Characteristics of Mills in Faunal Composition of Stored Product Pests; Their Role as a Reservoir of New Imported Pests^{1 2}

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INTRODUCTION

Grains imported into Japan by cargo ships are frequently infested by various kinds of stored product insects.

Insect-infested grains arriving in Japan are detained by the Plant Quarantine Station at each port before being released to industry. Wheat and barley are imported into Japan mainly from temperate countries of the world, e.g. U. S. A., Canada, Australia, Argentine etc., while maize is imported from tropical regions, e. g. Southeast-Asia, East Africa, South America and U. S. A.

Most of the imported cereals, barley, wheat and maize are first delivered to the mills en route to the consumers.

There is a possibility that new kinds of pests happen to survive insecticidal treatment given upon the arrival in Japan. Some of these insects are able to propagate and establish in mills that provide with some favorable conditions for the species which otherwise could not survive. The cosmopolitan distribution of the stored product pests suggests, their wide range, if not all, of tolerancy to the physical conditions as shown by SOLOMON & ADAMSON (1955). A few of those species that established in the mills, may have a chance to invade farm-storages and add new species to the domestic fauna of stored products. To evaluate the rôle

that mills play as a reservoir of new pests, extensive inspections of flour and barley cleaning mills and feed mixing factories were carried out in Kinki district for the period of 1957 to 1960.

METHOD

Investigations were made at thirty six flour mills, forty four barley cleaning mills and ten feed mixing factories which are distributed in Kinki district including following prefectures; Osaka, Kyoto, Siga, Nara and Wakayama. In Nov. 1957, Feb., April, May, July, and September 1958, Feb., May and July 1959 and September 1960, investigations were made 113, 135, and 35 times at the flour mills, barley cleaning mills and feed mixing factories, respectively. Thus, each mill or factory was examined at least three times in the course of this investigation at different time. In collecting insects, attention was paid not to confine the collection to a particular place, but to cover all kinds of places as much as possible. Mills or factories that deal with only domestic cereals were excluded in this survey.

Apart from these investigations, collection of insects was conducted at 163 places, mainly composed of consumers in Kyoto Prefecture during the period of July to September in 1956. The foodstuffs examined were various, including grains, flour and materials of animal origin.

¹ Contribution from the Entomological Laboratory, Kyoto University, No. 361.

² The work reported in this paper was carried out by the senior author at Entomological Laboratory, College of Agriculture, Kyoto University.

(Received for publication, October 30, 1962)

As an index of relative abundance of the species, the index of finding frequency (I) was calculated as follows;

$$I = \frac{(\text{Number of plots in which the species concerned were found})}{\text{Total number of plots examined}}$$

Discovery of a particular species in course of inspection of a mill is likely to be influenced by season owing to the facts that some species are at larval stage in a grain and others are not. Complex structure of the mill also affects the chance of discovery of the species, and this is most liable for the species with low level of population density.

Some of the species were found every time and others were found only once in spite of the repeated visits to the same mill. In making up a faunal list in relation to the sort of mills, however, only presence or absence of the species was recorded for each specified mill or factory irrespective of its frequency of encounter.

RESULT

1. Insect fauna in relation to the sort of mills and factories

Index of finding frequency calculated for each species in different sort of mills was compared with each 95% fiducial limit. The results were tabulated in Table 1. Most of the species were not significantly different in their finding frequencies in relation to the sort of mills, so the indices of these species were calculated in terms of the total of factories and mills inspected.

A comparison of insect fauna between flour and barley cleaning mills revealed that almost all the species were not different in their finding frequencies, except for *Tenebroides mauritanicus* and *Anagasta kuehniella*. The former was found more frequently and the latter was less frequently in barley cleaning mills than in flour mills. It can be said that the faunal compositions of both flour and barley cleaning mills are almost the same even taking an account of these exceptional species.

Table 1. Level of abundance of stored product insects compared with each 95% fiducial limit of frequency. Net numbers of factories were 36, 44 and 10 and average times of inspections were 3.19, 3.19 and 3.5 for flour mills, barley cleaning mills and feed mixing factories, respectively.

