf. Fig.3). No.874 was only a regular visitor. The weather was not clear in the morning, but as the sun sometimes appeared in the afternoon, the air temperature gradually rose to exceed 15℃. However, No.874 never performed ***DA*** (*dancing*) but

Table 4. Dance performances of No.862 (14 days old) visited the A-K points of the movable feeder in the Gene Farm of our museum. All behaviors were observed cases (● or ◎) and non-observed cases (× or a blank).

BEHAVIOR	*shaking*	*tremble dancig*	*round dancing*	*transition dancing*				*waggle dancing*	FEEDING PLACE	
CODE	*Sh*	$Td^r \leftarrow TD \rightarrow Td^w$	Da^r	Da^{t0}	Da^{t1}	Da^{t2}	Da^{t3}	Da^w		
TRIP									DISTANCE FROM HIVE POINT	(m)
1[1]			×	×	×	×	×	×	B	1
2			×	×	×	×	×	×	B	1
3			×	×	×	×	×	×	C	2
4			×	×	×	×	×	×	C	2
5			●						F	5
6			×	×	×	×	×	×	F	5
7			×	×	×	×	×	×	G	6
8					●				H	8
9			×	×	×	×	×	×	I	9
10			×	×	×	×	×	×	I	9
11			×	×	×	×	×	×	I	9
12			×	×	×	×	×	×	I	9
13					●				J	11
14					●				J	11
15					●				K	13
16			×	×	×	×	×	×	K	13
17						●			K	13
18							●		K	13
19							●		K	13
20							●		K	13
21							●		K	13
22					●				K	13
23			×	×	×	×	×	×	K	13
24			×	×	×	×	×	×	K	13
25					●				K	13
26					●				K	13
27					●				K	13
28[2]					●				K	13

[1] The start time was 12:25. [2] The finish time was 16:12。

Table 5. Dance performances of No.874 (14 days old) visited regularly the K points of the feeder in the Gene Farm of our Museum. All behaviors were observed in the observation hive on November 7, 2000 (Day 2). There are observed cases (● or ◎) and non-observed cases (× or a blank). The vigorous type of ***Da***^{t3} is shown in right end of the cell.

BEHAVIOR	*shaking*	*tremble dancig*	*round dancing*	*transition dancing*				*waggle dancing*	FLIGHT TIME[1]		FEEDING PLACE	
CODE	*Sh*	*Td*^{r} ←*TD*→ *Td*^{w}	*Da*^{r}	*Da*^{t0}	*Da*^{t1}	*Da*^{t2}	*Da*^{t3}	*Da*^{w}	HIVE ↓ FEEDER	FEEDER ↓ HIVE	DISTANCE FROM HIVE	
TRIP											POINT	(m)
1[2]			×	×	×	×	×	×	—	—	K	13
2		◎	×	×	×	×	×	×	—	—	K	13
3		◎			●				30	—	K	13
4					●				75	35	K	13
5						●			20	40	K	13
6						●			30	—	K	13
7							●		10	—	K	13
8							●		—	40	K	13
9			×	×	×	×	×	×	—	—	K	13
10							●		10	—	K	13
11							●		5	—	K	13
12							●		40	20	K	13
13							●		160	60	K	13
14			×	×	×	×	×	×	45	—	K	13
15						●			—	15	K	13
16							●		50	30	K	13
17							●		20	—	K	13
18							●		—	—	K	13
19							●		30	40	K	13
20							●		30	—	K	13
21	—	—	—	—	—	—	—	—	—	—	K	13
22							●		30	—	K	13
23							●		35	—	K	13
24							●		25	55	K	13
25							●		10	—	K	13
26			×	×	×	×	×	×	—	—	K	13
27							●		—	—	K	13
28							●		35	30	K	13
29							●		10	—	K	13
30							●		15	—	K	13
31			×	×	×	×	×	×	—	—	K	13
32							●		—	—	K	13
33							●		—	—	K	13
34							●		—	—	K	13
35			×	×	×	×	×	×	25	—	K	13
36							●		—	—	K	13
37				VIGOROUS TYPE			●		—	35	K	13
38							●		—	—	K	13
39							●		—	—	K	13
40							●		—	—	K	13
41			×	×	×	×	×	×	—	—	K	13
42							●		20	25	K	13
43							●		—	—	K	13
44							●		10	—	K	13
45							●		20	—	K	13
46							●		—	30	K	13
47			×	×	×	×	×	×	20	—	K	13
48			×	×	×	×	×	×	—	20	K	13
49			×	×	×	×	×	×	15	—	K	13
50							●		15	—	K	13
51			×	×	×	×	×	×	—	15	K	13
52			×	×	×	×	×	×	10	—	K	13
53							●		15	20	K	13
54							●		—	—	K	13
55							●		20	—	K	13
56							●		—	—	K	13
57			×	×	×	×	×	×	15	25	K	13
58			×	×	×	×	×	×	—	—	K	13
59			●						15	—	K	13
60			×	×	×	×	×	×	—	—	K	13
61			×	×	×	×	×	×	10	—	K	13
62			×	×	×	×	×	×	—	—	K	13
63			×	×	×	×	×	×	—	—	K[4]	13
64			×	×	×	×	×	×	—	—	K	13
65			×	×	×	×	×	×	—	—	K	13
66			×	×	×	×	×	×	—	65	K	13
67			×	×	×	×	×	×	30	35	K	13
68			×	×	×	×	×	×	—	—	K	13
69			×	×	×	×	×	×	—	—	K	13
70							●		10	—	K	13
71							●		—	40	K	13
72							●		—	—	K	13
73		◎	×	×	×	×	×	×	—	—	K	13
74		◎	×	×	×	×	×	×	—	—	K	13
75	◎						O[5]		—	25	K	13
76[3]		◎	×	×	×	×	×	×	30	—	K	13

[1] From the 5-s scaled paper registered the comunication by tranceivers. 2) The round trip started at 9:45.

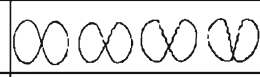
[3] The round trip finished at 16:35. [4] The deluted honey was changed into 2M sucrose solution. [5] The longer waggling was once observed.

only ***Sh*** (*shaking*) and ***TD*** (*tremble dancing*) (Table 8c). Other foragers (not visitors) performed ***Da***^{t3} (*transition dancing* with over 3 wagging motions) on the cell surface (Nos.915, 5352 & 5452). No.874 often continued lengthy ***Td***^{w} (*tremble walking*; av. ca.9 min-14 cases), changed ***Td***^{r} (*tremble running*) gradually, and at last performed ***Er*** (*excited running*) mostly after w***Fe***/w (*feeding* to another worker). There was an obscure boundary between ***Td***^{w} and ***Td***^{r} or between ***Td***^{r} and ***Er***, in other words, a smooth transition between the 3 behaviors (***Td***^{w}→***Td***^{r}→***Er***). When the pattern of ***Td***^{w}→***Td***^{r}→***Er***→***Go*** (*going out*) was repeated 8 times, an idea hit me:would surplus energy for flying change the power for dancing if the feeder was all at once moved close to the hive ?

5. An experimental trial on Day 5

After the 8th trip on Day 5, an experimental trial was executed forcibly (Table 8c, EXP1 & EXP2). We moved the feeder to the H-point of 8 m from the N-

Table 6. Dance performances of No.862 (15 days old) visited the K points of the feeder in the Gene Farm. All behaviors were observed in the observation hive on Day 2. There are observed cases (● or ◎) and non-observed cases (× or a blank).

