Entomological Science, 1999, 2(2): 197–203

Seed-insect Fauna of Pre-dispersal Acorns and Acorn Seasonal Fall Patterns of *Quercus variabilis* and *Q. serrata* in Central Japan

Hiroshi FUKUMOTO* and Hisashi KAJIMURA

Laboratory of Forest Protection, School of Agricultural Sciences, Nagoya University, Chikusa, Nagoya, 464–8601 Japan

Abstract. The seed-insect fauna of pre-dispersal acorns and acorn seasonal fall patterns were investigated in a mixed stand of *Quercus variabilis* and *Q. serrata* in central Japan. Five coleopteran species, one hymenopteran species and six lepidopteran species were found in pre-dispersal acorns of *Q. variabilis* and/or *Q. serrata*. In *Q. variabilis*, *Characoma ruficirra* (Lepidoptera: Noctuidae) was the most dominant species, followed by *Poecilips cardamomi* (Coleoptera: Scolytidae). On the other hand, acorns of *Q. serrata* were dominantly infested by a cynipid gall wasp. *P. cardamomi* and *Cydia glandicolana* (Lepidoptera: Tortricidae) were found in both *Q. variabilis* and *Q. serrata* acorns. There was an obvious difference in the falling period of insect-damaged acorns. Developing acorns absorbed by *Mechoris ursulus* (Coleoptera: Attelabidae) and those attacked by *P. cardamomi*, a cynipid wasp and *C. ruficirra* mainly fell before September, whereas those attacked by *M. ursulus*, *Curculio robustus* (Coleoptera: Curculionidae), *Curculio sikkimensis* (Coleoptera: Curculionidae) and tortricid moths and/or a blastobasid moth fell after September as sound acorns. This difference in seasonal fall of insect-damaged acorns would be closely associated with the difference in the time of attack and oviposition by seed insects.

Key words: Seed insect, *Q. variabilis*, *Q. serrata*, acorn, seasonal fall.

Introduction

The genus *Quercus* contains more than 500 species and is distributed in North America, Europe, the Mediterranean and Asia (Hora, 1981). Acorns of oaks have many predators, including insects, birds and mammals (Darley-Hill & Johnson, 1981; Gibson, 1971; Kikuzawa, 1988). Of these, insects are considered to be the most important predators. To date, approximately 67 species of phytophagous insects are known to attack acorns of oak trees in North America (Williams, 1989). They can play a significant role in mortality of pre-dispersal acorns (Kautz & Liming, 1939).

A total of 15 native species of oaks are recognized in Japan (Oba, 1989). Recently, much attention has been paid to interactions between acorn production of oaks and acorn predation by insects, and there are extensive field data on the interactions in Japan (Matsuda, 1982; Fujii, 1993; Maeto, 1995). These studies have been conducted in stands dominated by a single oak species such as *Q. serrata* Thunb. ex Murray (Matsuda, 1982; Fujii, 1993) or *Q. mongolica* Fisch. var. *grosseserrata* (Blume) Rehd. et Wils. (Maeto, 1995). However, there are fewer studies on seed insects in mixed oak stands composed of different *Quercus* species, where the interactions may be more complex due to asynchronous acorn production between oak species (Koenig *et al.*, 1994) and variation in host tree species attacked by the insects (Gibson, 1964). Ueda *et al.* (1992) also emphasized the importance of comparison of faunal components and life histories of the insects between different oak species in the mixed stand.

As the first step in understanding the interactions between acorn production of host trees and acorn predation by insects in a mixed stand, we investigated the seed-insect fauna of pre-dispersal acorns and acorn seasonal fall patterns in *Q. variabilis* Blume and *Q. serrata*, which co-dominate our study area in central Japan.

