

Ecological Studies on *Formica yessensis* Forel,  
with Special Reference to Its Effectiveness as  
a Biological Control Agent of the Pine  
Caterpillar Moth in Korea : II. Bionomics of  
*Formica yessensis* Forel (Hymenoptera:  
Formicidae) in Korea

Kim, Chang Hyo

Division of Insect Natural Enemies, Institute of Biological Control, Faculty of Agriculture,  
Kyushu University

Murakami, Yozo

Division of Insect Natural Enemies, Institute of Biological Control, Faculty of Agriculture,  
Kyushu University

<https://doi.org/10.5109/23724>

---

出版情報 : 九州大学大学院農学研究院紀要. 25 (2/3), pp.119-133, 1980-11. Kyushu University  
バージョン :  
権利関係 :



## Ecological Studies on *Formica yessensis* Forel, with Special Reference to Its Effectiveness as a Biological Control Agent of the Pine Caterpillar Moth in Korea

### II. Bionomics of *Formica yessensis* Forel (Hymenoptera: Formicidae) in Korea

Chang Hyo Kim\* and Yôzô Murakami

Division of Insect Natural Enemies, Institute of Biological Control, Faculty of Agriculture, Kyushu University 46-13, Fukuoka 812

(Received July 15, 1980)

The bionomics of *Formica yessensis* was studied in red pine stands in the Jinju district, Korea, in 1972-77, put emphasis on annual life cycle, nest structure, colony size, ratio of fertile nests, sex ratio and relation between worker size and division of labor. Extranidal activities were observed from April to November. Queens oviposited from mid April to late August. New workers appeared from early July to late October. Nuptial flights by new sexuals were observed from mid July to late August. Only workers and dealated females hibernated. A nest consists of mound and subterranean nest, the former develops as high as 80 cm in maximum. Number of workers per colony ranged between 1,900 and 100,000, that of queens between 4 and 278. Sexuals were produced only in large nests, the fertile nests occupying only 17% of large nests. A supercolony consisted of 31 to 113 colonial nests. Sex ratio of alates varied with nests and males outnumbered females in total, the latter being 27% of total alates. Size distribution of workers were different with task performance. Smaller workers were mainly engaged in nursing and aphid-visiting, larger workers in hunting and adult-transporting. Workers participated in nest building were intermediate.

### INTRODUCTION

There have been serial studies of biology and ecology on the huge population of *Formica* (*Formica*) *yessensis* Forel at the Ishikari Shore openland in Hokkaido, Japan. Among these studies, Ito (1973) has published on seasonal population trends and nest structure, Imamura (1974) on hibernation, Ito and Imamura (1974) on nuptial flight and internest relationship, Higashi (1974, 1978 a,b) on worker polyethism, its conservatism in task and area and internest drifting, and Imamura (1978) on adult transport.

In Korea, however, the bionomics of the ant has scarcely been known before the senior author and his collaborators (Kim *et al.*, 1978). From 1972

---

\* Present address: College of Agriculture, Gyeongsang National University, Jinju 620. Korea.

to 1977, the senior author investigated the annual life cycle, nest structure, population size, sex ratio and division of labor among workers. In this paper these features of the ant in Korea are presented in comparison with those obtained at Ishikari Shore in Hokkaido.

## METHODS

From 1972 to 1977, the annual life cycle of *F. yessensis* was investigated by field observations and nest excavations in several red pine stands in the Jinju district in order to know primarily the beginning of extranidal activities by post-hibernating workers, the oviposition by queens, the appearance of larvae, pupae and new workers, the nuptial flight of new sexuals and hibernations.

From April to October, 1973, nest structure was investigated in a red pine stand at Jinseung, Jinyang-gun. Height and basal diameter of nest mounds were measured, then these nests were excavated to investigate their structure and number of workers. To count the number of workers, 50 nests were excavated and all the workers were collected and put in a cloth bag with nesting material. Prior to the excavation, the nests were covered with ethylene sheet and smoked with CS<sub>2</sub> to paralyze ants early in the morning around 6 o'clock.

In order to investigate seasonal population trends of workers and queens per nest, 3 nests for each class in nest size were excavated monthly from April to October, 1975-77 in the same stand. Nests were classified into three classes in size for the sake of convenience; i.e., the large nests being more than 30cm in basal diameter of mounds, the medium 18-30 cm, the small less than 18 cm.

*F. yessensis* has been known to produce sexuals in only a fraction of nest population (Ito and Imamura, 1974). In order to know the ratio of fertile nests and number of nests in each supercolony, 1216 nests were inspected in 20 red pine stands at Jinyang, Sacheun, Goseung, Sancheung, Hadong and Namhae (see Fig. 1 in Kim and Murakami, 1980) during mid August, 1974-75.