BEHAVIOR	*shaking*	*tremble dancig*	*round dancing*	*transition dancing*				*waggle dancing*	FLIGHT TIME		FEEDING PLACE	
CODE	*Sh*	*Td*^{r} ←*TD*→*Td*^{w}	*Da*^{r}	*Da*^{t0}	*Da*^{t1}	*Da*^{t2}	*Da*^{t3}	*Da*^{w}	HIVE ↓ FEEDER	FEEDER ↓ HIVE	DISTANCE FROM HIVE	
TRIP											POINT	(m)
1[1]		◎	×	×	×	×	×	×	—	—	K	13
2	◎		×	×	×	×	×	×	—	—	K	13
3					●				—	—	K	13
4			×	×	×	×	×	×	—	—	K	13
5						●			—	—	K	13
6						●			—	—	K	13
7							●		—	—	K	13
8							●		50	—	K	13
9							●		—	—	K	13
10			×	×	×	×	×	×	—	—	K	13
11							●		—	—	K	13
12			×	×	×	×	×	×	—	—	K	13
13					●				—	—	K	13
14						●			—	—	K	13
15			×	×	×	×	×	×	20	—	K	13
16			×	×	×	×	×	×	—	—	K	13
17							●		—	—	K	13
18			×	×	×	×	×	×	—	—	K	13
19							●		—	—	K	13
20						●			—	—	K	13
21							●		—	—	K	13
22							●		—	—	K	13
23			×	×	×	×	×	×	—	—	K	13
24							●		—	—	K	13
25			×	×	×	×	×	×	—	—	K	13
26			×	×	×	×	×	×	—	—	K	13
27							●		—	—	K	13
28							●		—	—	K	13
29							●		—	—	K	13
30							●		—	—	K	13
31						●			—	—	K	13
32			×	×	×	×	×	×	—	—	K	13
33							●		—	—	K	13
34						●			—	—	K	13
35							●		—	—	K	13
36							●		—	—	K	13
37			×	×	×	×	×	×	—	—	K	13
38			×	×	×	×	×	×	—	—	K	13
39			×	×	×	×	×	×	—	—	K	13
40			×	×	×	×	×	×	—	—	K[2]	13
41			×	×	×	×	×	×	—	—	K	13
42						●			—	—	K	13
43						●			—	—	K	13
44			×	×	×	×	×	×	—	—	K	13
45							●		—	—	K	13
46						●			—	—	K	13
47						●			—	—	K	13
48							●		—	—	K	13
49				●	●				—	—	K	13
50[3]	—	—	—	—	—	—	—	—	—	—	K	13

[1] The round trip started at 11:33.

[2] The deluted honey was changed into 2M sucrose solution. [3] The trip finished at 16:11.

Table 7. A visiting record every 30 min by honey bees landed on the K-point feeder of 13 m from the hive on November 7, 2000. Several visitors were not registered, as the observer could not read their individual number. 'FOOD' means the food on the feeder and 'AGE' is the number of days after the emergence day.

INDIVIDUAL NO.[1]	→	835	**862**	**874**	967	2020	5404	5414	**5453**	**5504**	10135	**10435**	
TIME ZONE	FOOD / AGE→	15	15	14	14	13	15	14	14	14	13	12	TOTAL
10:00 – 10:30	diluted honey			○									1
10:30 – 11:00	diluted honey			○									1
11:00 – 11:30	diluted honey	○		○	○				○	○			5
11:30 – 12:00	diluted honey	○	○	○	○				○	○			6
12:00 – 12:30	diluted honey		○	○	○			○	○	○			6
12:30 – 13:00	diluted honey		○	○	○			○	○	○		○	7
13:00 – 13:30	diluted honey		○	○	○			○	○	○		○	7
13:30 – 14:00	diluted honey		○	○	○	○	○	○	○	○		○	9
14:00 – 14:30	diluted honey		○	○	○	○		○	○	○			7
14:30 – 15:00	diluted honey		○	○		○			○	○			5
15:00 – 15:30	2M sucrose		○	○		○			○	○			5
15:30 – 16:00	2M sucrose		○	○					○	○	○		5
16:00 – 16:30	2M sucrose		○	○					○	○	○		5

[1] Gothic numbers mean the foragers which visited the feeder on November 6 (cf. Table 2).

point of 21 m, and shut the sliding door of the small room in the Mesh House (see, Fig.1; Photo 4). No. 874 went out at 13:06:05. The behavior sequence of No.874 was redrawn in Fig.4 from the register paper with 5-s scale. She bumped her head 3 times against the wire gauze of the sliding door, and soon returned to the hive, without seeking the feeder placed on the H-point. No.874 seemed to sense danger from 3 strikes on the head and the obstruction of her flight. She performed ***Er*** (*excited running*) and ***Td'*** (*tremble running*) on the cell surface within the hive.

No.874 went out again at 13:10:00. She bumped again her head against the wire gauze of the door, and sat on it for 50 s, as if thinking about the predicament of impossible advance. She flew about wistfully before the gauze for 10 s after flying out at 13:11:00, and then returned to the hive. While she performed ***Td"*** within the hive, the feeder was returned to the N-point of 21 m. No.874 continued ***Td"*** (*tremble walking*) for about 15 min, and then performed ***Sh*** (*shaking*) once on another bee during ***Er*** (*excited running*) at 13:37:00. Then, she flew out as the 9th trip after the sequence of ***Sc'***→w/***Fe***→ ***Sc'*** →***Er***, and as usual landed on the N-point feeder. Only one ***Sh*** (*shaking*) appeared again at 13:42:55 (cf. Fig.4; Table 8c).

Our experimental trial (the shortening of flight path) resulted in the appearance of not ***DA*** (*dancing*) but ***Sh*** (*shaking*), probably because it had invited a sort of frustration rather than a surplus of energy.

6. The resumption of *DA (dancing)* by No.874

A supposition on Day 5: Dr. H. Ikeno (a partner in a Grant-in-Aid for Scientific Research) visited the Mesh House for information on Day 5. From the discussion with him, I was struck by a supposition on the behavior of No.874 (only underestimation of the bad weather). There were 2 doors to the small room of the Mesh House (cf. Fig.1). No.874 always had to pass through a narrow gallery (0.9×1.8×2.5 m). When she would return to the hive, especially, she had to aim for and enter a gaping hole of 0.9×1.8 m (cf. Photo 5), which became relatively smaller as the feeder was moved farther away. The psychological barrier of diving to the narrow gallery must disturb the stability of a flight path, which was conjectured as a cause of ***DA*** (Ohtani, 2000). For the purpose of seeking the critical distance from ***TD*** (*tremble dancing*) to ***DA*** (*dancing*), the feeder must be neared the hive.

Day 6 (November 11): As the weather was changeable, the air temperature became gradually lower, and it was the coldest day during our observation (cf. Fig.3). Our hands were nearly numb, making writing difficult. No.874 started to visit the P-point of the feeder, and performed once ***Da'*** (*round dancing*) after the 1st trip and once ***Da'²*** (*transition dancing* with 2 or 2.5 wagging motions) after the 2nd trip (see, ○ in Table 9a), but our "nearing trial" was executed. No ***DA*** (*dancing*) had been observed from the 3rd trip to the 7th trip (Table 9a). Although No.874 did not land on the feeder in her 5th trip, probably because of the low temperature, she performed usual ***Td'*** (*tremble running*) and ***Td"*** (*tremble walking*).