Materials and Methods

Acorn development of studied tree species

The two oak species studied, *Q. variabilis* and *Q.*

* Research Fellow of the Japan Society for the Promotion of Science.

serrata, belong to different section. *Q. variabilis* and *Q. serrata* belong to the section Cerris and section Prinus, respectively (Oba, 1989). In these two sections, the reproduction cycle differs markedly in the time between flowering and fertilization. In the Cerris cycle, as in *Q. variabilis,* which lasts two years, acorn development stops in the early summer of the first year shortly after pollination ('1st-year acorn' in this paper), and fertilization and acorn maturation occur during the second year ('2nd-year acorn' in this paper). By contrast, in the Prinus cycle, as in *Q. serrata,* flowers are produced in the spring, and acorns mature in the autumn of the same year.

Study site and methods

All experiments were conducted in a secondary forest located on the Nagoya University Campus, Aichi Prefecture in central Japan (50–80 m above sea level at 35°09′ N, 136°58′ E). This forest consists mainly of deciduous oaks (*Q. variabilis* and *Q. serrata*) and Japanese red pine (*Pinus densiflora* Sieb. et Zucc.). The annual precipitation and annual mean temperature at the Nagoya Weather Station nearby the study area are about 1500 mm and 15.1℃, respectively (National Astronomical Observatory, 1994).

To investigate the seed-insect fauna of pre-dispersal acorns of *Q. variabilis* and *Q. serrata,* falling acorns were collected using seed traps in 1995 and 1996 (Experiment 1). Five trees each of *Q. variabilis* (mean height, 20.0 m (18.0–21.5 m); mean diameter at breast height, 29.0 cm (22.0–36.0 cm)) and *Q. serrata* (mean height, 13.0 m (10.1–16.2 m); mean diameter at breast height, 25.0 cm (18.0–35.0 cm)), with no canopy overlap of adjacent conspecific oaks, were selected. Two seed traps, each with a projection area of 0.24 m^2, were set under the canopy of each tree on 1 June 1995. Acorns that fell into the traps were collected once a week from June to December in both 1995 and 1996. In this study, tiny *Q. serrata* acorns with a cupule width of less than 2 mm were regarded as flowers, according to the definition of Matsuda (1982), and were eliminated from the following analysis. Collected acorns were dissected, and were classified into sound, aborted, insect-infested and degenerated. The insect species in infested acorns were identified.

In Experiment 1, two seed traps were set under the canopy of the studied tree. However, it was considered that they were not enough to know the seed-insect fauna. Thus, in 1996 (Experiment 2), another tree each of *Q. variabilis* and *Q. serrata* was selected, and nine seed traps, each with a projection area of 1 m^2, were set under the canopy of each tree to collect more acorns than in Experiment 1. These extra two trees were of similar height (*Q. variabilis*: 11.0 m, *Q. serrata*: 10.0 m) and diameter at breast height (*Q. variabilis*: 24.0 cm, *Q. serrata*: 21.0 cm). In Experiment 2, the seed-insect fauna of pre-dispersal acorns was examined once a week from June 1996 to December 1996 as described above, and acorn seasonal fall patterns were also investigated.

To identify larvae of seed insects in the collected acorns, the insects were reared until adults stage in the field or laboratory (Experiment 3). In this study area, five 2nd-year immature acorns of *Q. variabilis* infested by moths were sampled from branches in August 1996. About 290 2nd-year mature acorns of *Q. variabilis* and about 540 mature acorns of *Q. serrata,* in some of which moths and weevils were hibernating, were collected randomly from the forest floor from October to November in 1995 and 1996. In this study, the acorns were classified into two developmental stages, immature and mature, according to their size in appearance. Each stage was defined as follow: 'mature acorns' were fully grown in both length and width, and the top of pericarp was fully protruded from the cupule; 'immature acorns' were smaller than mature acorns, and acorns were enclosed with cupule. The *Q. variabilis* acorns sampled from branches were put individually into a plastic tube (ϕ25 mm×65 mm), and the moth larvae were reared until adults in the laboratory. About 70 to 140 of each species of the *Quercus* acorns collected from the forest floor were placed in an emergence box (ϕ210 mm×170 mm) filled with sterilized soil, and then the boxes were buried in the forest floor. The top of the boxes were covered by nylon-screen to prevent predation by wood mice. Adult moths and weevils emerged in the boxes were collected every day from April 1996 to October 1997.

