Flight Patterns and White Grub Population Densities of Three Beetle Species (Coleoptera: Scarabaeidae) in the Mountains of Northwestern North Carolina[1]

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J. Entomol. Sci. 25(1): 34-43 (January 1990)

ABSTRACT Light-trap and soil-sampling studies were conducted at higher elevations in the Appalachian Mountains of northwestern North Carolina to determine adult flight patterns and white grub population densities and instar ratios of three scarab species: *Phyllophaga anxia* (LeConte) Glasgow, *P. fusca* (Froelich) Glasgow, and *Polyphylla comes* Casey. Flights of the two *Phyllophaga* species overlapped (May-June), preceding *Polyphlla* flights (July-August). Multiple flights of *Phyllophaga anxia* and *P. fusca* occurred over periods of 10 and 12 weeks, respectively. Multiple flights of *Polyphylla comes* lasted for 6 weeks. For all three species, peak flight densities occurred 3 to 4 weeks after initial flights. *Phyllophaga* males and females were captured in large numbers, but very few female *Polyphylla* were caught. Most *Phyllophaga* were caught before midnight, most *Polyphylla* between midnight and 0400 h. White grubs were found in the root zone from early May to late September. The mean (±SEM) and maximum grub densities observed were 14.6 ± 1.7 and 34.0 grubs per m^2, respectively.

KEY WORDS Coleoptera, flight, May beetles, North Carolina, *Phyllophaga anxia, Phyllophaga fusca, Polyphylla comes,* Scarabaeidae, white grubs.

Beetles of the genera *Phyllophaga* Harris and *Polyphylla* Harris are found throughout the United States and feed on foliage of broadleaf trees, shrubs, grasses, weeds, and field crops (Luginbill and Painter 1953; Ueckert 1979). Their white grub larvae live in the soil and feed on roots of grasses, shrubs and trees, and decaying plant matter, and can move laterally several meters to locate food (Hammond 1940; Speers and Schmiege 1961; Pike et al. 1977). Fibrous-rooted plants such as timothy grass, *Phleum pratense* L., are very susceptible to injury, whereas the root systems of sweet clover and alfalfa are more resistant to feeding. Tubers and roots of root crops and vegetables may be extensively damaged (Hammond 1940). White grubs also are destructive pests in forest tree nurseries where dense populations of seedlings are grown for transplanting (Shenefelt and Simkover 1951; Fowler and Wilson 1971).

In the southern Appalachian Mountains, beetles often oviposit in grass pastures, preferring mowed or shortgrass areas for grub feeding and development (Chamberlin and Callenbach 1943). White grubs also feed on conifer roots (Heit and Henry 1940; Fowler and Wilson 1971) and have recently caused mortality to Fraser fir, *Abies fraseri* (Pursh) Poir., in Christmas tree plantations (Kard and Hain 1987).

[1] Accepted for publication 18 July 1989.

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The predominant white grub species in the grass pastures in our study site are *Phyllophaga anxia* (LeConte) Glasgow, *Phyllophaga fusca* (Froelich) Glasgow, and *Polyphylla comes* Casey. Adults of both genera are nocturnal fliers, appearing during spring and summer nights in the southern Appalachians. They feed and mate at night, returning to the sod before dawn to oviposit in the root zone (Speers and Schmiege 1961). During the day they seek shelter under rocks, in leaf litter and soil, and in grass sod. Oviposition occurs over a period of several weeks. Eclosion occurs 2 to 3 weeks after oviposition.

In cool mountainous climates, life cycles of several grub species generally last 3 years, with grubs present for 2 years. Grubs molt twice prior to burrowing deeper into the soil to form oval-shaped pupal cells. In 3 to 4 weeks, pupae transform to adults which overwinter and emerge the next spring. However, lengths of life cycles vary, and all life stages can be found overwintering (Hammond 1940; Ives and Warren 1965). Adult emergence occurs every year, but flight patterns and white grub densities have not been documented at higher elevations in the Applachian Mountains in northwestern North Carolina.

The objectives of this study were to determine beetle flight patterns and sex ratios, and population densities and instar ratios of the white grub complex at our high-elevation study site during a typical growing season. This information will provide insight concerning effective timing and use of integrated control measures.