Table 8. Dance performances of No. 874 (15-17 days old) visited the feeder of K-P points on Days 3-5 (November 8-10, 2000). There are observed cases (◎) and non-observed cases (× or a blank).

BEHAVIOR / CODE / TRIP	*shaking*	*tremble dancig*		*round dancing*	*transition dancing*				*waggle dancing*	FLIGHT TIME		FEEDING STATION	
	Sh	*Td*^{r} ←*TD*→ *Td*^{w}		*Da*^{r}	*Da*^{t0}	*Da*^{t1}	*Da*^{t2}	*Da*^{t3}	*Da*^{w}	HIVE ↓ FEEDER	FEEDER ↓ HIVE	DISTANCE FROM HIVE POINT	(m)
a: Day 3 (November 8, 2000), observed from 10:00 to 13:57.													
1[1]		◎[2]	◎	×	×	×	×	×	×	30	25	K	13
2		◎	◎	×	×	×	×	×	×	25	20	K	13
3		◎	◎	×	×	×	×	×	×	20	—	K	13
4		◎	◎	×	×	×	×	×	×	20	25	K	13
5		◎	◎	×	×	×	×	×	×	15	40	K	13
6		◎	◎	×	×	×	×	×	×	—	—	L	15
7[3]				×	×	×	×	×	×	115	25	L	15
8		◎	◎	×	×	×	×	×	×	—	—	L	15
9		◎	◎	×	×	×	×	×	×	—	—	M	18
10[4]		◎	◎	×	×	×	×	×	×	—	35	M	18
b: Day 4 (November 9, 2000), observed from 10:00 to 16:08.													
1[5]				×	×	×	×	×	×	—	—	M	18
2				×	×	×	×	×	×	20	—	M	18
3[6]				×	×	×	×	×	×	5	—	M	18
4	◎	◎	◎	×	×	×	×	×	×	20	40	M	18
5	◎	◎	◎	×	×	×	×	×	×	115	40	M	18
6		◎		×	×	×	×	×	×	25	30	M	18
7		◎	◎	×	×	×	×	×	×	15	—	M	18
8		◎		×	×	×	×	×	×	75	40	N	21
9[7]		◎		×	×	×	×	×	×	40	40	N	21
c: Day 5 (November 10, 2000), observed from 10:00 to 17:00.													
1[8]	◎	◎	◎	×	×	×	×	×	×	—	15	N	21
2		◎	◎	×	×	×	×	×	×	10	—	N	21
3		◎	◎	×	×	×	×	×	×	15	25	N	21
4		◎	◎	×	×	×	×	×	×	20	—	N	21
5		◎	◎	×	×	×	×	×	×	15	130	N	21
6		◎	◎	×	×	×	×	×	×	15	—	N	21
7		◎	◎	×	×	×	×	×	×	20	—	N	21
8		◎	◎	×	×	×	×	×	×	15	20	N	21
EXP1.[9]		◎		×	×	×	×	×	×	5	—	H	8
EXP2.[9]	◎	◎		×	×	×	×	×	×	5	5	H	8
9	◎	◎	◎	×	×	×	×	×	×	40	10	N	21
10		◎	◎	×	×	×	×	×	×	15	15	N	21
11		◎	◎	×	×	×	×	×	×	25	—	O	25
12		◎	◎	×	×	×	×	×	×	—	15	O	25
13		◎	◎	×	×	×	×	×	×	135	10	O	25
14	◎	◎	◎	×	×	×	×	×	×	35	10	P	30
15[10]	◎			×	×	×	×	×	×	—	20	P	30

[1] The round trip started at 10:55. [2] All small double circles mean a bit of observation.

[3] The bee smelled the observer's lunch, but did not land on.

[4] The trip finished at 13:25. [5] The trip started at 10:19, but No.874 returned the hive soon. because the air temperature was only 13.3 ℃.

[6] The bee came to the feeder at 11:35, but did not land on. [7] The flight finiched at 15:37.

[8] The trip of Day 5 started at 10:12. [10] The trip finished at 16:24.

[9] We moved the feeder, suddenly and all at once, to the H-point of 8 m from the N-point of 21 m, and shutted the sliding door of a small rooom in the Mesh House. No.874 bumped against and sat on a wire gauze of the door, but never landed on the feeder.

The feeder was moved to the M-point of 18 m after the 8th trip, but No.874 did not go out afterwards.

Day 7 (November 12): As the temperature inside the hive was lower than 35℃ because Day 6 was too cold, the heater thermostat was set to a higher level than usual. This resulted in a hive temperature of 40℃ at 9:00 and the bees dispersed to peripheral corners. After half an hour, the bees settled down to their normal position, but No.874 had disappeared from view.

She was found at 10:38:45 inside of a polyethylene shopping bag left in the Mesh House. She might have been seeking food. As she soon returned to the hive, our observation started at 10:39:00. She performed ***Sh*** (*shaking*) very frequently, probably because of frustration that she could not visit the feeder (the doors of the small room were closed), and then flew out and visited the M-point of the feeder (18 m).

Da^{r} (*round dancing*) was observed after her 2nd and 3rd trip, and changed to ***Da***^{t2} (*transition dancing* with 2 or 2.5 wagging motions) from her 4th trip (15 m from the hive). We thought that we could find out the critical distance from ***TD*** to ***DA***. Therefore, the

Table 9. Dance performances of No. 874 (18 & 19 days old) visited the feeder on Days 6 and 7. There are observed cases (◎, ○ or ●) and non-observed cases (× or a blank). The vigorous type of Da^{t3} is shown in right end of the cell.

BEHAVIOR / CODE / TRIP	*shaking* Sh	*tremble dancig* $Td^r \leftarrow TD \rightarrow Td^w$	*round dancing* Da^r	*transition dancing* Da^{t0}	Da^{t1}	Da^{t2}	Da^{t3}	*waggle dancing* Da^w	FLIGHT TIME HIVE ↓ FEEDER	FLIGHT TIME FEEDER ↓ HIVE	FEEDING PLACE DISTANCE FROM HIVE POINT	(m)
a: Day 6 (November 11, 2000), observed from 10:00 to 15:50.												
1[1]		◎[2] ◎	○[3]						20	55	P	30
2		◎ ◎				○[3]			20	15	P	30
3		◎ ◎	×	×	×	×	×	×	25	25	O	25
4		◎ ◎	×	×	×	×	×	×	15	15	O	25
5[4]		◎ ◎	×	×	×	×	×	×	15	70	N	21
6		◎	×	×	×	×	×	×	25	20	N	21
7[5]		◎ ◎	×	×	×	×	×	×	20	45	N	21
b: Day 7 (November 12, 2000), observed from 10:00 to 16:00.												
0	◎		×	×	×	×	×	×	—	—	—	—
1[6]		◎ ◎	×	×	×	×	×	×	5	—	M	18
2		◎	●						—	20	M	18
3			●						25	15	L	15
4						●			—	10	L	15
5						●			15	10	L	15
6						●			15	35	M	18
7		◎[7]				●			20	15	M	18
8						●			20	30	N	21
9						●			—	10	N	21
10							●		15	20	O	25
11							●		20	15	O	25
12								●	15	30	P	30
13								●	10	25	P	30
14				VIGOROUS TYPE				●	—	25	Q	35
15								●	35	20	Q	35
16								●	160	60	R	40
17								●	15	45	R	40
18[8]				NO LANDING →				●	70	45	S	45
19		◎				○[9]			130	155[10]	S	45
20								●	25	25	S	45
21								●	25	25	T	50
22								●	—	15	T	50
23								●	25	15	T	50
24				VIGOROUS TYPE				●	25	20	T	50
25								●	25	10	T	50
26[11]								●	20	15	T	50

[1] The round trip started at 10:20. [2] A bit of observation. [3] Once observed.