10% below	
<i>Acedes fuscipunctella</i>	<i>Necrobia ruficollis</i> (FM+BM)
<i>Carpophilus marginellus</i>	<i>N. rufipes</i> (FM+BM)
<i>Dermestes maculatus</i> (FM+BM)	<i>Plinus</i> spp.
<i>Dermestes</i> spp. larvae (FM+BM)	<i>Tenebrio picipes</i>
<i>Gnathocerus cornutus</i>	<i>Sitotroga cerealella</i>
20% below	
<i>Aglossa dimidiata</i>	<i>Dermestes ater</i> (FM+BM)
<i>Alphitobius ovata</i>	<i>Carpophilus hemipterus</i>
<i>Anagasta kuehniella</i> (BM+F)	<i>Lasioderma serricorne</i>
<i>Anthrenus verbasci</i>	<i>Cryptophagus</i> spp.
<i>Aphomia gularis</i>	<i>Stegobium paniceum</i>
40% below	
<i>Alphitophagus</i>	<i>Typhaea stercora</i>
<i>bifasciatus</i>	<i>Homalopsycha</i> <i>agglutinata</i>
<i>Anagasta kuehniella</i> (FM)	<i>Laetheticus oryzae</i>
<i>Dendrophilus</i> spp. (FM+BM)	<i>Palorus subdepressus</i>
	<i>Plodia interpunctella</i> (FM+BM)
	<i>Tinea</i> spp.
50% below	
<i>Attagenus piceus</i>	<i>Tenebrio obscurus</i>
60% below	
<i>Alphitobius diaperinus</i> (= <i>piceus</i>) (FM+BM)	<i>Oryzaephilus</i> <i>surinamensis</i>
<i>Carpophilus pilosellus</i>	<i>Rhizopertha dominica</i>
<i>Cryptolestes</i> spp. (F)	<i>Tenebrio</i> spp. larvae
<i>Necrobia ruficollis</i> (F)	
70% below	
<i>Dermestes</i> spp. larvae (F)	<i>Tenebroides mauritanicus</i> (FM)
<i>Cadra cautella</i>	<i>Tribolium castaneum</i> (FM+BM)
80% below	
<i>Dermestes maculatus</i> (F)	<i>Palorus ratzeburgi</i>
<i>Dendrophilus</i> spp. (F)	
90% below	
<i>Cryptolestes</i> spp. (FM+BM)	<i>Sitophilus sasakii</i>
<i>Plodia interpunctella</i> (F)	<i>Tenebroides mauritanicus</i> (F)
<i>Pyrallis farinalis</i>	
100% below	
<i>Alphitobius piceus</i> (F)	<i>Tenebroides mauritanicus</i> (BM)
<i>Dermestes ater</i> (F)	<i>Tribolium castaneum</i> (F)
<i>Necrobia rufipes</i> (F)	<i>Tribolium confusum</i>
<i>Sitophilus oryzae</i>	

Note: FM: flour mill, BM: barley cleaning, and F: feed mixing factory.

On the other hand, the faunal composition of feed mixing factories differs a great deal from those of flour and barley cleaning mills due to the different nature of materials they deal with. The species that differed significantly in their finding frequencies at flour or barley cleaning mills were as follows; *Alphitobius diaperinus* (= *piceus*), *Cryptolestes* spp., *Dermestes* spp., *Dendrophilus* spp., *Necrobia* spp., *Tribolium castaneum* and *Plodia interpunctella*. Among them, only *Ctyptolestes* spp. were found less frequently in feed factories as compared with mills. It is noteworthy that those species with higher indices of finding frequency in feed factories have a preferendom to ground or deteriorated grain as well as materials of animal origin.

The species that were common in all sorts of the factories were *Sitophilus oryzae*, *Tribolium confusum*, *Sitophilus sasakii*, *Tribolium castaneum*, *Palorus ratzeburgi* and *Tenebroides mauritanicus* in Coleoptera, *Pyrallis farinalis* and *Cadra cautella* in Lepidoptera.

In addition to this, *Alphitobius diaperinus*, *Rhizopertha dominica*, *Cryptolestes* spp., *Carpophilus pilosellus*, *Oryzaephilus surinamensis* and *Tenebrio* spp., were the species which come next to common species that were mentioned above (Table 1).