Materials and Methods

Five light traps were placed in grass pastures adjacent to Fraser fir Christmas tree stands near Long Hope Mountain, Watauga County, NC (trap elevations = 1,359 to 1,372 m). The pastures and grass areas within the tree stands contained many white grubs in the root zone (Kard and Hain 1987). Pastures consisted of a mixture of annual and perennial grasses interspersed with broadleaf weeds, and were mowed for hay in the fall. Soil type was Porter loam (11 to 13% organic matter). Soil parameters were: pH 5.3 to 5.6; temperature at a depth of 10 cm, 16 to 20°C; soil moisture 19 to 23% by weight. These conditions are well suited for grub survival (Hammond 1948; Gaylor and Frankie 1979).

Light traps were separated by a distance ranging from 100 to 200 m. Each trap consisted of a vertically installed 30-watt tubular fluorescent ultraviolet (UV) bulb, 1.2 m in length, enclosed by four 1.2- by 0.2-m perpendicular vanes. Tops of traps were ca. 2 m above the soil surface. Traps were located so that adults emerging from the sod would need to fly toward them to reach nearby broadleaf trees to feed, and were 10 to 25 m from Christmas tree stands. Traps were illuminated once a week from 1800 to 0800 h from March through September 1984, encompassing all flight periods. Adult beetles were collected every 2 h during each of these 14-h periods of trap operation, separated by genus, and counted. Genitalia were extracted to separate adults of *Phyllophaga anxia* and *P. fusca* and to determine sex ratios.

During 1985, light traps were illuminated from March through September as in 1984, but only the sequence of species emergence and flight was determined. In 1985, many thousands of beetles were caught, but total numbers captured and sex ratios were not determined. Sampling for white grubs was conducted at the same time to determine if the period of time grubs were present in the root zone was similar to 1984. However, mean grub densities and instar ratios were not calculated.

To sample for grubs, three additional grass pasture sites, each 50 by 100 m, were selected in the same general area where the light traps were located. At weekly intervals beginning in mid-April and continuing through September, 10 randomly selected sod samples in each site were examined for grubs. Sections of sod (0.09 m^2) were turned back to expose and count grubs feeding in the root zone. The soil beneath each sample was gently scarified and examined to a depth of 10 cm using a three-pronged, hand-held garden weeder. Less than 1% grub mortality and injury occurred during these procedures. Uninjured grubs were placed back into the soil and covered with sod. Grubs were not separated by species; however, 1st, 2nd, and 3rd instars were easily separated as differences in head capsule and body sizes were clearly noticeable.

The flight pattern distributions of the 1984 season-long light trap catches for each beetle species were compared using the Kolmogorov-Smirnov two-sample test (Steel and Torrie 1980). The 1984 distributions of the overnight light trap catches during the periods of peak flight for each species were also compared using the same test.

Results

Initial and peak flight periods differed between species (Fig. 1). *Phyllophaga anxia* flights began in early May 1984, 1 week prior to initial *P. fusca* flights. Both species reached peak flight numbers 4 weeks after their initial flight. *Polyphylla comes* adults did not begin flying until early July, reaching peak flight density in 3 weeks. Multiple flights of *Phyllophaga anxia* and *P. fusca* occurred over periods of 10 and 12 weeks, respectively. Multiple *Polyphylla comes* flights occurred for 6 weeks. During 1985, the same species sequence of flights and the number of weeks to reach peak flight periods occurred as in 1984. However, initial flights for each species began 6 to 7 days later.

Males of both *Phyllophaga* species predominated during the early and late weeks of the flight period of this genus, when relatively small numbers of beetles flew. Both males and females flew in large numbers during periods of peak flight. *Polyphylla comes* males predominated throughout their flight season, comprising more than 95% of the total *P. comes* collected (Fig. 1). Most *Phyllophaga* were caught prior to midnight, with 87% of the total capture occurring from 2000 to 2400 h during weeks of peak flight (Fig. 2). In contrast, 40% of the total *Polyphylla comes* capture occurred before midnight, while 59% of the total were caught between 2400 and 0400 h.

The season-long and peak flight period flight pattern distributions differed significantly between beetle genera ($P \leq 0.01$). However, *Phyllophaga anxia* and *P. fusca* distributions were not significantly different ($P \geq 0.1$), indicating that the populations of these two species are closely related. Both the season-long peak flight period flight pattern distributions of *Polyphylla comes* were significantly different from these distributions for both *Phyllophaga* species ($P \leq 0.01$). Thus, the *Phyllophaga* and *Polyphylla* populations would not be considered closely related.