[4] No.874 approached the feeder, but never landed on it. [5] The trip finished at 13:29.

[6] The flight started at 11:00, after very frequent *Sh* were observed. [7] Once observed with a turning movement.

[8] No.874 approached the feeder and returned the hive without landing, but performed Da^{t3}.

[9] It was 2 or 3 waggling runs without a turning movement that we observed.

[10] No.874 fell to the ground because of a strong wind, and then rested for a while on the ground near the hive. [11] The trip finished at 15:41.

reverse process was executed. The feeder was moved farther away soon after No.874 visited twice at the same point. However, no change from ***DA*** (*dancing*) to ***TD*** (*tremble dancing*) was observed. On the contrary, vigorous Da^{t3} was observed after she visited the P-point at 30 m, and continued to the final distance (50 m) and the final flight (the 26th trip). We had to adopt only a rise in temperature (cf. Fig.3) rather than the psychological barrier of diving to the narrow gallery.

There was another psychological influence on the 18th trip. No.874 neared the feeder, but could not land on it. After returning to the hive, she usually performed Da^{t3}. A psychological effect of not landing seemed to appear in the next (19th) trip. After feeding at the feeder, she fell to the ground because of a strong wind, and then rested for a while (about 2 min) on the ground near the hive entrance. Her behavior inside the hive was somewhat abnormal: she performed Td^r (*tremble running*) and twice the 2 or 3 waggling run without a turning movement (regarded as Da^{t2} in Table 9). There seemed to be 2 elements in Da^t (*transition dancing*): waggling run and 2 turning movements. In relation to this, we observed the interesting behavior, Td^w with a sort of turning movement, after returning from the 7th trip.

7. *Transition dancing* at the feeder 50 m distant on Day 8 (November 13)

The T-point of the feeder was 50 m distant from the hive (cf. Photo 6). As it was placed at a dead end, it was regarded as the fixed feeder in Day 8. As one observer had a holiday, another observer worked at 2 places: the observation hive and the feeder. Day 8 was a clear day. The feeder was opened at 10:00. About 7 min later, No.874 landed on the feeder (10:06:50). No.874 began to perform the vigorous ***Da***^{t3} (*transition dancing* with over 3 wagging motions) from the 3rd trip (Table 10). She seemed to be tired after the 27th trip. 'Nondance' was observed only twice, one of which was a case of failing to reach the feeder after the 31st trip.

The experimental trial was repeated in returning from the 16th visit and the 19th visit: No.874 was shut out for 3 or 5 min outside the sliding door of the small room in the Mesh House (Table 10). She did not sit on the wire gauze of the door, but flew around the Mesh House. Soon after the door was opened, she entered the Mesh House in her usual manner, and performed as usual a vigorous ***Da***^{t3} (Table 10).

8. Moving the feeder once nearer to the hive and further away toward other direction on Day 9 (November 14)

We wanted to observe ***Da***^{w} (*waggle dancing*) which had never been performed by No.874 so far. Accordingly, we wanted to move the feeder much further away. Since the T-point was a dead end, however, we had to move the feeder once nearer toward the hive.

It was a clear day. Air temperature was 12.5℃ at 10:00, but 15.3℃ by 11:00, and then it was over 15℃ to the end of the observation. No.874 was the most active that she had been in her life. The average time per 1 trip (flights + intranidal time) was 8.05 min. This was longer than that of Day 2 (5.39 min), but the distance to the feeder was different, and No.874 performed dancing after all trips on Day 9. We were too busy writing to eat lunch.

The feeder was moved to the L-point, 15 m from the hive on the 17th trip. The feeder began to be moved farther to the south (cf. Fig.2; Table 11). It reached the S50-point of 50 m from L-point, i.e. 65 m from the hive, but No.874 did not perform ***Da***^{w}. Only

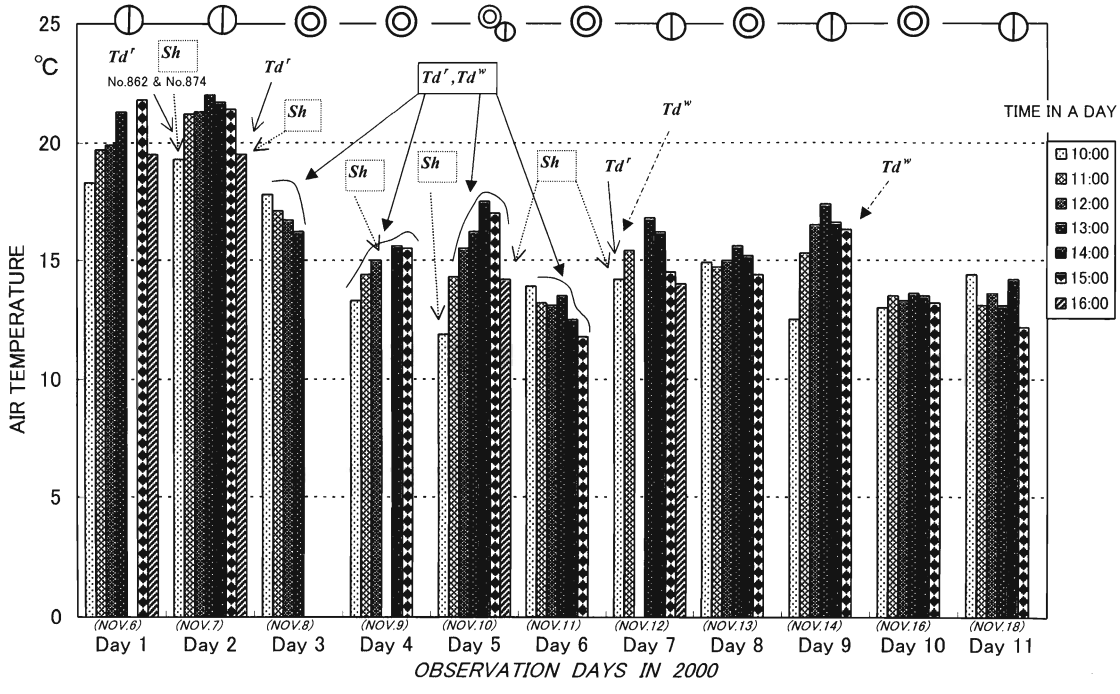


Fig.3. The daily change of air temperature in each observation day. It is also added within the figure when and where ***Sh*** (*shaking*), ***Td***^{r} (*tremble running*) and ***Td***^{w} (*tremble walking*) were observed in the observation hive. The weather symbol representing a day (or half day) is shown in the top of the figure (◯:a clear or nearly clear day;◎:a cloudy or changeable day).