Results

A few 1st-year acorns of *Q. variabilis* dropped accidentally into seed traps, in both Experiment 1 and Experiment 2, owing mainly to branches breaking. No infestation by insects was found in the 1st-year acorns of *Q. variabilis*. Thus, the following results are only for 2nd-year acorns of *Q. variabilis*.

In Experiment 3, few adults of *Cryptaspasma marginifasciata* (Walsingham) (Lepidoptera: Tortricidae) and *C. trigonana* (Walsingham) (Lepidoptera: Tortricidae) emerged in the emergence boxes. *C. trigonana* is known as post-dispersal acorn predator (Maeto, 1993; Ueda *et al.,* 1993). *C. marginifasciata* is related species of *C. trigonana* and possibly attacks post-dispersal acorns (Komai, F., personal communication). Thus, in this study, these two species were eliminated from the following results.

Seed-insect fauna in Q. variabilis *and* Q. serrata

Table 1 lists seed insects infesting acorns of *Q. variabilis* and/or *Q. serrata* in Experiments 1, 2 and 3. Five coleopteran species, one hymenopteran species and six lepidopteran species were found. Acorns of *Q. variabilis* were attacked by curculio weevils (*Curculio robustus* (Roelofs) and unidentified species), a scolytid beetle (*Poecilips cardamomi* (Shaufuss)), a blastobasid moth (unidentified species), tortricid moths (*Pammene nemorosa* Kuznetzov and *Cydia glandicolana* (Danilevsky)) and a noctuid moth (*Characoma*

Table 1. Seed insects infesting pre-dispersal acorns of *Q. variabilis* and/or *Q. serrata* from 1995 to 1997 in central Japan.

Order	Family	Species	Infested acorn
Coleoptera	Attelabidae	*Mechoris ursulus* (Roelofs)	*Q. serrata*
	Curculionidae	*Curculio robustus* (Roelofs)**	*Q. variabilis*
		Curculio sikkimensis (Heller)**	*Q. serrata*
		Unidentified	*Q. variabilis*
	Scolytidae	*Poecilips cardamomi* (Schaufuss)	*Q. variabilis, Q. serrata*
Hymenoptera	Cynipidae	Unidentified	*Q. serrata*
Lepidoptera	Blastobasidae	Unidentified**	*Q. variabilis*
	Tortricidae	*Pammene nemorosa* Kuznetzov**	*Q. variabilis*
		Cydia danilevskyi (Kuznetzov)**	*Q. serrata*
		Cydia glandicolana (Danilevsky)**	*Q. variabilis, Q. serrata*
		Cydia amurensis (Danilevsky)**	*Q. serrata*
	Noctuidae	*Characoma ruficirra* (Hampson)*	*Q. variabilis*

* The species emerged from 'immature acorns' in Experiment 3.
** The species emerged from 'mature acorns' in Experiment 3.