2. Finding frequency of the species as affected by the time of inspection

In making comparison between summer and winter, because of paucity of collection records at the feed factories, data only from flour and barley mills were used (Table 2).

Species of the stored product pests can be grouped into three according to the change of finding frequency in winter and summer. Among species of groupe 1, of which finding ferquencies were not different in summer and winter, there exist, in Table 2, such species claimed to be included in the group 2 as *Carpophilus marginellus*, *C. hemipterus*, *Gnathocerus cornutus* and *Necrobia rufipes* that were not discovered at the winter inspections.

The species of which finding frequency

Table 2. Finding frequency of the stored product pests in the different seasons, summer (May-Sept.) and winter (Oct.-April), at flour mills and barley cleaning mills.

I. Species of which finding frequency (%) was not statistically different in summer and winter:	
<i>Alphitobius ovata</i>	<i>Palorus ratzeburgi</i>
<i>Anthrenus verbasci</i>	<i>Sitophilus oryzae</i>
<i>Attagenus piceus</i>	<i>Stegobium paniceum</i> †
<i>Carpophilus marginellus</i> †	<i>Tenebrio picipes</i>
<i>C. hemipterus</i> †	<i>Tenebroides mauritanicus</i> (flour mill)
<i>Cryptophagus</i> sp.	<i>Tribolium castaneum</i>
<i>Dermestes ater</i> †	<i>Typhaea stercorea</i>
<i>D. maculatus</i> †	<i>Anagasta kuehniella</i>
<i>Dendrophilus</i> spp.	<i>Acedes fuscipunctella</i>
<i>Gnathocerus cornutus</i> †	<i>Sitotroga cerealella</i>
<i>Lasioderma serricorne</i> †	<i>Tinea</i> spp.
<i>Necrobia rufipes</i> †	
<i>Oryzaephilus surinamensis</i>	
†: denotes the species which was not discovered in winter (see text).	
II. Species of which finding frequency was significantly reduced in winter as compared with summer:	
<i>Alphitophagus bifasciatus</i> *	<i>Tenebrio obscurus</i> *
<i>Alphitobius diaperinus</i> ***	<i>Tenebroides mauritanicus</i> * (barley cleaning mill)
<i>Carpophilus pilosellus</i> *	<i>Tribolium confusum</i> ***
<i>Cryptolestes</i> spp.***	<i>Aglossa dimidiata</i> ***
<i>Laetheticus oryzae</i> ***	<i>Aphomia gularis</i> **
<i>Palorus subdepressus</i> *	<i>Cadra cautella</i> **
<i>Rhizopertha dominica</i> ***	<i>Pyrallis farinalis</i> ***
<i>Sitophilus sasakii</i> ***	
III. Species of which finding frequency was significantly increased in winter as compared with summer:	
<i>Ptinus</i> spp.*	<i>Homalopsycha agglutinata</i> ***
<i>Tenebrio</i> spp. larvae*	
*, ** and ***: denote $P < 0.05$, 0.01 and 0.001 , respectively.	

was significantly reduced in winter months as compared with summer months belong to the second group. Some species may be hindered to multiply by low temperature during winter months and moreover they pass winter-as larvae which makes them less detectable. Some species, among univoltine or bivoltine species,

Table 3. A comparison of finding frequency in summer and winter between related species.

Species	Summer	Winter	χ^2 -Test
<i>Palorus ratzeburgi</i>	68 (36.96)	22 (34.38)	$\chi^2 = 6.13^{**}$
<i>P. subdepressus</i>	27 (14.67)	2 (3.13)	
<i>Alphitobius ovata</i>	9 (4.89)	2 (3.13)	$\chi^2 = 116.9^{****}$
<i>A. diaperinus</i> (= <i>piceus</i>)	57 (30.98)	6 (9.38)	
<i>Sitophilus oryzae</i>	149 (80.98)	48 (75.00)	$\chi^2 = 30.75^{****}$
<i>S. sasakii</i>	117 (63.59)	15 (23.44)	
<i>Tribolium castaneum</i>	57 (30.98)	16 (25.00)	$\chi^2 = 114.4^{****}$
<i>T. confusum</i>	132 (71.74)	31 (48.44)	
<i>Anagasta kuehniella</i>	17 (9.24)	8 (12.50)	$\chi^2 = 13.53^{****}$
<i>Cadra cautella</i>	39 (21.20)	1 (1.56)	
Total No. of mills examined	184	64	

Note: Figures in the parentheses denote the indexes of finding frequency.

