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Bionomics of *Curculio ochrofasciatus* Morimoto (Coleoptera, Curculionidae)

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Abstract We examined the ecology and life cycle of the weevil *Curculio ochrofasciatus* in Minô Park, Osaka Prefecture, central Japan, and also in the laboratory. The weevil laid eggs singly on large developing seeds of *Maackia floribunda*. The larvae consumed the seeds and egressed from the seed pods after maturing throughout October. The destruction rate of the seeds was 78.3%. Of the seeds, at least 75.8% were attacked by weevil larvae. Under laboratory conditions, most of the matured larvae died of fungal infection during winter, and thus only 7.4% of them developed to adults in May or from September to November of the following year. This weevil is a unique *Curculio* species that uses Fabaceae as its host plant.

Introduction

Curculio Linnaeus, 1758 weevils have diversified primarily using seeds and chestnuts of various trees such as Fagaceae, Corylaceae, Betulaceae, Salicaceae, and Moraceae, but Fabaceae seeds are rare hosts (Gibson, 1969; Morimoto, 1984; Hughes & Vogler, 2004). This host-use pattern is in contrast to bean weevils (Chrysomelidae, Brucinae), which monopolize seeds of various Fabaceae species and potentially compete with other seed-eating insects.

Curculio ochrofasciatus Morimoto, 1981 is a relatively rare species found in Hokkaido, Honshu, Shikoku, Kyushu, and the Korean peninsula (Morimoto, 1984; Kume, 2002). *Curculio ochrofasciatus* adults were collected on *Maackia amurensis* (Rupr. et Maxim.) (Horikawa, 2002) and *Maackia floribunda* (Miq.) Takeda (Fabaceae) (Sawada, 2002). Sawada(2002) reported *C. ochrofasciatus* adults bored their rostra into *M. floribunda* buds. Although these reports suggested that this weevil used both *Maackia* trees, no previous studies have reported on its larval hosts or other ecological aspects. We found that *C. ochrofasciatus* larvae feed on *M. floribunda* seeds, and observed a part of life cycle of the weevil in Osaka, central Japan. Here, the ecological aspects of this unique Fabaceae-feeding *Curculio* weevil are described.

Materials and Methods

Maackia floribunda (Hanemi-inu-enjyu in Japanese) occurs throughout montane areas of western Honshu, Shikoku, and Kyushu of Japan (Ohashi, 1989). It blooms late July to mid-August and its seeds mature from late October to early November. The pods are ca. 20–60 mm long and ca. 10 mm wide and contain 0–4 seeds (Ohashi, 1989, Yamazaki, personal observations). The related species *M. amurensis* grows in Hokkaido and eastern Honshu, and *M. tashiroi* (Yatabe) Makino is restricted to the coastal areas of Wakayama Prefecture (western Honshu), Shikoku, and southern islands of Japan (Ohashi, 1989). Thus, three *Maackia* species occur allopatrically in Japan.

We collected the seed pods (n=252) from twigs of a *M. floribunda* tree 2–3 m above the ground in Minô Park (34°51′N, 135°29′E, ca. 280 m above sea level), Minô City, Osaka Prefecture, central

Japan, on October 4, 2011. The *M. floribunda* tree grew along the Minô-gawa stream, where deciduous *Acer palmatum* THUNB. (Aceraceae), *Zelkova serrata* (THUNB.) MAKINO (Ulmaceae), and *Celtis sinensis* PERS. var. *japonica* (PLANCH.) NAKAI (Cannabaceae) trees predominated. We transferred the pods with plastic bags, and preserved in three 500-mL plastic cups under laboratory conditions (ca. 18–28°C, seminatural day length). After larvae emerged, they were maintained in two 200-mL plastic cups, which contained Akatama soil ca. 50 mm in depth under laboratory conditions. Several tiny holes were punctured in the lids of the cups for ventilation. We sprayed distilled water over the soil once a week. We checked adult emergence daily until December 17, 2012, when the soil was spread on a white sheet of paper to check the remaining larvae.

To examine seed conditions, infestation rate, and fate of *C. ochrofasciatus* larvae, the pods were dissected individually under a stereomicroscope. The remaining seeds in the pods were classified as undeveloped (<5 mm long) or developing ones (>5 mm long, usually ca. 7 mm long, 5 mm wide) based on their sizes, although seeds attacked by the weevil larvae were often completely consumed and could not be classified. When the seeds were largely consumed and small emergence holes (ca. 2 mm in diameter) were found on the pods, we determined that the larvae have completed development and successfully emerged. When the seeds showed evidence of feeding, such as fecal pellets, and contained dead larvae, we concluded that the larvae have died before emergence. When the seeds were heavily damaged together with the pods, their conditions and damage by the weevil larvae were unknown. The number of seeds in each pod, attack rate of seeds, larval emergence rate, and adult eclosion rate were calculated.

To clarify annual fluctuation of seeding and the consumption rate of seeds by the weevils in the field, we revisited the sampled tree and searched for the pods both above the tree and on the ground on November 22, 2012.