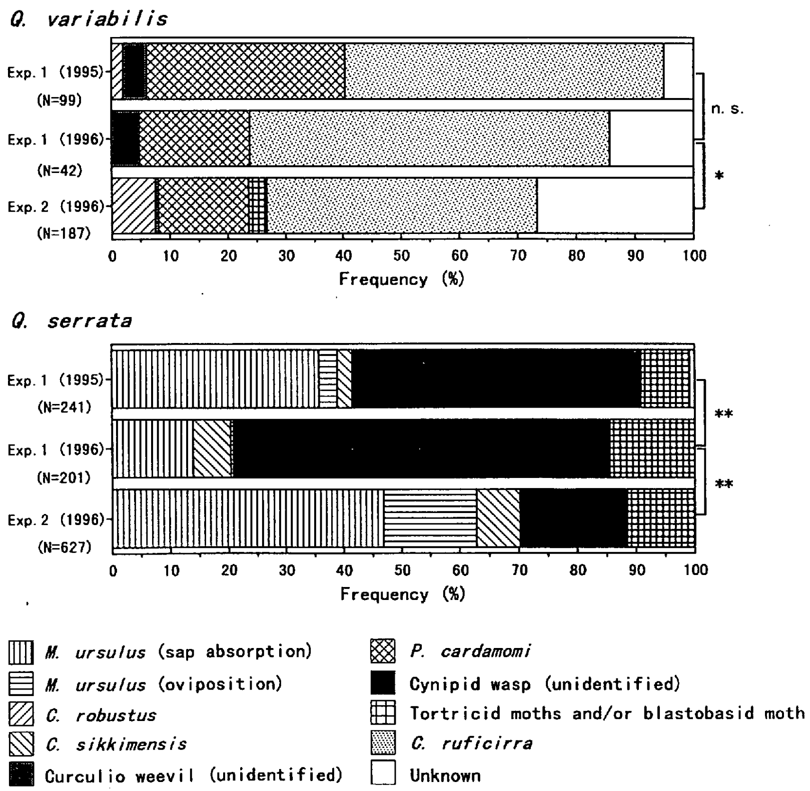

Fig. 1. Species composition and relative dominance of seed insects in acorns of *Q. variabilis* and *Q. serrata* falling into seed traps in Experiments 1 and 2, 1995 and 1996. The total number of damaged acorns is the sum of the number of acorns infested by each insect species. (Asterisk means significant difference according to χ^2-test: * $P<0.05$, ** $P<0.01$, $^{n.s.}$ no significant)

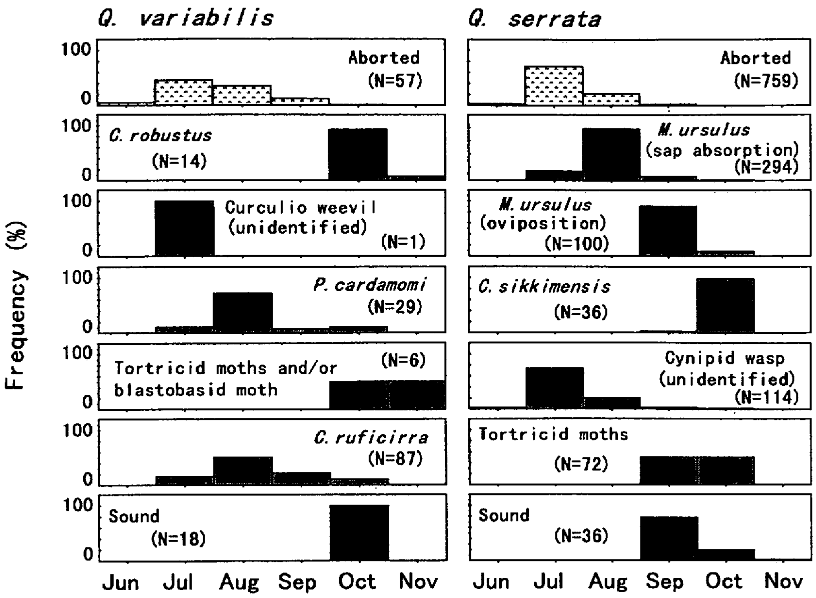

Fig. 2. Seasonal falling patterns of aborted, insect-infested and sound acorns of *Q. variabilis* and *Q. serrata* in Experiment 2, 1996. The number of acorns falling in each month is sum of the number of acorns collected in each sampling week.

ruficirra (Hampson)). Acorns of *Q. serrata* were infested by a total of seven insect species: a mechoris weevil (*Mechoris ursulus* (Roelofs)), a curculio weevil (*Curculio sikkimensis* (Heller)), a scolytid beetle (*P. cardamomi*), a cynipid wasp (unidentified species) and tortricid moths (*Cydia danilevskyi* (Kuznetzov), *C. glandicolana* and *C. amurensis* (Danilevsky)). In the present study, *P. cardamomi* and *C. glandicolana* were found in both *Q. variabilis* and *Q. serrata* acorns (Table 1).