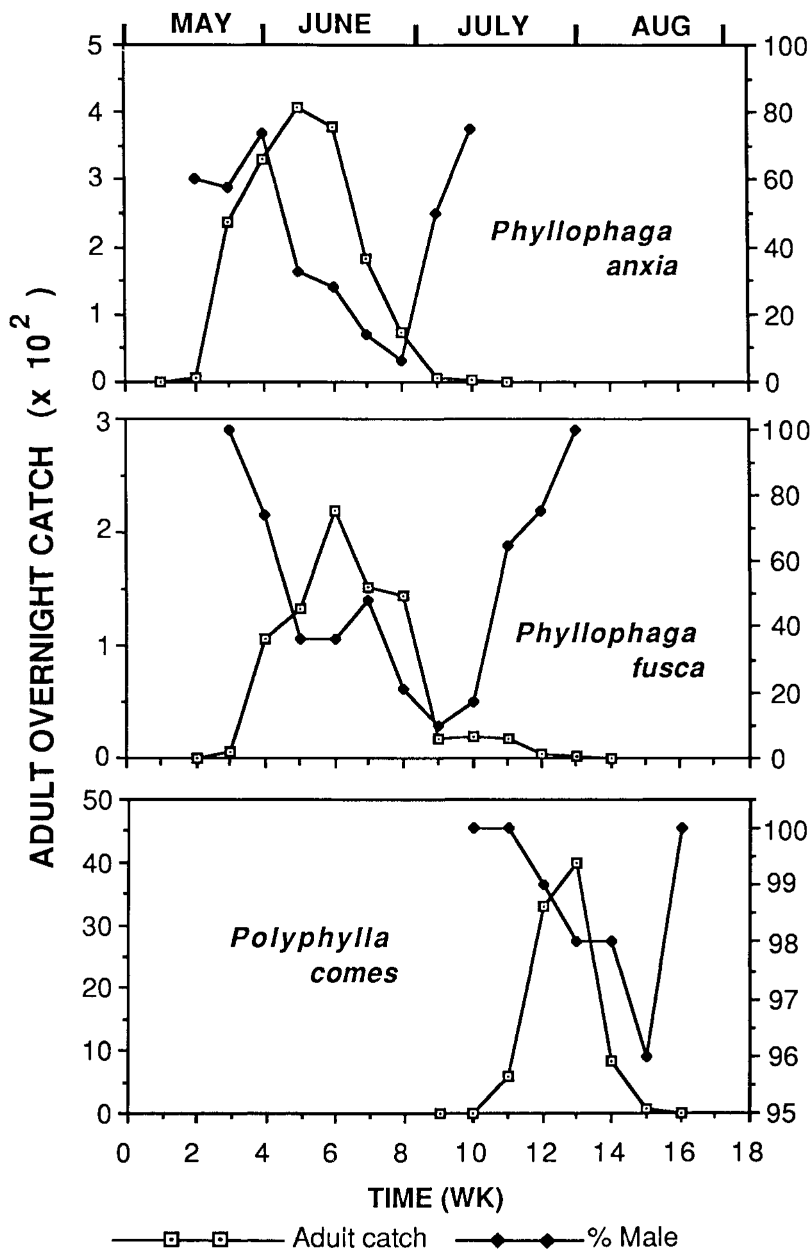

Fig. 1. Number of beetles caught overnight in ultraviolet light traps (sum of 5 traps) at high elevations in the mountains of northwestern North Carolina and the percentages of males caught from May through August 1984 (wk 0 = May 1st).