In order to estimate the sex ratio of the ant, 26 large (fertile) nests were excavated in 7 red pine stands at Jinseung, Chunggok Temple, Goseung, Guam, Gonyang, Namhae and Mt. Jiri (see Fig. 1 in Kim and Murakami, 1980) from mid to late August, 1976. All the winged female and male ants and pupae were collected, of which the sex of pupae was determined with their size and genital organs.

The body size of *F. yessensis* workers is observed to be variable. The relation of task performance to it has been known in the population at Ishikari Shore, Hokkaido (Higashi, 1974). To estimate the seasonal trends of body size of workers emerged, the length of pupal cocoons was measured monthly from mid June to mid October, 1975. The collection of cocoons was carried out from large, medium and small nests in a red pine stand at Sacheun. To investigate the relation of worker body size to task performance, workers performing different tasks were collected and measured from a natural habitat in a red pine stand at Jinseung from 10 : 00 to 17 : 00, July 20, 1976. The tasks

were divided into five categories; i.e., hunting, nest-building, nursing, adult-transporting and aphid-visiting activities. In order to investigate the seasonal change of the division of labor among workers, a supplemental sampling of aphid-visiting workers was carried out in the same forest stand on October 5. Prior to these investigations, body size of hibernating workers was measured which were collected from a nest by excavation in March. As for the measurement of body size, Lee (1938) adopted body length from front of mandibles to gastric tip in *Camponotus japonicus* var. *aterrimus* Emery. Higashi (1974) chose the maximum outerorbital distance as the index for body size of *F. yessensis*. In the present study the maximum outerorbital distance was adopted.

## RESULTS AND DISCUSSION

### Annual cycle of colony activities and breeding

#### 1) Beginning of extranidal activities by post- hibernating workers

Extranidal activities by post-hibernating workers began in early April, but the period may be delayed more or less depending on places and years. As the temperature was low at this time, the activity was still at a low level. It became gradually active as the temperature rised with season. In Hokkaido, the extranidal activity begins in mid April just after thawing, and becomes active at late May when the honey dew secreted by aphids becomes available (Ito, 1973).

#### 2) Oviposition

The queens began to oviposit in mid April. On excavation of nests, eggs were observed until late August in a few nests. Thus, the oviposition was seemed to be continued for approximately 4 months, being most active from early June to early August. In Hokkaido, the period of oviposition lasts from early May to late July (Ito, 1973).

#### 3) Appearance of larvae and pupae

Larvae were found in nests in early May first and observed till September. The larvae were most abundant from mid June to late August. Pupae appeared in mid June and remained till mid October. The maximum number of pupae was observed from early July to late September. These data show that larvae and pupae are present in nests in the Jinju district for longer period than in Hokkaido (Ito, 1973).

#### 4) Appearance of new workers

New workers appeared in early July and the emergence continued till late October in nests. The maximum number of workers emerged from late July to mid September. In Hokkaido, they emerge from early August to mid September, slightly after the emergence of new sexuals (Ito, 1973).

#### 5) Nuptial flight and mating

Nuptial flights were observed from mid July to late August in the Jinju district. Observations of the flight activity were made three times. The results are as follows. The flights were observed between 5 : 00 and 7 : 00 in

the morning of fine and warm days. After flown up to about 1 m high, the alates alighted on herbs and shrubs and copulated there. Copulation lasted 50 seconds to 6 minutes. After mating females descended to the ground and returned to the mother nests. Some females, however, did not enter nests but rambled. To these rambling females, a number of workers aggregated, then the females searched nesting sites together with workers to found new nests. The wings of these queens were casted off by these workers.

Ito and Imamura (1974) have intensively observed the nuptial flight and mating behaviour at Ishikari Shore in Hokkaido in August, 1971. They estimated the flight season as late July to mid August. They observed that alates emerged from nests onto the nest surface between 5 : 00 and 5 : 30 and disappeared between 7 : 55 and 8 : 20. After climbing herbs and grasses nearby nests, males flew up to about 0.5 to 1 m high. They did not observe the flight by alate females prior to copulation. After alighted on the plant, males approached females and copulated. Copulation lasted 30 seconds to 9 minutes.

#### 6) Hibernation

Extranidal activities of workers dropped in mid October and ceased in November. Only workers and dealated females (queens) hibernated in subterranean nests till next March.