Figure 1 shows the species composition and relative dominance of the seed insects in acorns of *Q. variabilis* and *Q. serrata* that fell into the seed traps in Experiments 1 and 2. Since only 12 acorns were attacked by two insect species in both Experiments 1 and 2, the category of concurrent infestation is not included in Figure 1. Consequently, the total number of infested acorns is the sum of the number of acorns infested by each insect species. In *Q. variabilis, C. ruficirra* was the most dominant species, followed by *P. cardamomi* (Fig. 1). *C. robustus* and another curculio weevil (unidentified species) occurred in less than 10% of all damaged acorns of *Q. variabilis* in both Experiments 1 and 2. Tortricid and/or blastobasid moths were observed only in Experiment 2.

In *Q. serrata,* cynipid wasp and *M. ursulus* (sap absorption and oviposition) were co-dominant, although their relative dominance differed significantly between years (χ^2-test: $P<0.01$) and experiments (χ^2-test: $P<0.01$) (Fig. 1). Tortricid moths and *C. sikkimensis* infested *Q. serrata* acorns consistently, with percentages ranging from 2% to 15% of all attacks.

Seasonal fall of acorns

Figure 2 shows the seasonal fall patterns of aborted, insect-infested and sound acorns of *Q. variabilis* and *Q. serrata* in Experiment 2 in 1996. In *Q. variabilis,* acorns attacked by *C. ruficirra* and *P. cardamomi* fell from July to October with a peak in August, but those attacked by tortricids, blastobasid moth and *C. robustus* fell after October (Fig. 2). Aborted acorns continued to fall from June to October, but sound acorns dropped only in October.

In contrast, in *Q. serrata,* acorns infested by a cynipid wasp, *M. ursulus* (absorbing sap, ovipositing), and *C. sikkimensis* fell mainly in July, August, September, and October, respectively (Fig. 2). Tortricid moth-infested acorns fell in September and October. Aborted acorns fell from June to October with a peak in July, while sound acorns fell from September to November.

Discussion

It is clear from our field study that three coleopteran species and four lepidopteran species attack *Q. variabilis* acorns (Table 1). This is the first description of seed-insect fauna of *Q. variabilis* in the literature, except for *C. glandicolana* and *C. ruficirra* (Table 2). Of these insects, *C. ruficirra* were most common (Fig. 1). The species is capable of attacking acorns of *Q. variabilis,* although it has been known as foliage feeder (Teramoto, 1993). Attacks by *C. ruficir-*

Table 2. Host acorns for the seed insects found in the present study.

Insect species	Host acorn					
	Q. acutissima	*Q. variabilis*	*Q. mongolica* var. *grosseserrata*	*Q. serrata*	*Q. glauca*	*Q. myrsinaefolia*
Coleoptera						
Mechoris ursulus (Roelofs)				●○[1,3,4]	○[3]	○[3]
Curculio robustus (Roelofs)	○[2]	●				
Curculio sikkimensis (Heller)			○[5]	●○[1,3,4]	○[3]	○[3]
Curculio weevil (Unidentified)		●				
Poecilips cardamomi (Schaufuss)		●		●○[3,4]	○[3]	○[3]
Hymenoptera						
Cynipid wasp (Unidentified)			○[7]	●○[7]		
Lepidoptera						
Blastobasid moth (Unidentified)		●	○[5]	○[3]	○[3]	○[3]
Pammene nemorosa Kuznetzov		●	○[5]			
Cydia danilevskyi (Kuznetzov)			○[5]	●		○[3]
Cydia glandicolana (Danilevsky)	△	●△	○[5]	●△	△	△
Cydia amurensis (Danilevsky)	△	△	△	●△	△	○[3]
Characoma ruficirra (Hampson)	○[6]	●○[6]		○[6]		