: $P < 0.025$, **: $P < 0.005$.

Fig. 1. Monthly fluctuation in temperature and relative humidity of various places.

Table 4. Difference in faunal composition in relation to places of collection

Locality	Kinki	Kinki	Kinki (Kyoto)	Kinki	Kyushu (Miyazaki)
Sample size	80	10	163	210	59
Composition of samples	Flour mills:36 Barley mills: 44	Feed factories:10	Consumers:124 Farmers: 24 Other: 16	Consumers:166 Farmers: 139 *Mills: 5	Farmer's barley:33 wheat: 26
Authors	present	present	present	KIRITANI, 1956	YOSHIDA & KAWANO, 1959
<i>Ahasverus advena</i>	—	—	1	—	—
<i>Alphitophagus bifasciatus</i>	24	3	1	1	—
<i>Alphitobius ovata</i>	9	3	—	—	—
<i>A. diaperinus</i> (= <i>piceus</i>)	40	8	—	1	—
<i>Anthrenus verbasci</i>	10	1	9	37	—
<i>Attagenus megatoma</i>	31	7	1	1	—
<i>Carpophilus marginellus</i>	3	—	—	—	—
<i>C. pilosellus</i>	34	5	8	54	22
<i>C. hemipterus</i>	7	1	—	—	—
<i>Cryptolestes</i> spp.	60	2	2	12	38
<i>Cryptophagus</i> , <i>Holopara-</i> <i>mecus</i> , <i>Cartodere</i> and <i>Cryptophilus</i>	6	—	1	9	—
<i>Dermestes ater</i>	7	7	3	1	—
<i>D. maculatus</i>	1	4	—	1	—
<i>D. tessellatocollis</i>	—	—	1	1	—
<i>Dermestes</i> larvae	—	3	1	—	—
<i>Dendrophilus</i> spp.	21	5	—	—	—
<i>Gnathocerus cornutus</i>	1	—	—	—	—
<i>Lasioderma serricorne</i>	7	—	—	—	—
<i>Lophocateres pusillus</i>	—	—	—	—	1
<i>Dinoderus minutus</i>	—	—	2	3	—
<i>Laetheticus oryzae</i>	25	3	—	1*	—
<i>Necrobia ruficollis</i>	—	2	—	—	—
<i>N. rufipes</i>	1	2	—	—	—
<i>Oryzaephilus surinamensis</i>	36	7	12	29	57
<i>Palorus ratzeburgi</i>	59	6	3	10	2
<i>P. subdepressus</i>	22	1	—	—	—
<i>Ptinus</i> spp.	2	1	—	2	—
<i>Rhizopertha dominica</i>	36	5	—	1	5
<i>Sitophilus oryzae</i>	76	10	63	159	55
<i>S. sasakii</i>	65	7	2	12	55
<i>Stegobium paniceum</i>	5	2	—	2	—
<i>Tenebrio obscurus</i>	27	4	5	10	—
<i>T. picipes</i>	4	—	1	9	—
<i>Tenebrio</i> larvae	38	4	3	26	—
<i>Tenebroides mauritanicus</i>	48	7	22	86	28
<i>Tribolium castaneum</i>	48	10	45	93	11
<i>T. confusum</i>	71	8	—	3*	—
<i>Typhaea stercorea</i>	4	2	1	1	—
<i>Anagasta kuehniella</i>	9	1	—	—	—
<i>Acedes fuscipunctella</i>	1	—	—	—	—
<i>Aglossa dimidiata</i>	8	2	1	55	—
<i>Aphomia gularis</i>	10	2	17	21	—
<i>Cadra cautella</i>	39	8	21	61	—
<i>Homalopsycha agglutinata</i>	20	4	—	—	—
<i>Plodia interpunctella</i>	25	7	10	41	35
<i>Pyralis farinaria</i>	62	8	1	10	—
<i>Sitotroga cerealella</i>	4	—	1	24	2

confine their active period of adult to a definite season or months in the year. These phenomena are often responsible for the absence of winter record of the species notwithstanding its presence in summer months.