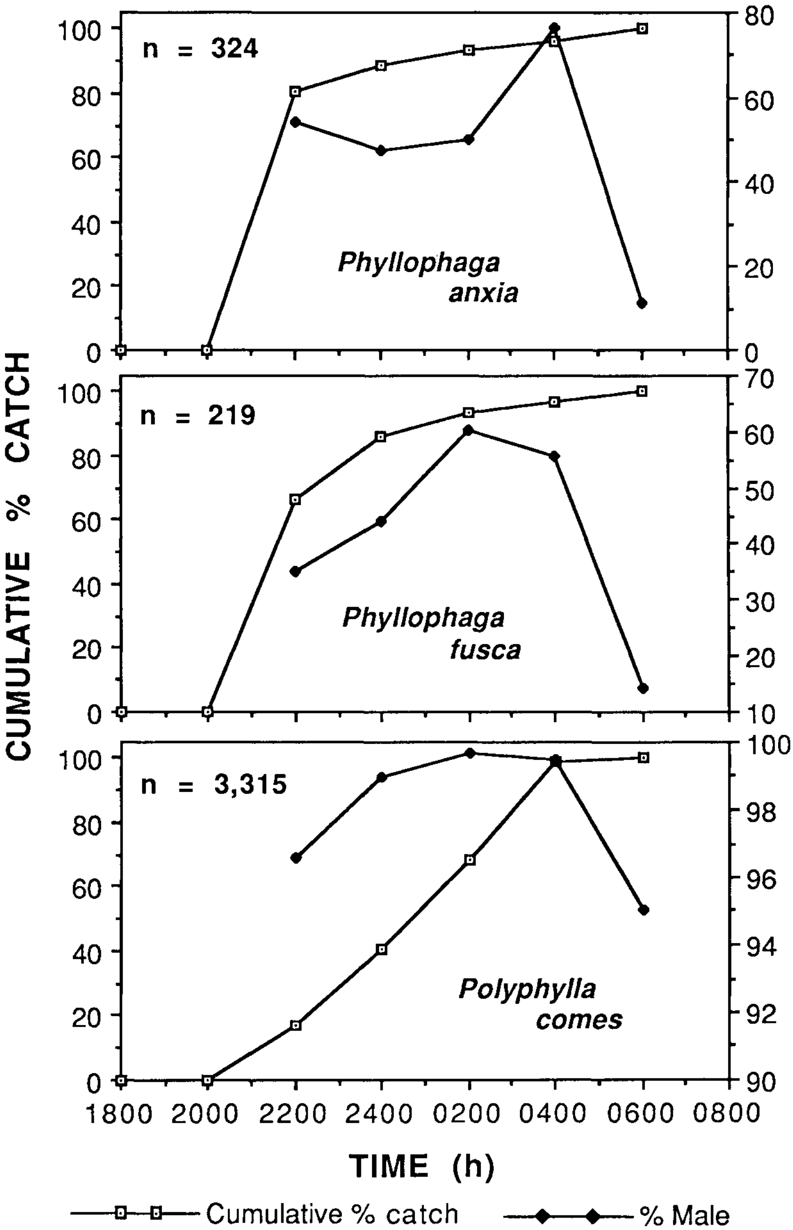

Fig. 2. Cumulative percentages of adult beetles caught in one night in five ultraviolet light traps at high elevations in the mountains of northwestern North Carolina, times of flight, and percentages of males caught during the week of peak flight, 1984 (n = sum of 5 trap catches).

After overwintering in the soil, white grubs moved upward to the sod root zone in early May 1984, 1 to 2 weeks before initial flights of *Phyllophaga* occurred. Grub densities peaked in early June and late August, with 3rd instars most numerous (Fig. 3). Grubs caused severe feeding damage to roots at these times; the sod was easily peeled back by hand to expose grubs. The prominent, short-duration peak in grub density in early July may have been caused by eclosion of large numbers of eggs laid in June. There was a noticeable increase in numbers of first instar grubs from mid-to-late June as well as in late July and early August.

In July and August, many pupae and adults began to appear in the soil just below the root zone. All flights ended by late august; however, grubs remained in the root zone until mid-September, at which time they moved downward to overwinter below the frost line. During 1985, grubs were first recovered from the root zone during mid-May, 1 week later than in 1984. They remained in the root zone until late September. Soil sampling during the winter revealed grubs at depths of 0.6 to 0.8 m below the soil surface.

Discussion

Johnston and Eaton (1939) noted that 75% of *Phyllophaga* spp. at lower elevations in the Carolinas completed their life cycles in 2 years, the remaining 25% in 3 years. In our study, the many pupae that appeared in the soil after *Phyllophaga* flights ended would produce overwintering adults. Adults from *Polyphylla* pupae found during the same period may have emerged to fly, mate, and oviposit in August, and some pupae and adults may have overwintered. Several hundred hectares around the study site have been grass pasture for decades, providing an ideal habitat for build-up of white grub populations. This accounts for the abundance of adult beetles.

Phyllophaga anxia and *P. fusca* are closely related species and grubs are difficult to separate by sight (Heit and Henry 1940). White grubs of *Polyphylla comes* are similar to *Phyllophaga anxia* and *P. fusca* in appearance, and all three species were present at the same time in the root zone throughout the 1984 and 1985 growing seasons. Thus, they were treated as a combined population.

All grub instars as well as adults and eggs of the three beetle species were found in the root zone throughout the summer. This diversity may reduce mortality due to predators and parasites because a mixture of beetle life stages and sizes may spread the risk of predation or parasitism of a life stage that may be most susceptible to attack. Tinbergen (1960) found that the probability of a prey insect being consumed by a predator was directly related to the size of the prey. Small adults and larvae were at reduced risk of predation and the developmental stage of the prey was an important factor. Larvae, pupae, and adults were not equally consumed by predators. Abundance of prey influences predation, and if fewer numbers of a particular insect or life stage are present, the chances of predation are reduced (Tinbergen 1960).