●: The present study.
○: The past studies ([1]Matsuda (1982), [2]Morimoto (1984), [3]Ueda *et al.* (1992), [4]Fujii (1993), [5]Maeto (1993, 1995), [6]Teramoto (1993) and [7]Yukawa & Masuda (1996)).
△: Hosts recorded by assumptive expression in Teramoto (1993).

ra occurred in not mature acorns but immature acorns (Table 1). Cupules of *Q. variabilis* acorns are green-colored and foliaceous at immature stage. These facts suggest that *C. ruficirra* has possibly evolved from foliage feeder into foliage/acorn feeder.

It has been reported that *M. ursulus, P. cardamomi, C. sikkimensis,* cynipid wasp and lepidoptera species attack acorns of *Q. serrata* (Table 2). Matsuda (1982), Ueda *et al.* (1992) and Fujii (1993) also found *Curculio dentipes* (Roelofs) and *Kobuzo retictirostris* (Roelofs) in *Q. serrata* acorns. In the present study, it is noteworthy that a cynipid wasp dominantly exploited *Q. serrata* acorns (Table 1 and Fig. 1). This cynipid wasp lays eggs in the pistillate flowers of *Q. serrata,* and then the flower develops a gall containing a single larva of the wasp (Yukawa & Masuda, 1996). Similar phenomenon has been reported in another cynipid gall wasp, *Andricus quercuscalicis* (Burgsdorf) (Claridge, 1962; Collins *et al.,* 1983), which damages 35 to 60% of *Q. robur* Pall. acorns in England (Hails & Crawley, 1991). Thus, cynipid gall wasps would have a fatal effect on acorn production of *Quercus* trees.

Seed insects found in this study area have attacked more than two *Quercus* species, except for curculio weevil (unidentified) (Table 2), which suggests that the insects are generalist predators of *Quercus* acorns. In fact, *C. glandicolana* and *P. cardamomi* attacked both *Q. variabilis* and *Q. serrata* acorns (Table 2). However, there was a marked difference in insect fauna between *Q. variabilis* and *Q. serrata,* both of which dominate the study area (Table 1). Of the observed insects, *C. robustus,* a curculio weevil (unidentified), a blastobasid moth (unidentified), *P. nemorosa* and *C. ruficirra* attacked only acorns of *Q. variabilis,* whereas *M. ursulus, C. sikkimensis,* a cynipid wasp (unidentified), *C. danilevskyi* and *C. amurensis* attacked only *Q. serrata* acorns. In our study area, *C. ruficirra* was most dominant in acorns of *Q. variabilis,* not occurring in acorns of *Q. serrata* (Fig. 1). However, attacks by *C. ruficirra* have been reported in acorns of *Q. serrata* in another study site (Table 2). Thus, it is presumed that *C. ruficirra* prefer *Q. variabilis* acorns to *Q. serrata* acorns in the area. Neither a blastobasid moth (unidentified) nor *C. amurensis* also attacked their host acorns of the *Quercus* species in the area, although these two species attack acorns of most *Quercus* species (Table 2), implying their oviposition preferences.

In this study, *C. robustus* and *C. sikkimensis* attacked acorns of *Q. variabilis* and acorns of *Q. serrata,* respectively (Table 1). It has been reported in other studies (Table 2) that a host for *C. robustus* is acorns of *Q. acutissima* Carruth. (Morimoto, 1984), and that *C. sikkimensis* has a wide host range of acorns of *Q. mongolica* var. *grosseserrata, Q. serrata, Q. glauca*

Thunb. ex Murray and *Q. myrsinaefolia* Blume (Ueda *et al.,* 1992; Maeto, 1993, 1995). Acorns of *Q. acutissima* and *Q. variabilis* have thick and spiny cupules, whereas the other *Quercus* acorns have thin and scale-like cupules. These findings suggest that morphological characteristics of acorn cupule strongly affect acorn utilization of the curculio weevils. *M. ursulus* also attacked only *Q. serrata*-typed acorns (Table 2). This would be closely associated with oviposition preference of the seed insect due to differences in the cupule characteristics.