Td *(tremble walking)* were observed in the last 2 trips (Table 11).

9. The evening of No.874's life on Days 10 and 11

November 15 was a rainy day. We suspended our observations.

Day 10 (November 16): It was a cold (13.0-13.5℃) and unsettled day. No.874 was 23 days old. She was not active, probably due to the cold, and her age. She did not visit the feeder of S60-point in the 4th and5th trips, just when it caught the sun on the wire gauze of the south wall. We missed her on her 4th trip, but a new observer (Mr. J. Matsubayashi) found No.874 who flew straight toward and sat on the wire gauze of the south wall (nearby the F-point, see Fig.1). She probably tried to shorten her usual flight-path with attraction of the direct sunlight. She performed ***Da***^{t} without the filled honeystomach after the 4th trip, but nondance after the 5th trip. Her behavior became very slow. In the 10th (last) trip, she took much time in flying out from the feeder and in entering the Mesh House because of the coldness and/or her age. No.874 performed an abnormal ***Da***^{t2} with only waggling and no turning movement (see, ○ in Table 12a). The feeder was moved to the S80-point of 95 m.

November 17 was a rainy day in the morning, and cloudy in the afternoon. We suspended our observations.

Day11 (November 18): It was a clear but cold (12.2-14.4℃) day. No.874 unsteadily performed all her behaviors because of her age and/or the coldness. She could not visit in almost half of her trips (1st, 2nd, 4th, 9th, 13th and 14th flights, see, Table 12b), when she did not dance at all. She could not reach the feeder in the 1st, 2nd, 4th and 13th trips. The memory center in her brain might have been numbed because of the cold. On the 9th and 14th trips, she tried to take a short cut, but her flight was stopped by the wire gauze of the south wall as on Day 10. Since she did not return to the hive from the gauze in the 14th (last) trip, we caught her with an insect net, and released her outside the Mesh House. She landed on the ground of the S90 -point (without the feeder) before she reached the S 100-point feeder of 115 m. No.874 did not go to the S

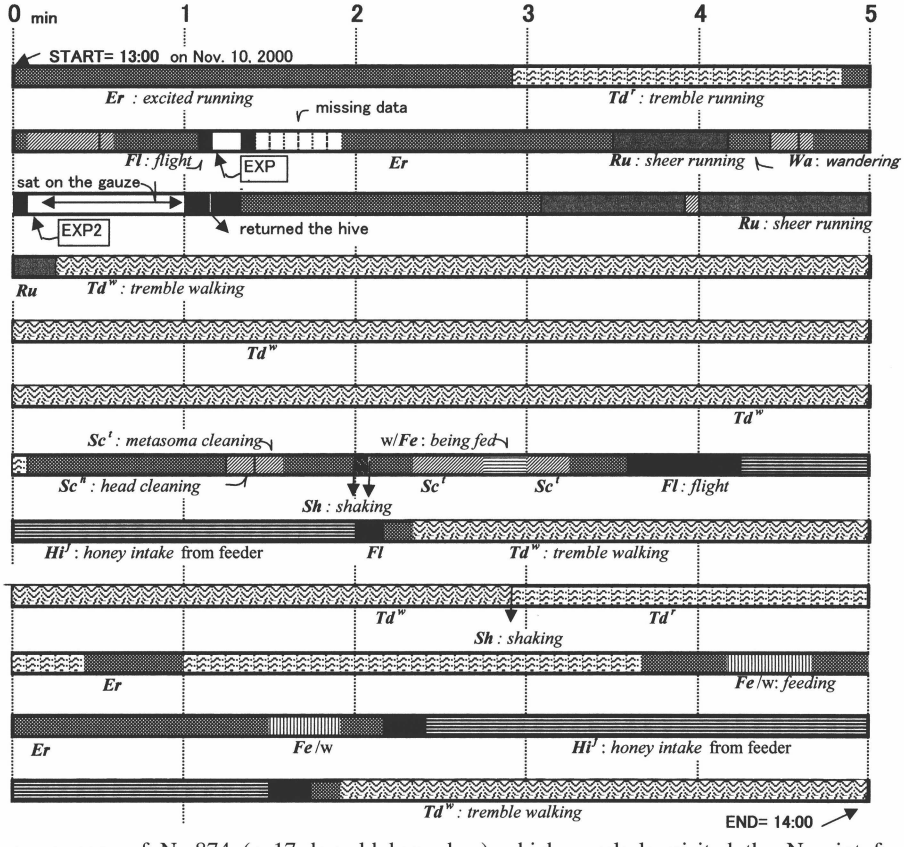


Fig.4. The behavior sequence of No.874 (a 17-day-old honeybee) which regularly visited the N-point feeder, 21 m from the observation hive. This is redrawn from the 1-hour sheet of my exclusive paper registered with 5-s scale. One long bar denotes the sequence of 300 s or 5 min. All behaviors were registered from 13:00 to 14:00 in Day 5, which corresponds to our observation from the intranidal behavior after the 8th trip to that soon after the 10th round trip in Table 8c.

100 point, but had returned to the hive at 15:09, and the round trips in Day 11 were all over.

In the above circumstances, No.874 performed not ***TD*** (*tremble dancing*) but ***DA*** (*dancing*). This may be due to acclimation to the door barrier.

Considering the advance of the cold weather and the bee's age, we decided to terminate this trial.

Discussion

Our trial started without a carefully worked-out plan. We wished to locate some concealed problems in the experimental procedure by von Frisch. Some unexpected results must be yielded in the soil of a fixed idea or belief. We should discuss our unexpected results.

1. The psychological barrier of 2 doors with wire gauze

When our trial started, we intended to observe the bee's round trip within the Mesh House. We felt soon, however, that it was lacking in space to observe the bee's flight. The feeder was placed outside the Mesh House, which had double doors to prevent the escape of animals previously kept there. The double doors created really a small room, which was also 'a gallery space' for foraging bees to pass through.

First of all, we perceived the long flight time of No.874 in her round trip to the 13-m feeder (cf. Table 5), which needed only a few seconds, given the flight speed of 7.5 m/s in honeybees (Wenner, 1963). Her flights took ca.30 s (37 HIVE→FEEDER: 26.89 s ±26.08; 21 FEEDER→HIVE: 33.33 s ±13.48). Therefore, we should have checked the flight

Table 10. Transition dancing (***Da^t***) of No.874 (20 days old) visited the feeder (50 m) on Day 8 (November 13, 2000). There are observed cases (●) and non-observed cases (× or a blank). Experimental trials were executed in the 16th trip and the 19th trip.