As above, the causes of the reduction in frequency in winter are variable. It is conceivable, however, that the reduction of finding frequency of such tropical species as *Alphitophagus bifasciatus*, *Laetheticus oryzae*, and *Rhizopertha dominica* that are characteristic of the mill fauna in Kinki district, can be elucidated by their susceptibility to low temperature in winter. It is interesting to make a comparison of finding frequency between the related species in regard to the season (Table 3).

In spite of the similarity in habit and body size between paired related species, different finding frequency relative to the season suggests that there is some difference in their tolerance to winter condition.

Species that are found more frequently in winter than in summer, belong to the third group, which includes *Ptinus* spp., *Tenebrio* larvae and *Homalopsycha agglutinata*. *Ptinus* is more common in cool temperate countries than in warm temperate ones. *Tenebrio* hibernates during winter as larvae and is very conspicuous because of its large size. As to *H. agglutinata* of which moth emerges around February. These conditions seem to be responsible for the increased finding frequency in winter.

3. The characteristics of the faunal composition of mills and factories

The physical conditions of the mills are very different as compared with those of farm-storage. Inside temperature of farm storage is likely to be under direct influence of outdoor condition, whereas room temperature of the mills is raised to a considerable degree by the heat released from working machines.

One of the examples is given in Fig. 1, showing the curves of average monthly

temperature and relative humidity of different places, such as outdoor, ware house, grain in the warehouse, in the rooms of shifter and rool. It shows that the room temperature of shifter and roll invariably about 10°C higher yet, the relative humidity of these rooms is 10 to 20 per cent lower than outdoor and warehouse.

Thus, in this respect, it is noteworthy that the room temperature of both shifter and roll is maintained at about 10°C higher than the outdoor even in winter. These remarkable conditions of the mills enable a species to survive through winter. Otherwise the severity of winter would be fatal to them.

A comparison of faunal composition of stored product pests in relation to the

Table 5. List of species characteristic of mills and factories.

I. Species that are foreign to the domestic fauna:	
<i>Alphitophagus bifasciatus</i>	<i>Laetheticus oryzae</i>
<i>Alphitobius ovata</i>	<i>Necrobia rufipes</i> *
<i>A. diaperinus</i> (= <i>piceus</i>)	<i>N. ruficollis</i> *
<i>Carpophilus marginellus</i>	<i>Palorus subdepressus</i>
<i>Gnathocerus cornutus</i>	<i>Tribolium confusum</i>
	<i>Anagasta kuehniella</i>
II. Species that are found in both mills and farmstorages, but their propagation is favored by the special condition of the mills and the factories than that of farm-storages:	
<i>Attagenus piceus</i>	<i>Sitophilus sasakii</i>
<i>Cryptolestes</i> spp.	<i>Tenebrio obscurus</i>
<i>C. hemipterus</i>	<i>Tribolium castaneum</i>
<i>Dermestes</i> spp.*	<i>Cadra cautella</i>
<i>Lasioderma serricorne</i>	<i>Homalopsycha</i>
<i>Palorus ratzeburgi</i>	<i>agglutinata</i>
<i>Rhizopertha dominica</i>	<i>Pyrallis farinalis</i>
III. Species that are domestic:	
<i>Anthrenus verbasci</i>	<i>Tenebroides mauritanicus</i>
<i>Carpophilus pilosellus</i>	<i>Typhaea stercorea</i>
<i>Oryzaephilus</i>	<i>Aglossa dimidiata</i>
<i>surinamensis</i>	<i>Aphomia gularis</i>
<i>Ptinus</i> spp.	<i>Plodia interpunctella</i>
<i>Tenebrio picipes</i>	<i>Sitotroga cerealella</i>

Note: * Species characteristic of feed factories.

places of collection was made by using results of the present and the other authors (Table 4). It can be easily noted that mills and feed factories have many species which are found rarely or none, at all in the storages of farmers and consumers. What is more, some foreign or imported species are found in the fauna of mills. Those species can be divided according to their different status of invasion and establishment as follows. First, species that are foreign to the domestic fauna. Secondly, species that are domestic, but their propagation is more favoured by the special condition of the mills and factories than that of farm-storages. Finally, species that are domestic, and common in both mills and farm storages (Table 5).