### Nest structure and colony inhabitants

#### 1) Nest structure and its utilization

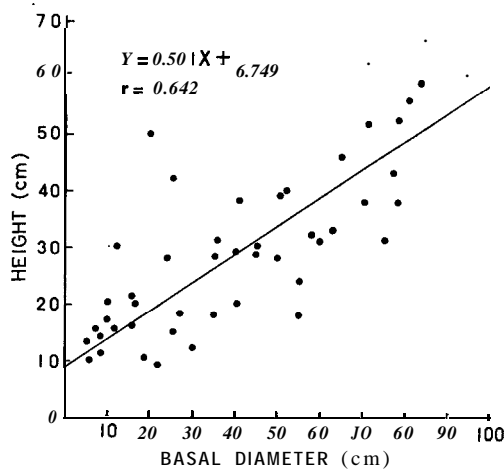
A nest consisted of two parts, mound and subterranean nest. The mound (Fig. 1) was constructed with various broken vegetable matters mainly of dead leaves and twigs of red pine trees. Mound size varied with its developmental degrees. Basal diameter of mounds ranged between approximately 5 cm in young nests and more than 1m in well-developed ones. Height of mounds ranged between approximately 10 cm and 80 cm.



**Fig. 1.** A mound of nest of *F. yessensis* in a pine stand in the Jinju district, Korea.

Some relations were recognized between basal diameter and height of mounds (Fig. 2). However, the height of mounds was sometimes influenced

by such events as collapsing by heavy rains and other physical factors, and by decaying of pine leaves and other nest materials inside nests, therefore it was not reliable as the index of nest size. In the Ishikari Shore openland the mound does not develop well partly because of the poverty of building materials and some local climate conditions which may decrease mound building activity (Ito, 1973). In the red pine forests in Korea it developed much well than in Ishikari Shore because of the plenty of building materials.



**Fig. 2.** Relation between basal diameter and height of mounds in a red pine stand at Jinseung in the Jinju district.

The mound was utilized as the breeding site of mature larvae and pupae. On the hot day in summer, they were put in a upper portion of the mound at night whereas they were moved to the deeper portion in the daytime. Sometimes, workers built a temporary nest which lacked a subterranean part in the shade beside a pine tree several meters apart from the mother nest where they transported larvae and pupae in the daytime to protect from the exposure to solar radiation, then returned them to the mother nest in the evening. This type of nest has been called as the incipient or bivouac nest by Ito (1973). Thus, it is obvious that the mound was prepared to protect the brood from heating in summer.

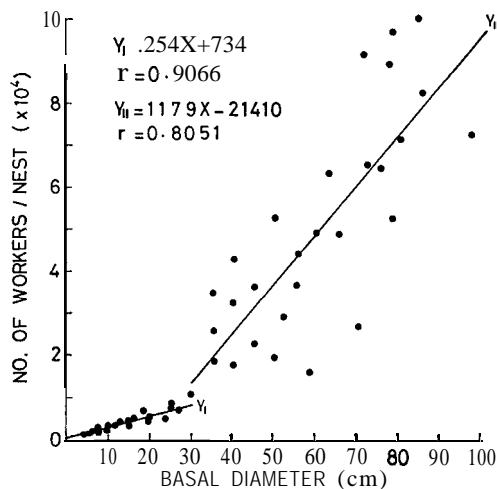
The mound was also serves as the pupation site. The larvae were observed pupating in the deeper portion of a mound where workers transported up the mature larvae immediately before pupation from the subterranean nest. Observations in summer showed the pupae just after pupation were placed in the deeper portion of nests whereas those just before emergence were placed in the upper portion.

The subterranean nest consisted of brood section and vertical shafts, the former being made immediately beneath the mound and the latter descending down from the former. At the midway of the vertical shafts, small chambers and larger oval chambers were sometimes observed.

The brood section was utilized as the breeding site of eggs, larvae and pupae from spring to autumn. Up and down transportation of the brood with variable temperature and moisture was also observed in the brood section as in the mound. The vertical shaft was utilized as the passage of workers, the small chamber as the food-storing site where a number of workers aggregated, and the oval chamber as the ovipositing site where larvae and pupae were being nursed by numerous workers surrounding queens. The oval chambers were frequently observed at the bottom portions of the subterranean nests. Queens hibernate in the bottom oval chambers in winter, then they move to the upper oval chambers after April.