TRIP	shaking *Sh*	tremble dancig *Td^r ←TD →Td^w*	round dancing *Da^r*	transition dancing *Da^{t0}*	*Da^{t1}*	*Da^{t2}*	*Da^{t3}*	waggle dancing *Da^w*	FLIGHT TIME HIVE ↓ FEEDER	FLIGHT TIME FEEDER ↓ HIVE	FEEDING PLACE DISTANCE FROM HIVE POINT	(m)
1[1]							●		—	—	T	50
2							●		25	15	T	50
3							●		5	25	T	50
4							●		—	—	T	50
5							●		20	20	T	50
6							●		20	40	T	50
7							●		25	—	T	50
8							●		25	20	T	50
9							●		30	—	T	50
10							●		20	25	T	50
11							●		15	20	T	50
12							●		15	15	T	50
13							●		35	—	T	50
14							●		15	75	T	50
15							●		10	10	T	50
16[2]							●		40	***170***	T	50
17							●		15	20	T	50
18							●		25	40	T	50
19[3]							●		30	***480***	T	50
20							●		15	90	T	50
21							●		20	25	T	50
22							●		10	30	T	50
23							●		10	60	T	50
24							●		20	—	T	50
25							●		—	20	T	50
26							●		15	25	T	50
27							●		5	100	T	50
28							●		5	120	T	50
29							●		5	25	T	50
30			×	×	×	×	×	×	10	195	T	50
31[4]			×	×	×	×	×	×	—	—	T	50
32							●		5	25	T	50
33							●		5	25	T	50
34							●		10	20	T	50
35							●		10	30	T	50
36							●		5	15	T	50
37[5]							●		5	—	T	50

NORMAL TYPE

VIGOROUS TYPE

SHUTTED OUT FOR 3 MIN

SHUTTED OUT FOR 5 MIN

[1] The round trip started at 10:06.

[2] No.874 could not enter in the Mesh House for about 3 min, because of shtting the sliding door of the small room.

[3] No.874 was shutted out for about 5 min. [4] No.874 could not reach the feeder. [5] The trip finished at 15:59.

Table 11. Transition dancing (*Da*^{t}) of No.874 (21 days old) visited the movable feeder from 15 to 65 m on Day 9 (November 14, 2000). There are observed cases (● or ◎) and non-observed cases (× or a blank). The Feeder was moved more remotely southward after being neared eastward.

BEHAVIOR / CODE / TRIP	*shaking* *Sh*	*tremble dancig* *Td*^{r} ←*TD*→ *Td*^{w}	*round dancing* *Da*^{r}	*transition dancing* *Da*^{t0}	*Da*^{t1}	*Da*^{t2}	*Da*^{t3}	*waggle dancing* *Da*^{w}	FLIGHT TIME HIVE ↓ FEEDER	FLIGHT TIME FEEDER ↓ HIVE	FEEDING PLACE DISTANCE FROM HIVE POINT	(m)
0[1]			×	×	×	×	×	×	—	—	T	50
1							●		20	10	T	50
2							●		15	10	T	50
3							●		70	10	S	45
4							●		15	10	S	45
5							●		90	10	R	40
6				VIGOROUS			●		40	10	R	40
7							●		35	10	Q	35
8							●		15	10	Q	35
9							●		80	15	P	30
10				NORMAL TYPE			●		50	15	P	30
11							●		55	10	O	25
12						●	●		45	15	O	25
13						●	●		20	10	N	21
14							●		45	15	N	21
15						●	●		20	10	M	18
16						●	●		20	20	M	18
17						●	●		10	15	L	15
18						●			10	5	L	15
19							●		5	5	S1	16
20							●		5	15	S1	16
21							●		10	5	S2	17
22							●		5	25	S2	17
23							●		—	25	S3	18
24						●	●		10	15	S3	18
25						●			10	20	S4	19
26							●		5	25	S4	19
27							●		5	25	S5	20
28							●		10	20	S5	20
29						●	●		40	20	S7	22
30						●			60	20	S7	22
31						●			35	—	S10	25
32							●		55	20	S10	25
33							●		60	15	S15	30
34						●	●		55	15	S15	30
35						●	●		55	20	S20	45
36							●		40	—	S20	45
37							●		—	20	S25	50
38					●				85	20	S25	50
39						●	●		50	50	S30	55
40					●	●			65	20	S30	55
41						●			65	45	S40	60
42		◎			●				70	20	S40	60
43[3]		◎			●				55	20	S50	65

[1] The round trip started at 10:08, but No.874 returned the hive 40 s later because the sliding door was closed yet.
[2] The vigorous type of *Da*^{t3} is shown in the right end of the cell for the distinction from a normal type. [3] The trip finished at 15:54.

behavior of No.874, but we were too busy to observe the flight behavior. It took me all my time to check the intranidal behaviors of Nos. 874 and 862. It also took Mr. Koga all his time to register many visitors (cf. Table 2).

Nevertheless, fortunately, only a few cases, I could observe the return path of the bee's flight from the 13 m feeder outside the Mesh House on Day 3. When No.874 would return to the hive, she did not enter directly but flew over the roof, and turned to circle around the Mesh House. Then, she came back near the feeder, and hovered in a moment, and then entered decisively through a gaping hole of 0.9×1.8 m in the Mesh House. This diving to the narrow gallery seemed to become a psychological barrier.

2. The sunlight and the scent at the feeder

The Mesh House is nearly same as the outdoors. The wind, the rain and the sunlight came freely into the Mesh House. The observation hive sometimes had its covering blown off on a windy day. The rain was a cause of the broken thermostat in the old observation hive. The south sunlight often disturbed the bees' departure from the north entrance of the observation

Table 12. Transition dancing (*Da^t*) of No. 874 (23-25 days old) visited the southward feeder from 65 to 105 m on Day 10 (November 16) and Day 11 (Novenber 18, 2000). There are observed cases (● or ◎) and non-observed cases (× or a blank).

BEHAVIOR / CODE / TRIP	*shaking* *Sh*	*tremble dancig* *Td^r ← TD → Td^w*	*round dancing* *Da^r*	*transition dancing* *Da^{t0}*	*Da^{t1}*	*Da^{t2}*	*Da^{t3}*	*waggle dancing* *Da^w*	FLIGHT TIME HIVE ↓ FEEDER	FLIGHT TIME FEEDER ↓ HIVE	FEEDING PLACE DISTANCE FROM HIVE POINT	(m)
a : Day 10 (November 16, 2000), observed from 10:00 to 15:30. Temperature 13.0-13.5℃												
1[1]				VIGOROUS TYPE →			●		155	35	S50	65
2							●		35	100	S50	65
3				NORMAL TYPE ⇢			●		35	40	S60	75
4[2]						●	●		—	—	S60	75
5[3]			×	×	×	×	×	×	—	—	S60	75
6						●			40	30	S60	75
7[4]	—	—	—	—	—	—	—	—	30	190	S70	85
8						●			145	110	S70	85
9							●		35	40	S80	95
10[5]						○			30	165	S80	95
b : Day 11 (November 18, 2000), observed from 10:00 to 15:20. Temperature 12.2-14.4℃												
1[6]			×	×	×	×	×	×	—	—	S80	95
2			×	×	×	×	×	×	—	—	S80	95
3							●		535	35	S80	95
4			×	×	×	×	×	×	—	—	S80	95
5				●		●	●		225	40	S80	95
6							●		210	—	S80	95
7							●		195	65	S80	95
8							●		35	155	S80	95
9[7]			×	×	×	×	×	×	—	—	S80	95
10							●		130	40	S80	95
11							●		145	70	S90	105
12				●			●		240	135	S90	105
13			×	×	×	×	×	×	—	—	S90	105
14[8]			×	×	×	×	×	×	—	—	S100	115

[1] The round trip started at 10:40. [2] No.874 did not visit the feeder of S60.

[3] No.874 returned the hive only after sitting on the wire gauze of the Mesh House. [4] No recording of video by mistake in operating.