DISCUSSION

ELTON (1958) postulated that, in general, invasions of a species most often come to cultivated land, or to land much modified by human practice, and often follow *ecological explosion*. Because, the *ecological resistance* that checks their establishment and reproduction is less severe as compared with that of uncultivated land, such as virgin forest. It is fairly an established fact that insect pests of stored product are being constantly carried around the world in the course of trade (ref. FREEMAN 1956, KIRITANI 1959). This is also supported by the fact that almost all the economic important species of stored products are cosmopolitan in their distribution. Because the environment of the mills is a typical example created by human activity.

Mills are exposed to continuous drift of new insect species and the artificial conditions of mills enables them survive through winter, although they have difficulty in passing through this period under unheated conditions.

It seems to be beyond a question that mills provide with a favorable condition of explosive multiplication for some newly introduced species, because of their

simplicity in community structure or ecological relation. A classic example is *Anagasta kuehniella* which was found first as a pest of flour mills in England in 1877 and then spread out as a serious pest in flour mills in Europe and North America in the next twenty years (ZACHER 1939). The reason of this explosive multiplication was caused mainly by the introduction of artificial power into mills.

From the point of view of preventing infestation of newly imported or established pests in the domestic products, the discovery of the species foreign to the domestic fauna is a matter of first importance. Among them, *Alphitobius ovata*, *Anagasta kuehniella*, *Carpophilus marginellus*, and probably both species of *Necrobia* were recorded first in Japan by this present survey. KIRITANI (1957) reported the presence of *Alphitobius diaperinus*, *Laetheticus oryzae* and *Tribolium confusum* and YOSHIDA (1958) also found *Gnathocerus cornutus* and *Palorus subdepressus* in flour mills in Kinki and Miyayaki districts, respectively.

Establishment of these species in the mills is out of controversy except the case of *Necrobia* spp., *Gnathocerus cornutus* and *Carpophilus marginellus*.

But *G. cornutus* which was found to have infested a flour mill according to the inspection of Nov. 1957 persisted at least until the last inspection made in July 1959. This suggests that *G. cornutus* is able to survive through winter and can establish in the flour mill. As to *C. marginellus*, it can be said that the situation may be almost the same as for *G. cornutus*. The status of *Necrobia* spp. in a feed factory is uncertain and it requires a further investigation because of their absence during the winter survey.

Anagasta kuehniella was found first in Nara Prefecture in Sept. 1958. After that finding, this moth has been found in nine flour mills and one feed factory in the prefectures of Osaka, Kyoto, Siga and Nara. It is blamed that the infestation in the feed factory by *A. kuehniella* was

caused by receiving bran from one of the flour mills already infested by this species. Since the finding of *Anagasta* moth, inspections of mills and feed factories have been carried out by the authority of the Plant Protection throughout Japan. These extensive inspections revealed that *A. kuehniella* is spreading out in every part of Japan from Hokkaido to Kyushu. The fraction of infested mills, however, was small in Kinki district, and this might indicate that the status of *Anagasta* was at an early stage of dispersion. It was observed that there was a tendency that *Cadra cautella* and *Plodia interpunctella* avoided co-occurrence with *A. kuehniella*. But the test of co-occurrence of any two species according to the method of WILLIAMS and LAMBERT (1959) has shown that the proportion of samples in which both species' occurrence did not significantly exceed the value expected by chance.

Tribolium confusum is a species characteristic of the mills and they seem to have no particular importance to the domestic products. On the other hand, *Laetheticus oryzae* which is tropical in origin should be noticed with attention, because it is possible to become serious pests in domestic stored cereals, provided that it can survive through winter under farm-storage condition. Among the species belonging to the group (II) (Table 5), *Rhizopertha dominica* and *Sitophilus sasakii* must be specially elucidated.

These primary pests of grain are rarely found in the farm-storages in Kinki district, though they are the most common pests of stored products in southern part of Japan, such as Miyazaki Pref. in Kyushu Island (Table 4). On the other hand, *Sitophilus oryzae* is common both in mills and farm-storages. Obviously, *R. dominica* and *S. sasakii* can find more favorable condition for their breeding in indoor condition of the mills and factories than that of farm-storages. Others, such as *Attagenus megatoma* (= *piceus*), *Cryptolestes* spp., *Tribolium castaneum* and *Pyrallis*

farinalis are considered to be favoured by the physical conditions as well as types of food found in the mills and factories, also.