The mixture of life stages in the root zone may reduce inter- and intra-specific competition for food sources. Second-instar grubs are the most voracious feeders, whereas 1st and 3rd instars cause less damage to plant roots (Hammond 1941; Schwardt 1942). This variation in feeding requirements within the grub complex may result in minimized competition for food (Price 1984). The three beetle species have a 3-year life cycle at our study site, but these cycles do not

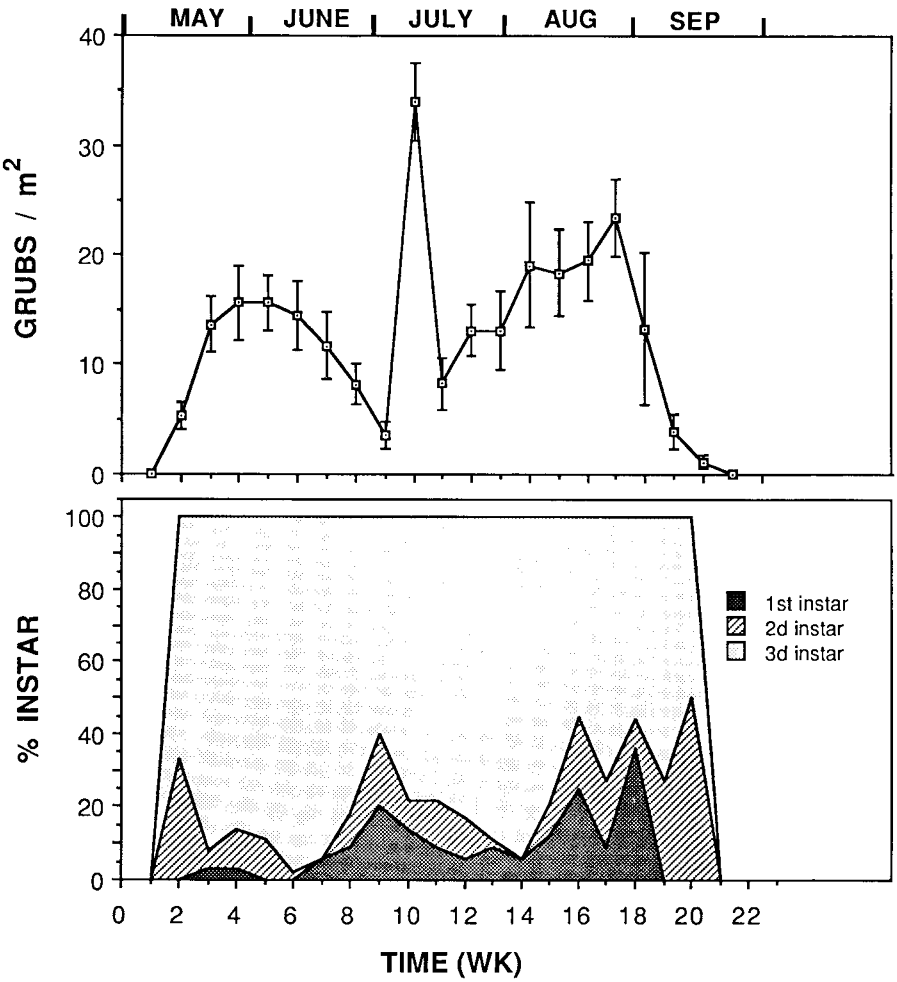

Fig. 3. Mean white grub density (± SEM) and instar percentages of a beetle complex (*Phyllophaga anxia, Phyllophaga fusca, Pollyphylla comes*) at high elevations in the mountains of northwestern North Carolina during 1984; the vertical distance within each instar area (areas do not overlap; percentages always sum to 100%) represents the mean percentage for that instar (wk 0 = May 1st).

necessarily coincide, and different broods of each species may be flying, mating, and ovipositing during successive growing seasons. These differences reduce competition for limited resources, ensuring the 2nd-instar grubs have adequate food supplies. Pupae are the most fragile stage. Their short 2- to 3-week developmental period may enhance survivability (Maheux and Gauthier 1944).