## 2) Relation between nest size and colony size

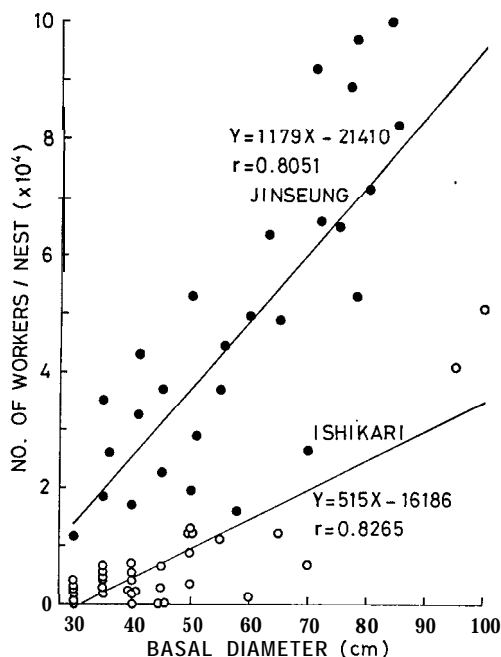
Relation between basal diameter of mounds (nest size) and number of workers per nest (colony size) is shown in Fig. 3. These data are based on the investigations of 50 nests excavated at a natural habitat in a red pine stand at Jinseung from May to September, 1973. Individual number of workers per nest ranged between 1,900 and 100,000. The relation is represented by two regression lines. In smaller nests with their basal diameter of mounds less than 30 cm, number of workers gradually increases with nest size, while in larger ones the slope is steeper.



**Fig. 3.** Relation between basal diameter of mounds and worker population size in a red pine stand at Jinseung.

Ito (1973) stated that the adult population per nest was generally proportional to the nest diameter in the population at Ishikari Shore, but he did not calculate the regression. Based upon his crude data on number of workers (Appendix I in Ito, 1973) and on nest diameter (Appendix II in the same paper), the regression line was calculated and compared with Jinseung population (Fig. 4). So far as the nests larger than 30 cm in basal diameter were

concerned, number of workers per nest in Ishikari Shore was considerably less than in the Jinseung red pine stand. The difference seems to come from differences in the environmental conditions in nesting site between them; i.e., amount and kind of nesting material available, soil texture and underground water level.



**Fig. 4.** A comparison of the relation between nest diameter and worker population in Korea (Jinseung) and Japan (Ishikari Shore).

### 3) Seasonal trends of worker and queen number per nest

*F. yessensis* has some peculiar mode of life. Nests often stand closely nearby and interconnected by the drifting of inhabitants, forming a polydomous system. Due to this peculiarity, the individuals sampled in a given nest are not necessarily those produced there (Ito, 1973). Such polydomous ants often ensure their colony multiplication by budding. That is, new colonies are established by the departure of a group of workers from one nest to the site nearby, which later transport the queens from the mother nest or adopt new queens soon after nuptial flight. *F. yessensis* **also** exhibits such proliferation of nests by budding (Ito, 1973; Higashi, 1976). Thus, the number of adult inhabitants changes seasonally.

Fig. 5 shows the seasonal trends of the average number of workers and queens per nest and the queen worker ratio for three years (1975-77) in the natural habitat at Jinseung. The tendency of the seasonal change in number of workers and queens was similar with each other among small, medium and



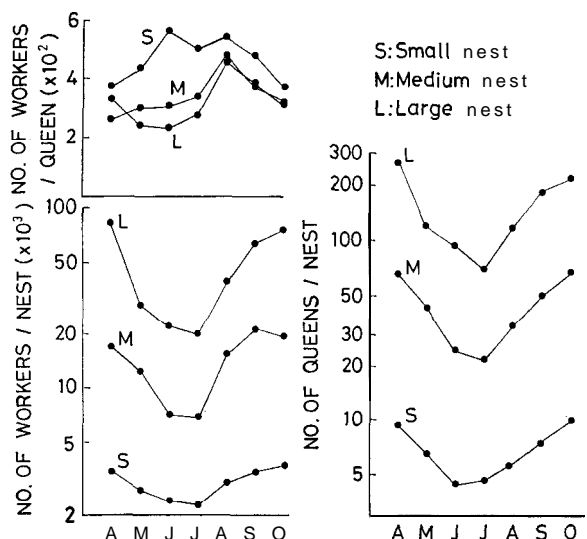


Fig. 5. Seasonal trends of worker and queen number and queen worker ratio in a red pine stand at Jinseung. The data refer the mean number for three years (1975-77).

large nests, decreasing till July and increasing afterwards. The decrease in number of workers and queens per nest from May to July can be explained by the fact that the proliferation by budding is frequent in the period. The number of queens per nest ranged between 4 (small nests in June) and 278 (large nests in April), showing that this ant exhibited a polygynous system.