CONCLUSION

KIRITANI, *et al.* (1959) asserted from the viewpoint of plant quarantine that it is necessary to distinguish following three stages, namely, invasion of new pest, its establishment and its becoming economic pest. Then interception of invasion, eradication and control ought to be employed according to the respective stages. The present investigations demonstrate that flour mills and feed mixing factories which deal with imported cereals are harbouring many insect pests that are foreign to the domestic fauna. Some of them are looking for a chance to invade into the farm-storages. Here, it becomes important to employ a method appropriate to the economic status of the species concerned in order to prevent further spread into farm-storages as well as mills that are yet free from the infestation with the pest.

SUMMARY

The rôle that mills and factories dealing with imported cereals play as a reservoir for new kind of pests was studied in the Kinki district for the period of 1957 to 1960. Thirty six of flour mills, forty four of barley cleaning mills and ten of feed mixing factories were inspected 113, 135, and 35 times, respectively. Thus each mill or factory was examined at least three times. Mills and factories dealing with domestic cereals only were excluded from the surveys. Apart from these investigations, collection of insects was carried out at 163 different places mainly composed of consumers in Kyoto prefecture in 1956. Flour mills and barley cleaning mills were almost the same in their faunal composition. But they differed a considerable degree from feed factories which are characterized by the high finding frequency of *Alphitobius dia-*

perinus, *Dermestes* spp., *Necrobia* spp., *Tribolium castaneum* and *Plodia interpunctella*.

From the point of view of preventing infestation in the domestic products by newly imported or established pests, the discovery of the species foreign to the domestic fauna is a matter of first importance. They are *Alphitophagus bifasciatus*, *Alphitobius ovata*, *A. diaperinus*, *Carpophilus marginellus*, *Gnathocerus cornutus*, *Laetheticus oryzae*, *Necrobia rufipes*, *N. ruficollis*, *Palorus subdepressus*, *Tribolium confusum*, and *Anagasta kuehniella*. Secondly, there are other species that are found in both mills and farm-storages, but their propagation is much more favored by the special condition of mills than in farm-storages. They are *Attagenus megatoma*, *Cryptolestes* spp., *Carpophilus hemipterus*, *Dermestes* spp., *Lasioderma serricornis*, *Palorus ratzeburgi*, *Rhizopertha dominica*, *Sitophilus sasakii*, *Tenebrio obscurus*, *Tribolium castaneum*, *Cadra cautella*, *Homalopsycha agglutinata*, and *Pyrallis farinalis*.

In conclusion, it is important to employ the method appropriate to the economic status of the species in order to prevent their further spread into farm-storages as well as mills that are yet free from the foreign pests.

ACKNOWLEDGEMENTS

The authors wish to convey their special

thanks to Prof. S. UTIDA, Entomological Laboratory, College of Agriculture, Kyoto University, for his helpful advices and criticism in preparation of this paper.

Mr. I. HIRANO, Ex-chief of the Osaka Branch, Kôbe Plant Protection Station, and Mr. E. ISHIDA, Chief of the Station, are gratefully acknowledged for their interest and encouragement in course of this study. The authors also express their appreciation to the officers of Osaka Branch for their assistance.

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摘 要

製粉・精麦・飼料工場の貯穀害虫相の特徴

—新害虫の定着の足がかりとしての役割—

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輸入玄麦およびトウモロコシをあつかう製粉・精麦および飼料工場が新害虫の侵入定着の足がかりにどのような役割をしているかを評価するために 1957~1960 年に

わたり近畿地方の外麦処理工場を対象として調査をおこなった。すなわち製粉工場 36, 精麦工場 44, 飼料工場 10 をそれぞれ延べ 113 回, 135回, 35 回調査した。別