Chamberlin and Seaton (1941) noted that many more male than female June beetles are captured in light traps, suggesting that *Phyllophaga* species males may outnumber females in nature. However, their subsequent collecting of adult beetles from food plants over a 5-year period demonstrated that the sex ratios were nearly equal, and *P. anxia* and *P. fusca* males comprised 55 and 49% of the totals of these two species captured, respectively. In a Texas study, 75% of *P. crinita* Burmeister captured in UV light traps were males, and males were more active fliers that females (Stone 1986). The majority of females *P. crinita* flew during a very narrow time frame (2100 to 2130 h), never exceeding 24% of the total *P. crinita* capture.

The dominance of males of *Phyllophaga* spp. caught in light traps is documented by several other authors (Hayes 1925; Chamberlin and Seaton 1941; Lim et al. 1979). June beetles captured in light traps by Maheux and Gauthier (1944) were 88% males and 12% females, but foliage collections produced a 1:1 male to female ratio. In Ontario, Canada, Guathier (1944) collected *P. fusca* in light traps. Females were not strongly attracted to lights and males comprised 95% of the *P. fusca* captured. Chamberlin and Seaton (1941) determined that different species of June beetles in the same locality do not emerge and fly at the same time in the season, and that males tended to be more abundant early in the season. Females may emerge and feed in greater numbers than the males during preoviposition and early oviposition periods.

Light-trap collections alone may not provide a highly accurate estimate of the proportion of males and females in a population. Thus, it may be necessary to supplement UV-light-trap capture data with additional collection methods to gain a true picture of sex ratios. In this study, the many thousands of beetles caught in UV light traps provided an accurate picture of the relative numbers of male and female beetles attracted to lights, but may not represent the actual sex ratios of the three species. The seasonal flight periods and times of peak flights determined using light traps will be valuable in timing and implementing control measures.

At lower elevations in the Carolinas, some *Phyllophaga* species require only 2 years to complete their life cycles (Johnston and Eaton 1939). Adults emerge from the soil and fly in early April, about 1 month before flights begin at our higher elevation test site. The lengths of flight periods are similar (10 to 12 weeks) at both low and high elevations, but at low elevations peak flight periods are less pronounced. In the coastal areas of the Carolinas, similar numbers of beetles flew each night during most of the flight season, and most *Phyllophaga* adults were captured before 2400 h (Johnston and Eaton 1939).

Beetle emergence and flight is influenced by temperature. Chamberlin et al. (1943) noted reductions in June beetle flights when air temperatures were below 18°C in Wisconsin, although some flight still occurred. *Phyllophaga fusca* flew in moderate numbers and comprised 90% of all beetles captured if air temperatures were 13 to 15°C. If air temperatures were 16°C or higher, another June beetle, *P. rugosa* Melsheimer, predominated in light trap catches. In Wisconsin, Petch and Hammond (1926) noted that if air temperatures were 22°C or higher, large numbers of June beetles were flying, but that if air temperatures were between 10 and 22°C, many *P. anxia* flew between the hours of 2000 and 2200.

In our study site, the number of beetles in flight was reduced if air temperatures fell below ca. 13°C in clear weather and in foggy or rainy weather at higher temperatures. Less than 25 beetles were caught overnight in all five traps during these conditions. If these adverse weather conditions occurred, light-trap collections were postponed for 1 to 2 nights, until warmer, drier weather returned. These rare postponements never exceeded 48 h. Thus, the data in Figures 1 and 2 do not include reduced beetle flights during adverse weather.

Air temperatures during the winter of 1984 were colder than normal (0 to -10°C) in the study site, and a low of -37°C was noted. This may account for the ca. 1 week delay in initiation of beetle flights and presence of grubs in the root zone in the spring of 1985. Periods of flight for the three beetle species occurred in the same overlapping succession during 1984 and 1985, and the total flight period lasted for ca. 16 weeks during both years. This succession may reduce competition for feeding and oviposition sites among species, possibly enhancing survival. Oviposition occurred over several weeks, causing a mixture of instars in the soil.

Acknowledgments

We thank W. M. Brooks, F. Gould, and G. J. House, Department of Entomology, North Carolina State University, for reviewing an earlier draft of this manuscript. We also thank M. G. Klein, USDA Japanese Beetle Laboratory, Wooster, OH, for providing light traps. We are indebted to Jack and Linda Gentry, Bald Mountain Farms, Todd, NC, and Marlies E., Jessica A., and Rachel R. Kard, Cary, NC, for their cooperation in support of this study. We thank the Smith-Richardson Foundation, Greensboro, NC, for providing research sites and funding to conduct this experiment. This is Paper No. 11,267 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695-7601.

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