[5] No.874 took much time in flying out and entering the Mesh House. The round trip finished at 13:59 in Day 10. A white circle (○) means *Da^{t2}* with once waggling and no turning movement.

[6] No.874 flew out at 10:12, but could not visit the feeder, and neither in the 2nd, 4th, 9th, 13th and 14th trips.

[7] No.874 did not visit, and sat on or flew about the wire gauze in the south wall of the Mesh House.

[8] We caught No.874 who sat on the wire gauze of the south wall, and released her outside the Mesh House. She landed on the ground of the S90-point, and then returned the hive at 15:09 in the temperature of 12.2℃.

hive. We had to bring a black partition for the south side of the observation hive (cf. Photo 1).

The sunlight seemed to be related to the short cut of the flight path on Day 10. Von Frisch (1967: 172-181) executed several detour experiments, and described on the short cut of the bee flight. He found out that bees pointed to the feeder directly with their ***Da^w*** (*waggle dancing*) in their detour trips, and often shortened their flight paths by pointing of ***Da^w*** if an opportunity was offered. The south sunlight seemed to prevent No.874 from seeing the wire gauze and make her try to shorten her flight path rather than the detour flight.

Honeybees are fascinated by the sunlight, and also sensitive to scent. When the food on the feeder changed from the diluted honey to the 0.5M-sucrose solution in the next day, many visitors did not stop to visit the feeding station. No.874 was sensitive also to the scent around the feeding station. Whenever an observer by a station became new, No.874 seemed to smell the observer. When I began to eat lunch while watching the 15-m feeder on Day 3, No.874 hovered before me, and then flew around me. She was apt to land on the feeder, but flew away. After 80 s, she entered the observation hive (cf. footnote [3] of Table 8).

Since we humans are not sensitive to scent, we have little consideration of it. Wenner and Wells (1990:133) also described a failure regarding scent in their experiment (an episode of clove-flavored gum chewed by an assistant). To the contrary, scent may be usable in the experiment of hindering flight path, although we physically hindered the bee's flight in Days 5 and 8.

3. Low temperature and age of workers

Both factors seem to have influenced No.874 simultaneously towards the evening of her life on Days 10 and 11, but are essentially independent each other.

Insects are poikilotherm. There seemed to be an unexpected influence of the low temperature on the behavior of honeybees. It was on Days 3 and 7 that the behavior of No.874 greatly changed from the previous day. On Day 3, it was getting colder although the early morning temperature was somewhat lower than that of Day 2 (cf. Fig.3). On Day 7, however, it was getting warmer contrary to Day 6, when it had been getting colder. This makes us consider the acclimation to temperature. To the present, based on the data of this trial, a clear day (i.e. toward warmer) with average temperature of over 15℃ is optimum for us to gather the data on dance performances.

The age of material animal is almost always ignored in physiology, often even in ecology. Since adult insects do not molt, all body parts of an individual deteriorate little by little and day by day. Contrary to this, however, the experience of an individual must be accumulated gradually within its nervous system. Both these aging factors must firmly influence the behavior of an individual. Accordingly, we should observe the known-age individual continuously and as long as possible in a favorable condition.

4. *Shaking* in a sort of frustration

We observed ***Sh*** (*shaking*) in the early morning or /and the evening on Days 2, 5 and 7, which were clear or nearly clear days. No ***Sh*** was observed in other clear days (Days 1, 8 & 11), and cloudy or changeable days (cf. Fig.3). Ohtani (1994) speculated that *shaking* to a queen (w***Sh***/q) might be a isplacement behavior due to a state of conflict between 2 drives, fleeing and aggression. If a similar speculation were adopted here, ***Sh*** would be a displacement behavior due to a state of conflict between 2 behaviors, dancing and resting. In the early morning of a clear day, the ultraviolet light may stimulate dancing, but the body condition may be awakening and half-power. Such impatience, i.e. a sort of frustration, may release ***Sh.*** When the dancer would become tired in the evening of a clear day, she may be placed between 2 behaviors, dancing and resting. This may result in a sort of frustration, which would release ***Sh.***

Sh in a sort of frustration was also observed twice otherwise. One was ***Sh*** after the experimental trial on Day 5 (cf. Fig.4), and the other was ***Sh*** after the bee was released from the shopping bag in Day 7.

Low temperature may be related to the appearance of ***Sh***. Indeed, the temperature is low in the early morning and the evening of a day. The appearance of ***Sh*** in the evening does not support the speculation by Seeley (1992; 1995) of an awakening signal to increase a troop of foragers.

5. *Tremble dancing:* 'unripe' dancing

We could amply observe ***TD*** (*tremble dancing*) in this trial. The appearing situation of ***TD*** was partially similar to that of ***Sh*** (*shaking*): the appearance in the early morning and/or the evening of a clear day (cf. Fig.3). In the 4 days of Days 3-6, however, the situation of ***TD*** was greatly different from that of ***Sh***. Tremble running (***Td***^{r}) and *tremble walking* (***Td***^{w}) were observed all day long. There seems to be a concealed key to dance performances of honeybees.

The appearance of ***TD*** (*tremble dancing*) throughout a day seems to demonstrate that there is some reason whereby ***TD*** could not proceed to ***DA*** (*dancing*), compared with ***TD*** on Days 2 and 7. That something is inferred to be the psychological barrier and/or the low temperature referred to in the above discussion. There is a possible supposition on Day 5 that the 2-door barrier is stronger with moving the feeder farther away. The main factor on Days 3 and 4 seems to have been the low temperature in bad weather. In nearly clear Day 5, however, the main factor may have been the barrier because of moving the feeder from 21 to 30 m.

The symptom of resuming ***DA*** (*dancing*) was ***Da***^{r} and ***Da***^{r2} once observed soon after the 1st and 2nd returns from the 30-m feeder (cf. Table 8). This may result from acclimation to the barrier. There is indeed the acclimation to the barrier in the flight toward the feeder. In the long flight time in her round trip to the 13-m feeder discussed above, that after the 41st trip was shorter than that before the 40th trip (22 before : 15 after = 33.64±31.70 : 17.00±6.27, $p<0.05$ by Mann-Whitney's U test; based on Table 5). There may be, however, little acclimation to the barrier in the flight toward the hive (11 before : 10 after = 36.36 ±12.63 : 30.00±13.60, no significance by U test; based on Table 5). In the barrier of 2 doors, that in entering seems to work more strongly than that in

going-out.

After the 2nd trip on Day7, ***Td***^{w} (*tremble walking*) and ***Da***^{r} (*round dancing*) were observed. As this ***Td***^{w} was sometimes observed with a turning movement, it was similar to ***Da***^{r} (cf. Table 9). In other words, when ***Td***^{w} is connected tightly with a turning movement, a behavior pattern, ***Da***^{r} seems to be borne. Only one ***Td***^{w} with a turning movement was again observed in the 7th trip. On the contrary, ***Da***^{t2} without a turning movement was also observed in the 19th trip (cf. Table 9). Since clear waggling movements were perceived, it was categorized as ***Da***^{t2}, and was similar to ***Td***^{w}. This, ***Da***^{t2} without a turning movement, is observed again in the last trip on Day10 (cf. Table 12). Considering these facts, ***Td***^{w} seems to be a 'unripe' ***DA*** (*dancing*) without a turning movement.