に 1956 年に京都市およびその周辺部のおもに消費者を対象として 163 ケ所を調べた。製粉と精麦工場の害虫相にはほとんど違いはないが、飼料工場では、ガイマイゴミシダマシ *Alphitobius diaperinus*, カツオブシムシ類 *Dermestes* spp., ホシカムシ類 *Necrobia* spp., コクヌストモドキ *Tribolium castaneum*, ノシメコクガ *Plodia interpunctella* が前 2 者でみられるよりはるかに高い頻度でみられる。

本調査で発見された種類のうち農家などではみられない種類はフタオビゴミシダマシ *Alphitophagus bifasciatus*, *Alphitobius ovata*, *A. diaperinus*, ケシキスイの 1 種 *Carpophilus marginellus*, オオヅノコクヌストモドキ *Gnathocerus cornutus*, コメノコクヌストモドキ *Laetheticus oryzae*, アカアシホシカムシ *Necrobia rufipes*, アカクビホシカムシ *Necrobia ruficollis*, ヒラタヒメコクヌストモドキ *Palorus subdepressus*, ヒラタコクヌストモドキ *Tribolium confusum*, スズコナマダラメイガ *Anagasta kuehniella* である。農家、

工場の両方において発見されるが、工場内の特殊な環境条件がその定着、増殖を助けられていると考えられる種類はヒメカツオブシムシ *Attagenus megatoma*, カクムネヒラタムシ類 *Cryptolestes* spp., クリヤケムシ *Carpophilus hemipterus*, カツオブシムシ類 *Dermestes* spp., タバコシバンムシ *Lasioderma serricorne*, ヒメコクヌストモドキ *Palorus ratzeburgi*, コナナガシムシ *Rhizopertha dominica*, ココクゾウ *Sitophilus sasakii*, コメノゴミシダマシ *Tenebrio obscurus*, コクヌストモドキ *Tribolium castaneum*, コナマダラメイガ *Cadra cautella*, ナカバヒロズコガ *Homalopsycha agglutinata*, およびカシノシマメイガ *Pyrallis farinalis* である。

結論としてこれらの新害虫の土着化を防ぐためには、害虫の侵入一定着—害虫化という各段階に応じて侵入阻止—ほく滅—防除 (control) の方法が原則として取られるべきことを強調した。

抄

録

耐性の判定に用いたちく次抽出

COLE, LAMONT C. (1962) A closed sequential test design for toleration experiments. *Ecology* 43: 749~753.

ここ十数年の間、ザリガニなどの水生動物で、環境や習性の違いが、高温に対する耐性や酸素不足に対する耐性に差を生じさせるという実験が多く行なわれてきた。この差を検討して統計的に有意であるとするためには、通常相当数の反覆を行なう必要があるが、もっと少い反覆数で結論を得るためにちく次抽出を用いてみた。

無作為にとり出した雌、雄一対ずつのザリガニを、40°C の恒温槽の中に入れて、どちらが先に死ぬかを見たところ、12回中すべて雌が先に死んだ。この場合、確率の計算から、5% の過誤の範囲で、雌の方が耐性が小さいと結論するには、6 回の反覆で十分であることがわかる。

このような all-or-none という結論を得る場合については、COLE (1945) による 'sign test' があるが、FISHER (1952) と BROSS (1952) は、'閉じた' ちく

次抽出を用いた。これは定めた過誤 (第 1 種および第 2 種の) の範囲で、 $A > B$, $B > A$, $A = B$ という三つの結論のどれかを得るまで、反覆を続けるというもので、48 以下の反覆数ですむという特徴をもっている。

ザリガニで得たデータから、第 1 種の過誤を 5% と定め、試行法によって、BROSS と同様の閉じたちく次抽出を設計した。これによると結論を得るのに 41 以下の反覆数ですみ、平均 20 以下ですむことになる。

比較すべき A, B に差がない場合 (すなわち $P = 0.5$ のとき) これによって $A = B$ と結論する確率は、94.92% である。 A がわずかに大きいとき (すなわち $P = 0.6$ のとき)、正しく結論する確率は、14.61% であるが、この場合でも $B > A$ とする確率はほとんど 0 に等しい。 $P = 0.9$ のときには、99.90% の場合に正しい結論を得る。

このように少ない実験数ですむということは、この方法が all-or-none といった結論を得る場合に有用なものであろう。

(農技研 中村 和雄)