The queen worker ratio ranged between 1 : 278 (large nests in June) and 1 : 576 (small nests in June). Comparing with the number of workers and queens per nest, the ratio was not largely different with nest size and did not much fluctuate seasonally.

However, the seasonal trends of the ratio from April to August were different with nest size. In small nests the number of workers per queen increased (that is, queen ratio decreasing) from April to June, while in large ones it decreased, medium ones intermediate. Ito (1973) showed that the ratio in the Ishikari Shore population was 1 : 340 and the lower number of workers per queen were relatively frequent in spring and autumn than in summer.

#### 4) Ratio of fertile nests and number of nests per supercolony

Ito and Imamura (1974) investigated the ratio of fertile nests producing sexuals in July, 1971, at Ishikari Shore, and stated that only 11 out of 178 nests examined or 6.4% contained sexual pupae but it was slightly underestimated. For a better estimation, they considered the budding frequency because young nests formed by budding might not produce sexuals, and estimated the real ratio of fertile nests among more or less established nests as 13.7 %. They also stated that fertile nests tended to have larger mounds than sterile ones.

In the Jinju district, Korea, only 90 out of 1,216 nests examined or 7.4 %

**Table 1.** Number of fertile nests out of small, medium and large nests examined in mid August, 1974-75. The nest size is classified by the basal diameter of its mound into three classes; small (less than 18 cm), medium (18-30 cm) and large (more than 30cm).

Locality	Station	Total no. of nests examined	No. of fertile nests (numerators)/No. of nests examined (denominators)			Percentage of fertile nests
			Small nests	Medium nests	Large nests (percentages in parentheses)	
Jinyang	A	46	0/27	0/9	2/10(20.0)	4.3
	B	113	0/16	0/39	13/58(22.4)	11.5
	C	72	0/12	0/20	8/40(20.0)	11.1
Sacheun	A	67	0/23	0/19	3/25(12.0)	4.5
	B	56	0/19	0/13	6/24(25.0)	10.7
	C	43	0/16	0/10	3/17(17.6)	7.0
	D	60	0/12	0/16	7/32(21.9)	11.7
	E	60	0/17	0/11	6/32(18.8)	10.0
Goseung	A	80	0/20	0/23	7/37(18.9)	8.8
	B	83	0/23	0/26	2/34(5.9)	2.4
Sancheung	A	65	0/30	0/16	2/19(10.5)	3.1
	B	45	0/20	0/10	2/15(13.3)	4.4
	C	65	0/16	0/21	4/28(14.3)	6.2
Hadong	A	65	0/15	0/20	3/30(10.0)	4.6
	B	77	0/21	0/22	4/34(11.8)	5.2
	C	51	0/27	0/10	2/14(14.3)	3.9
Namhae	A	31	0/16	0/5	2/10(20.0)	6.5
	B	51	0/15	0/12	5/24(20.8)	9.8
	C	40	0/17	0/7	4/16(25.0)	10.0
	D	46	0/11	0/9	6/26(19.2)	10.9
Total		1216	0/373	0/318	90/525(17.1)	7.4

were fertile nests which produced sexuals (Table 1). All the fertile nests were included in large nests larger than 30cm in basal diameter of mounds.

*F. yessensis* has a supercolonial system (Higashi, 1978 a). Ito (1971) estimated the number of nests established in an area of 400 ha at Ishikari Shore as 72,000. These nests are regarded as a supercolony. The nests in each station in the Jinju district shown in Table 1 constitutes each supercolony. The number of nests per supercolony in these natural habitats ranged between 31 (Namhae A) and 113 (Jinyang B), the average being 61 (Table 1). Comparing with the supercolony in Ishikari Shore, those in the Jinju district are extremely small in size. However, this does not necessarily mean supercolonies in Korea are smaller than those in Hokkaido, because a small supercolony comprising only 3 nests has been recorded at Tsukisappu, Sapporo, Hokkaido (Imamura, 1976). Instead, the supercolony in Ishikari Shore is exceptionally large.

##### 5) Sex ratio

The result of sex ratio investigated by excavation 26 nests in the Jinju district is shown in Table 2. The sex ratio varied considerably with nests ranging from that producing only males (Gonyang No. 1) to that with females

Table 2. Sex ratio of *F. yessensis* examined in August, 1976.