In the present study, there were significant differences in species composition and their relative dominance of the seed insects between the years and between the experiments. In *Q. variabilis,* seed-insect fauna was significantly different between Experiment 1 and Experiment 2 of 1996 (Fig. 1). In Experiment 2, attacks by *C. robustus,* blastobasid moth and/or tortricid moths occurred, but not in Experiment 1. This result is likely to be explained by difference in the number of collected acorns between the experiments. The smaller number of acorns in Experiment 1 probably caused under-estimation of the seed-insect fauna. In *Q. serrata,* seed-insect fauna was significantly different not only between the experiments but also between the years (Fig. 1). In particular, the dominance greatly varied in the percentages of cynipid wasp and *M. ursulus* (sap absorption and oviposition) to all damaged acorns, although the reasons are not clear.

There was an obvious difference in the falling period of damaged acorns (Fig. 2). In *Q. variabilis,* most acorns infested by *C. ruficirra* and *P. cardamomi* fell in August (Fig. 2). In acorns of *Q. serrata* dispersed before September, attack by a cynipid wasp and sap absorption by *M. ursulus* were observed (Fig. 2). Matsuda (1982) also reported that sap absorption by *M. ursulus* was found in *Q. serrata* acorns from mid-July to mid-August in Mitaka City, Tokyo. On the other hand, in both *Q. variabilis* and *Q. serrata,* acorns infested by tortricid moths, *C. robustus* and *C. sikkimensis* dropped after September along with sound acorns (Fig. 2). The difference in seasonal fall of insect-damaged acorns would be closely associated with the differences in the period of adult emergence and/or the time of attack by the seed insects. However, we lack firm data on the relationship between acorn phenology and insect colonization time. We should clarify the seasonal trends in emergence of the insects and the time of insect attacks on pre-dispersal acorns on the tree during acorn growth after flowering by direct observations and field experiments.

Acknowledgments

The authors thank Dr. F. Komai of Osaka University of Arts, Dr. K. Morimoto of Kyushu University, and Mr. A. Ueda of Kansai Research Center, Forest and Forest Products Research Institute, for identifying the seed insects. We also thank Prof. E. Shibata of Nagoya University, for his critical reading of the manuscript, and Dr. N. Hijii of Nagoya University, for his valuable suggestions. Thanks are also extended to the members of the Laboratory of Forest Protection, Nagoya University, for their helpful suggestions. This study was supported in part by a Grant-in-Aid for Scientific Research from the Japan Ministry of Education, Science and Culture (No. 09001647 and No. 11460068) and Nippon Life Insurance Foundation.

References

Claridge, M. F. 1962. *Andricus quercuscalicis* (Burgsdorf) in Britain (Hym.: Cynipidae). *The Entomologist,* **95**: 60–61.

Collins, M., Crawley, M. J. & McGavin, G. C. 1983. Survivorship of the sexual and agamic generations of *Andricus quercuscalicis* on *Quercus cerris* and *Q. robur. Ecological Entomology,* **8**: 133–138.

Darley-Hill, S. & Johnson, W. C. 1981. Acorn dispersal by blue jay (*Cyanocitta cristata*). *Oecologia,* **50**: 231–232.

Fujii, S. 1993. Studies on acorn production and seed predation in *Quercus serrata* —Growth, falling phenology, estimation of production, and insect seed predators—. *Bulletin of Osaka Museum of Natural History,* **47**: 1–17.