Results and Discussion

The sampled pods (n=252) contained 281 seeds in total; 86.5% of the pods had only one seed, 10.7% had two seeds, 1.2% had three seeds, and 1.6% had none. The pod with no seeds could be discriminated from that with seeds which was completely consumed by weevil larvae, because the latter contained egg and larval exuviae, frass and fecal pellets. Of the 281 seeds, 9.6% were undeveloped, small and thus possibly aborted, whereas the remaining 90.4% were large developing seeds. Although matured seeds have hard seed coats, all the seeds sampled had soft seed coats and thus were thought to be unmatured. Therefore, female adults seemed to have oviposited on developing seeds. There is a little possibility that females also lay their eggs on matured seeds, although those seeds were not sampled in this study. The undeveloped small seeds were not attacked by the weevil. We found that 75.8% of the seeds were attacked by the weevil larvae, 12.1% were not attacked, and 2.5%, together with the pods, were heavily damaged. The heavily damaged pods contained dead unidentified lepidopteran caterpillars, their fecal pellets, or exuviae. If these caterpillars attack pods and seeds indiscriminately regarding the presence of weevil larvae, they may contribute to mortality of the weevil larvae.

Each seed was attacked by only one weevil larva (n=213), because of the egg capsule (oval shape, ca. 0.5 mm long), two larval head capsules, and an emergence hole remaining in the pod. However, only one seed contained two egg capsules. The high attack rate (i.e., 75.8%) and very rare example of multiple oviposition indicate that gravid adults carefully select their egg-laying sites to circumvent larval competition, resulting in a uniform distribution of the eggs. In some insects such as two gall-parasitic weevils *Wagnerinus costatus* (HUSTACHE) and *Orchestes hustachei* (KLIMA), and a leafminer, *Agromyza frontella* (Rondani), adult females avoid multiple ovipositions and subsequent intraspecific larval competition using oviposition-deterrent pheromone or by killing eggs of other individuals (e.g., McNeil & Quiring, 1983; Yamazaki & Sugiura, 2001; Sugiura *et al*., 2004).

Of the 213 weevil larvae, 76.1% developed and emerged from the pods, while 23.9% died in the pods. Full-grown larvae were cream-colored with yellowish-brown heads, and ca. 6.5 mm long and ca. 3.0 mm wide. The larvae egressed from the pods and burrowed into the Akatama soil from October 5 to October 31, 2011. Some larvae remained still at the bottom of the rearing cups, while others were more active and appeared repeatedly on the surface. Pupation took place in small pupal chambers in the soil from April to November 2012. As a result of rearing, five males and two females of *C. ochrofasciatus* emerged from May 7 to November 13, 2012 (May 7: 1 ♂; May 21: 1 ♂; May 31: 1 ♂; late September: 1 ♂; October 3: 1 ♂, 1 ♀; November 13: 1 ♀). By December 17, 2012, no larvae remained in the soil. The eclosion rate was 7.4% (n=95). Most of the matured larvae died of fungal infection, as evidenced by white fungal hyphae. These results suggest that larval mortality is relatively low in the pods but high during overwintering in the soil, although this report is limited under laboratory conditions and other mortality factors such as predation by birds and arthropods may be involved in the field.

On November 22, 2012, the sampled *M. floribunda* trees had no seed pods, implying considerable annual variation of seed production. Several *Curculio* weevils exhibit a prolonged diapause up to four overwinterings as larvae to cope with the annual seeding variation (Manu & Debouzie, 1993; Maeto & Ozaki, 2003). In the case of *C. ochrofasciatus*, all the adult individuals emerged within the next year, but adults which emerged in autumn may overwinter and reproduce in the following year. Further research such as field surveys will clarify the life cycle of this weevil.

We showed that *C. ochrofasciatus* larvae feed on *M. floribunda* seeds in western Japan. However, in eastern and northern Japan, *M. amurensis* is the host instead of *M. floribunda*. Horikawa (2002)'s collection which recorded many *C. ochrofasciatus* adults on *M. amurensis* suggests that *M. amurensis* is a larval host plant in those regions. To elucidate geographical patterns of host use in this weevil, *M. tashiroi* in coastal areas of western Japan as well as *M. amurensis* will be examined.

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要　　約

山崎一夫・藤本博文：キオビシギゾウムシ *Curculio ochrofasciatus* (Morimoto)（コウチュウ目ゾウムシ科）の生活史．── 大阪府箕面産のキオビシギゾウムシ *Curculio ochrofasciatus* 個体群において，卵，幼虫期の生態と生活環を野外観察と室内飼育により調査した．卵はハネミイヌエンジュの発育中の大型種子に1個ずつ産卵されていた．幼虫は種子を食べつくした後，10月中にさやから脱出し土中に潜って越冬した．種子の昆虫による被食率は78.3%であった．そして，全種子の少なくとも75.8%がゾウムシ幼虫による攻撃を受けていた．多くの幼虫は越冬中に菌感染により死亡した．羽化は翌年の5月と9–11月に行われ，羽化率は7.4%であった．以上のように，本種はマメ科植物を寄主とするユニークなシギゾウムシであることが判明した．

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