Locality	Nest no.	No. of winged females			No. of males			Female / (Female + male)
		Adult	Pupa	Total	Adult	Pupa	Total	
Jinseung	1	83	28	111	585	67	652	0.15
	2	0	11	11	67	8	75	0.13
	3	4	1	5	130	3	133	0.04
Chunggok	1	134	135	269	468	212	680	0.28
			18	152	37	121	158	0.49
	3	128	21	49	175	114	289	0.14
Temple	4	51	19	70	50	107	157	0.31
Goseung	1	114	16	130	21	0	21	0.86
	2	18	31	49	4	15	19	0.72
	3	1020	117	1137	0	18	18	0.98
Guam	1	1	0	1	53	0	53	0.02
	2	10	29	39	669	21	690	0.05
	3	5	8	13	226	35	261	0.05
Gonyang	1	0	0	0	73	0	73	0
	2	18	0	18	139	13	152	0.11
	3	1	0	1	255	0	255	0.00
	4	8	26	34	886	51	937	0.04
Namhae	1	253	61	314	493	242	735	0.30
	2	27	4	31	1700	95	1795	0.02
	3	13	5	18	34	105	139	0.11
Mt. Jiri	1	164	0	164	207	0	207	0.44
	2	141	57	198	138	12	150	0.57
	4	133	66	199	14	0	14	0.93
	5	202	30	50	200	128	328	0.13
			5	17	178	36	214	0.07
	6	4	3	7	41	19	60	0.10
Total		2396	691	3087	6843	1422	8265	0.27

98% (Goseung No. 3). Usually, males outnumbered females, the female ratio being 27% in total. Nests where females outnumbered males (female ratio being more than 0.5) were only 5 out of 26 ones. This shows a striking contrast to the result reported by Ito and Imamura (1974) in colonies at Ishikari Shore where the sex ratio was approximately 1 : 1.

Scherba (1961) observed on reproduction of a North American ant, *Formica (Formica) opaciventris* Emery and reported that some nests produced only males, some only females, others both males and females, and that nests produced only males were more numerous than those produced only females and both sexes. He also stated that males and females were observed in a ratio of approximately 18 : 1. Talbot (1959) observed flights by sexuals of *Formica obscuripes* Forel in Michigan for two weeks from mid to late June and recorded more than 4,500 males and 695 females from a nest. Talbot (1964) also reported on *Formica obscuriventris* Mayr, another North American ant, that 2, 587 males and 422 females flew from a colony from late July to late August. Thus, many species of the genus *Formica* produce more males than females. Therefore, it is undoubtedly exceptional that the sex ratio was 1 : 1 in the colonies of *F. yessensis* in Ishikari Shore.

### Division of labor among workers with reference to their body size

#### 1) Seasonal change in body size of workers

Fig. 6 shows the seasonal change in length of pupal cocoons of workers excavated monthly from small, medium and large nests. Regardless of the nest size, relatively high ratio of small workers emerged from June to August, particularly in July. In September and October, however, medium workers emerged in relatively high ratio. Thus, size of workers tended to increase from summer to autumn.

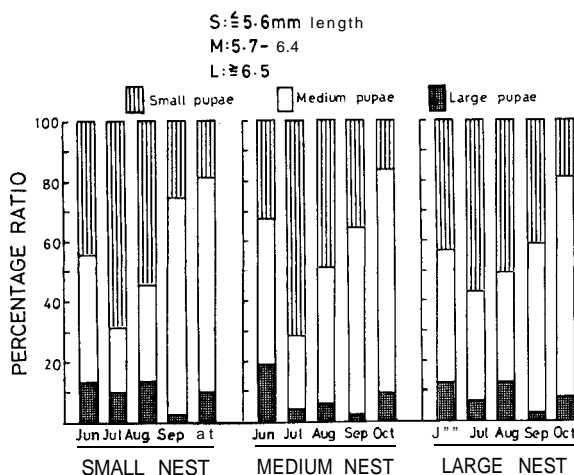


Fig. 6. Seasonal change of pupal size of workers in small, medium and large nests excavated in a red pine stand at Sacheun in the Jinju district.

#### 2) Relation between worker size and division of labor

Using the measurement of the maximal outerorbital distance as index for body size, the workers were divided into three classes; small (less than 1.3 mm), medium (1.3-1.5 mm) and large (larger than 1.5 mm).

The size distributions in workers performing different tasks in July and hibernating workers are shown in Fig. 7.