Gibson, L. P. 1964. Biology and life history of acorn-infesting weevils of the genus *Conotrachelus* (Coleoptera: Curculionidae). *Annals of the Entomological Society of America,* **57**: 521–526.

Gibson, L. P. 1971. Insects of bur oak acorns. *Annals of the Entomological Society of America,* **64**: 232–234.

Hails, R. S. & Crawley, M. J. 1991. The population dynamics of an alien insect: *Andricus quercuscalicis* (Hymenoptera: Cynipidae). *Journal of Animal Ecology,* **60**: 545–562.

Hora, B. 1981. The Oxford encyclopedia of trees of the world. Oxford University, Oxford.

Kautz, L. G. & F. G. Liming. 1939. Acorn crops in the Missouri Ozarks. *Journal of Forestry,* **37**: 904.

Kikuzawa, K. 1988. Dispersal of *Quercus mongolica* acorns in a broadleaved deciduous forest. 1. Disappearance. *Forest Ecology and Management,* **25**: 1–8.

Koenig, W. D., Mumme, R. L., Carmen, W. J. & Stanback, M. T. 1994. Acorn production by oaks in central coastal California: Variation within and among years. *Ecology,* **75**: 99–109.

Maeto, K. 1993. Acorn insects of *Quercus mongolica* var. *grosseserrata* in Hitsujigaoka natural forest, Hokkaido —Life-history of the principal species and their impacts on seed viability—. *Transaction of the Meeting in the Hokka-*

ido Branch of the Japanese Forestry Society, **41**: 88–90. (In Japanese.)

Maeto, K. 1995. Relationships between size and mortality of *Quercus mongolica* var. *grosseserrata* acorns due to predispersal infestation by frugivorous insects. *Journal of the Japanese Forestry Society,* 77: 213–219.

Matsuda, K. 1982. Studies on the early phase of the regeneration of a konara oak (*Quercus serrata* Thunb.) secondary forest I. Development and premature abscissions of konara oak acorns. *Japanese Journal of Ecology,* **32**: 293–302.

Morimoto, K. 1984. Curculionidae. In Hayashi, M. *et al.* (eds.), *The Coleoptera of Japan in color Vol. IV*: 269-345. Hoikusha, Osaka. (In Japanese.)

National Astronomical Observatory. 1994. Chronological Scientific Tables. Maruzen, Tokyo. (In Japanese.)

Oba, H. 1989. Fagaceae. In Satake, Y. *et al.* (eds.), *Wild flowers of Japan woody plants I,* 66–78. Heibonsha, Tokyo. (In Japanese.)

Teramoto, N. 1993. Catalogue of host plants of lepidopterous insects in Japan (Fagaceae). *Bulletin of the Shiga Prefecture Agricultural Experiment Station, Extra issue,* **1**: 1–185. (In Japanese.)

Ueda, A., Igarashi, M., Ito, K. & Koizumi, T. 1992. Acorn infestation by insects on three evergreen oaks, *Quercus glauca, Q. myrsinaefolia* and *Pasania edulis* (I) Their invasion term and level before acorn dropping and comparison with the deciduous *Q. serrata. Transaction of the 103th Annual Meeting of the Japanese Forestry Society*: 529–532. (In Japanese.)

Ueda, A., Igarashi, M. & Ito, K. 1993. Acorn infestation by insects on three evergreen oaks, *Quercus glauca, Q. myrsinaefolia* and *Pasania edulis* (II) Their invasion term and level after acorn dropping. *Transaction of the 104th Annual Meeting of the Japanese Forestry Society*: 681–684. (In Japanese.)

Williams, C. E. 1989. Checklist of north American nut-infesting insects and host plants. *Journal of Entomological Science,* **24**: 550–562.

Yukawa, J. & Masuda, H. 1996. *Insect and mite galls of Japan in color,* Zenkoku-Noson-Kyoiku-kyokai, Tokyo. (In Japanese.)

(Received January 8, 1999; Accepted May 28, 1999)