Acknowledgements

I thank Mr. Taijirou Koga, Mr. Jun Matsubayashi and my son, Ichigo Ohtani for their help in collecting data. And I am grateful to Dr. Hidetoshi Ikeno (Himeji Institute of Technology, School of Humanities for Environmental Policy and Technology) for stimulating discussions and his valuable comments after reading through the manuscript.

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Received: February 14, 2002
Accepted: May 24, 2002

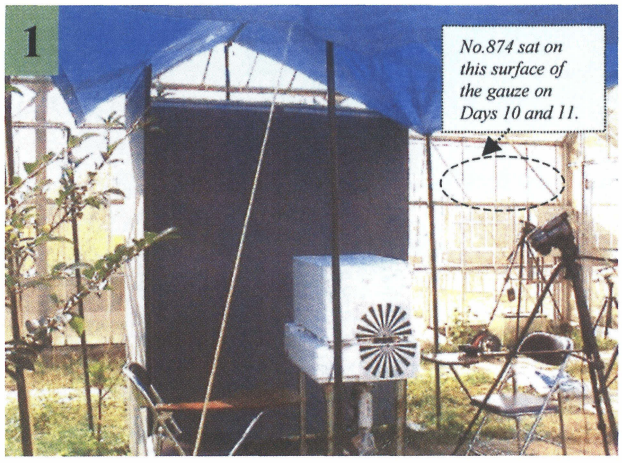

Photo 1. An observation hive in the Mesh House. It was covered with a box which was made by 5 styrene-foam boards. Its entrance was put a radial mark. Brought in were a black partition for avoid-ance of the direct sunlight, and a blue sheet as a shelter from rain.

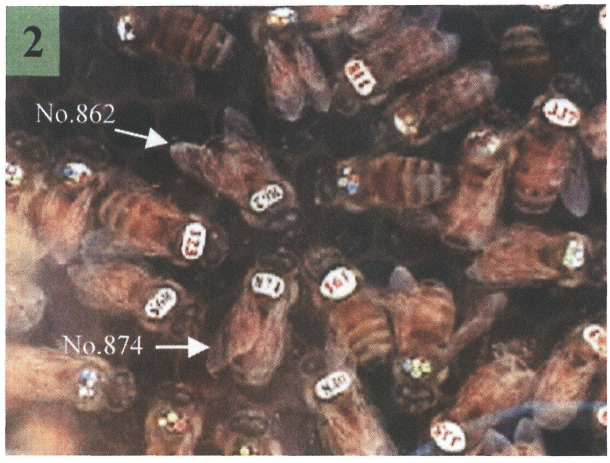

Photo 2. Two foragers, No.862 and No.874 with other nestmates. Each bee was marked with a numbered or a color-spotted paper-disc, which was stuck on bee's mesosoma (cf. Ohtani, 1974).

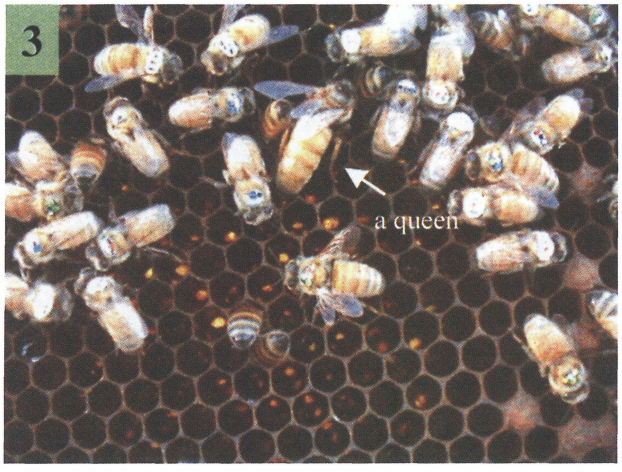

Photo 3. A virgin queen (an arrow) introduced in the observ-ation hive on October 26, 2000. An EXCELL-table of paper discs was printed out and used for marking.

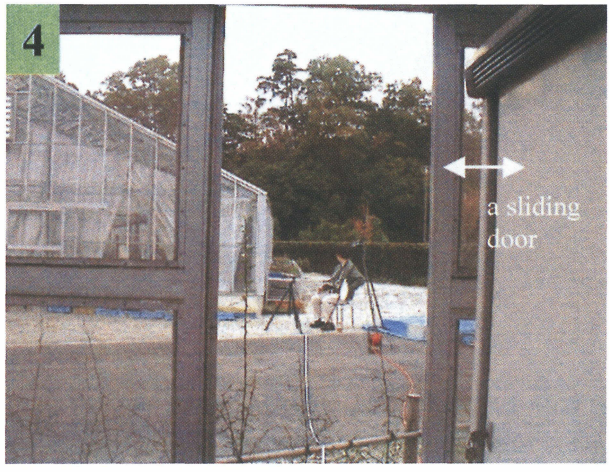

Photo 4. The N-point feeder of 21 m. A view from the inside of the Mesh House. An observer was Taijirou Koga who sat by the feeder. Foragers always passed through the space slit by a sliding door.

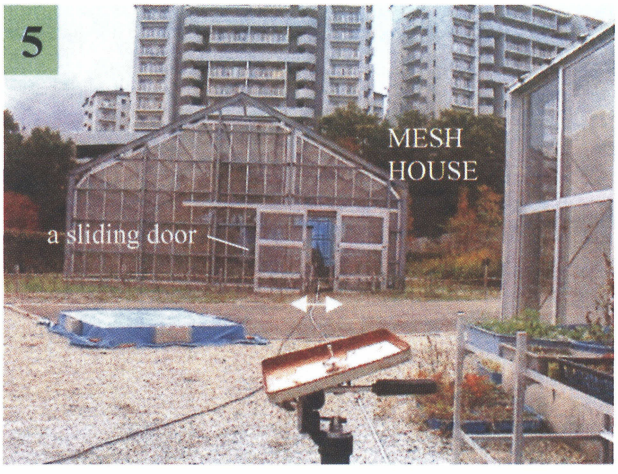

Photo 5. The O-point feeder of 25 m. A view from the outside of the Mesh House. The blue sheet as a roof was seen from the space slit by a sliding door (⇔).

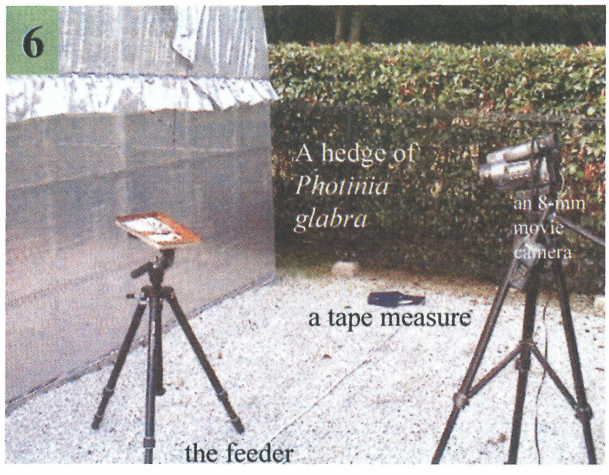

Photo 6. The T-point feeder of 50 m. A hedge on the right-hand side was the dead end westward. It was an 8-mm movie camera that functioned as an observer by the feeder on Day 8 (November 13, 2000).