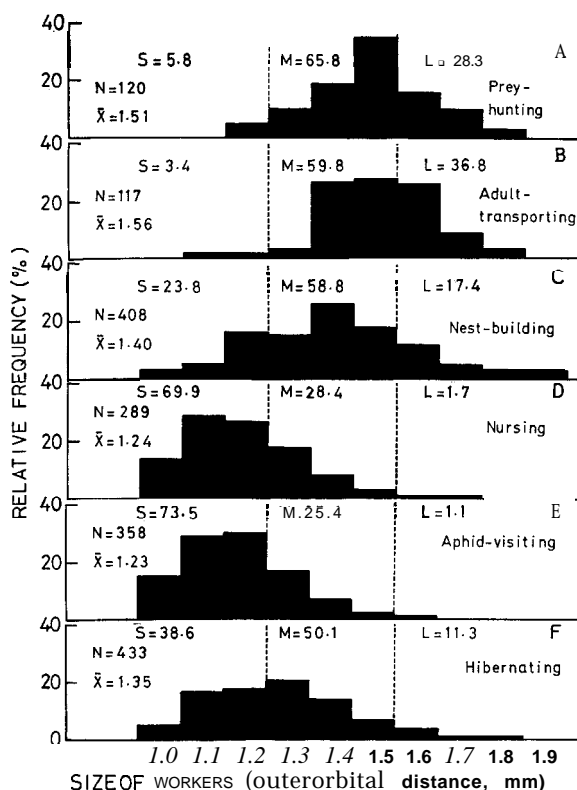
From a hibernating nest, 433 workers were collected and measured. The percentage ratios of small and medium workers were 38.6% and 50.1% respectively while large workers only 11.3%. The mean size was 1.35 mm (Fig. 7F).

The size distribution in 120 individuals of hunting worker followed the normal curve, but the percentage of small worker decreased, occupying only 5.8% while medium worker 65.8% and large worker 28.3%. The mean was 1.51 mm (Fig. 7A). Thus, the workers which do hunting are mostly medium and large in size.

Imamura (1978) observed at Ishikari Shore that live workers of *F. yessensis* were sometimes transported by other workers of the same species with mandibles between nests. He stated that the adult transport was frequent in spring and that transporters were as large as hunters and transportees similar

to thatchers and diggers. He concluded the adult transport seemed to promote the expansion of nests because it was likely that transportees participate in digging in target nests. In the natural habitat at Jinseung, 117 workers performing adult transport were collected and measured. The size distribution was similar to that of hunting workers with the percentage ratios of small, medium and large workers 3.4 %, 59.8 % and 36.8 % respectively, giving a slightly higher mean size 1.56 mm (Fig. 7B). It means the workers who perform adult transport are almost equal in size to hunters, and the result mentioned here agrees with that by Imamura (1978).

Nest building task includes extranidal building activities carrying nest materials and founding mounds on the nest surface and intranidal building ones carrying sand particles from inside to outside of the nest. 408 individuals performing such task were collected and measured. The percentage of small individuals was distinctly higher than in case of hunting and adult-transporting, occupying 23.8 %, while large workers decreased to 17.4 % with a decrease of the mean to 1.40 mm (Fig. 7C). Among them workers who carried nest mate-



**Fig. 7.** Size distributions of workers performing different tasks in July (A-E) and a hibernating colony (F) in a red pine stand at Jinseung. N: Total number of individuals measured.  $\bar{x}$ : Mean size. S, M, L: Percentage ratios of small, medium and large workers.

rials were rather larger than those engaged in intranidal building. Higher percentage of medium and small workers was observed in the nest-building activities as a whole.

Some workers were observed in nests nursing the eggs, larvae, pupae and queens, sometimes carrying them for protecting from variable environmental conditions such as high temperature and humidity. 289 workers performing such activities were collected and measured. The percentage of small individuals was extremely high, attaining 69.9 %, medium workers occupying 28.4 % while large workers only 1.7 %, giving a very low mean size 1.24 mm (Fig. 7D). That is, workers who participate in nursing activities are mostly small and medium in size.

In red pine forests in Korea, many workers of *F. yessensis* visit aphids, *Cinara piniformosa* Takahashi to collect honey dew. 358 individuals of such workers were collected and measured. The size distribution was very similar to that of nursing workers with the percentage ratios of small, medium and large workers 73.5 %, 25.4 % and 1.1% respectively, giving a mean size 1.23 mm (Fig. 7E). Thus, aphid-visiting workers are mostly small and medium individuals, and large workers scarcely participate in the task.

However, the size distribution of aphid-visiting workers varied according to the season. On October 5, 221 aphid-visiting workers were collected and measured. As shown in Fig. 8, medium and large individuals apparently increased to 51.1% and 14.0% respectively, and small ones decreased to 34.8%, the mean increasing 1.34 mm.

As mentioned above, *F. yessensis* exhibits a marked correlation between task performance and body size of workers. Smaller workers are engaged in nursing and aphid-visiting in summer. On the other hand, larger individuals participate in hunting and adult-transporting tasks. Workers who participate in nest-building activities are intermediate between hunting and nursing workers. However, the size-linked polyethism is not firmly fixed but plastic seasonally as shown in difference in size distributions of aphid-visiting workers between in summer and autumn. The difference may be reflected in part by the seasonal change in body size of workers. Besides, it may be because large-



Fig. 8. Size distributions of aphid-visiting workers in summer and autumn.

er workers which do hunting in summer might change their task to aphid-visiting for decrease in prey densities in autumn. According to Higashi (1978 a), most workers might be able to practice most tasks during their life, though the degree of conservatism to each task is different among workers.

Higashi (1974) studied the relation between task performance and body size in *F. yessensis* at Ishikari Shore and concluded that smaller workers were apt to make intranidal tasks and aphid-visiting and larger ones hunting, and that workers who participate in building activities are intermediate between nursers and hunters. The results obtained in the present study agree well with those at Ishikari Shore.

#### ACKNOWLEDGEMENTS

The authors wish to express their hearty thanks to Professor Y. Hirashima for his constant guidance and critical reading of the manuscript. Thanks are also due to Dr. Jin Sik Choi, Mr. Jong Man Kim, Mr. Sok Hyon Kim and Mr. Bu Gun Jeung of Gyeongsang National University for their kind cooperation in the course of field investigations in Korea. The senior author also thanks Dr. Tae Gyu Yoon, the ex-President of the University, for his help promoting the present study and encouragement.

#### REFERENCES

- Higashi, S. 1974 Worker polyethism related with body size in a polydomous red wood ant, *Formica (Formica) yessensis* Forel. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 19: 695-705*
- Higashi, S. 1976 Nest proliferation by budding and nest growth pattern in *Formica (Formica) yessensis* in Ishikari Shore. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 20: 359-389*
- Higashi, S. 1978a Task and areal conservatism and internest drifting in a red wood ant *Formica (Formica) yessensis* Forel. *Jap. J. Ecol., 28: 307-317*
- Higashi, S. 1978b Analysis of internest drifting in a supercolonial ant *Formica (Formica) yessensis* by individually marked workers. *Kontyû, 46: 176-191*
- Imamura, S. 1974 Observations on the hibernation of a polydomous ant, *Formica (Formica) yessensis* Forel. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 19: 438-444*
- Imamura, S. 1976 Life of *Formica yessensis* Forel. *Anima, 4 (3): 13-20* (in Japanese)
- Imamura, S. 1978 Adult transport in a supercolony of *Formica (Formica) yessensis* Forel. with special reference to its relation with digging. *Jap. J. Ecol., 28: 73-84*
- Ito, M. 1971 Nest distribution of *Formica yessensis* Forel in Ishikari Shore, in reference to plant zonation. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 18: 144-154*
- Ito, M. 1973 Seasonal population trends and nest structure in a polydomous ant, *Formica (Formica) yessensis* Forel. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 19: 270-293*
- Ito, M. and S. Imamura 1974 Observations on the nuptial flight and internidal relationship in a polydomous ant, *Formica (Formica) yessensis* Forel. *J. Fac. Sci., Hokkaido Univ., Ser. VI, Zool., 19: 681-694*
- Kim, C. H., J. S. Choi and S. H. Kim 1978 Studies on the biological control of pine caterpillar (*Dendrolimus spectabilis* Butler) by red wood ants (*Formica rufa truncicola* var. *yessensis* Forel). *J. Inst. Agr. Resource Util., Gyeongsang Univ., 12: 91-123* (In Korean with English Summary)
- Kim, C. H. and Y. Murakami 1980 Ecological studies on *Formica yessensis* Forel. with special reference to its effectiveness as a biological control agent of the pine caterpillar

- moth in Korea I. Geographical and ecological distributions of *Formica yessensis* Forel (Hymenoptera: Formicidae). *J.Fac. Agr., Kyushu Univ.*, 24: 239-245
- Lee, J. 1938 Division of labor among the workers of the Asiatic carpenter ants (*Campotonotus japonicus* var. *aterrimus*). *Peking Nat. Hist. Bull.*, 13: 137-145
- Scherba, G. 1961 Nest structure and reproduction in the mound-building ant *Formica opaciventris* Emery in Wyoming. *J. New York Ent. Soc.*, 69: 71-87
- Talbot, M. 1959 Flight activities of two species of ants of the genus *Formica*. *Amer. Midl. Natur.*, 61: 124-132
- Talbot, M. 1964 Nest structure and flights of the ant *Formica obscuriventris* Mayr. *Anim. Behav.*, 12: 154-158