BIOLOGY AND PEST MANAGEMENT STRATEGIES FOR THE SUNFLOWER BEETLE IN CULTIVATED SUNFLOWER IN NORTH AMERICA

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Summary

The sunflower beetle, *Zygogramma exclamationis* (F.) is the major defoliating pest of cultivated sunflower in the United States. Adults and larvae feed on sunflower foliage and when populations are high, yield loss can occur. Although the beetle can be controlled with insecticides, there are inherent problems associated with long-term pesticide use including natural enemy destruction, high input costs, and insecticide resistance. The best way to control the sunflower beetle is with an integrated pest management (IPM) approach that uses a variety of tactics, relying on pesticides only as a last resort. The discovery of successful IPM techniques is important in the development of sustainable agriculture and will offer additional choices in managing sunflower beetle populations to prevent yield reductions. Studies were initiated to increase our knowledge about the beetle, its natural enemies, and to determine the impact of cultivation, seed treatment, and planting date as management tactics to reduce producer losses. These studies added to our understanding of the beetle's life history and its overwintering habits. Insecticides were effective when used as a foliar treatment but not when incorporated onto the seed. Although cultivation was not effective in reducing beetle numbers, delayed planting was successful as a management tool. Natural enemies are significant mortality factors for this sunflower pest and should be conserved when possible. The long-term goal for beetle control should be the use of a variety of IPM strategies. While effective, chemical control should remain as a last resort, utilized only when the economic threshold has been reached.

Introduction

The sunflower beetle, *Zygogramma exclamationis* (F.), (Coleoptera: Chrysomelidae), is the only major defoliating pest of sunflower (*Helianthus annuus* L.). in North America and occurs from Texas to Manitoba, Canada. This species feeds on both cultivated and native sunflower. Economic damage has been confined to North and South Dakota and Minnesota in the U.S. and Manitoba, Canada. Adults overwinter in the soil and emerge during May to early June and feed on the first available sunflower foliage. Beetles mate shortly after emergence and eggs are deposited on wild or volunteer sunflower until cultivated plants become available. Larvae develop through four instars and feed on plants from mid-June through late July. Mature larvae move off the plants and pupate in the soil, emerging as new-generation adults from late July to early August. These adults usually cause minimal damage to sunflower and leave the plants by mid-September to overwinter in the soil. There is one generation per year. Both the adult and larval stages consume the leaf tissue. Larval populations of 25 or more per plant can completely defoliate a plant and reduce yields by as much as 30%. Population densities of only two adults per plant plus the resulting larval feeding can reduce seed yield by over 20% (Westdal 1975, Charlet et al. 1997). The primary control strategy for the sunflower beetle has been the use of insecticides directed at either the adults or larvae feeding on the sunflower leaves. While this tactic has proven to be successful, the use of an integrated pest management (IPM) system provides long-term benefits. IPM utilizes a number of different approaches including host-plant resistance, cultural control, biological control, relying on pesticides only as a last resort to reduce populations below economic injury levels. Reliance on pesticides can result in resistance of the pest and destruction of both pollinators and natural enemies of both the sunflower beetle and other sunflower pests as well. Knowledge about the pest's biology and population dynamics is also essential in order to implement an effective IPM strategy.

The objectives of these studies were to investigate aspects of the biology of the sunflower beetle, its overwintering and emergence pattern, the impact of cultivation on adult survival, the natural enemies (parasitoids and predators) attacking the larvae in native and cultivated sunflower, efficacy of chemically treated seeds for adult and larval control, and whether altering planting dates could reduce the impact of sunflower beetle feeding on cultivated sunflower.

Materials and Methods

Egg production and longevity. Adult sunflower beetles were collected in sunflower fields in early June 1996, and 1997 and brought back to the laboratory. Three females and three males were placed together in plastic containers with sunflower leaves and water. A total of 90 adults were included in each study. The adults were monitored three times per week and the number of eggs produced, oviposition period, percent of eggs hatching, and longevity of both males and females determined.

Overwintering biology. A sunflower field in southeastern North Dakota, that had been infested with sunflower beetles in 1995 was sampled in May 1996 to determine the location of overwintered adults. Eleven soil samples from untilled portions of the field were removed at three soil depths (0-5, 5-10, 10-15 cm). The soil was sieved to extract the adults and counts were made of the number at each depth. Ten samples were taken from the field margin using the same procedure. In October 1996, additional soil samples were taken from an adjacent field that had been infested with sunflower beetles. Sixteen samples were taken from within the field and 13 from the field margin. Another sunflower field was sampled in May 1997. Soil was collected from a total of 24 locations within the field and 11 from the field margin to determine the number of adults within each sample.

Cultivation. The sunflower field sampled in May 1996 for overwintering adults was used to compare the effect of cultivation on survival and emergence. Treatments included an area disked in mid-October 1995, an untilled strip, and an area disked in late April 1996. Six conical wire screened cages were randomly placed in each of the three treatments in May 1996. Glass jars were fitted to the apex of each emergence cage. The sunflower beetle adults emerged from the soil and climbed to the peak of each cage and into the jar where they were removed and counted. The cages were monitored at 7-10 day intervals beginning mid-May until emergence ceased. The experiment was repeated again in 1996-1997. The field was treated in one of the following ways: a fall cultivation, a spring cultivation, and an untreated check. The treatments were replicated three times in a randomized block design. Twelve cages were randomly placed in each of the three treatments in early May. Emergence was again monitored at weekly intervals.

Seed treatment. Selected insecticides were evaluated for their ability to control adult and larval stages of the sunflower beetle in 1997. Trials were carried out in eastern North Dakota. Chemicals and rates tested included the following: seed treatment with imidacloprid (8, 16, 32 fl.oz/cwt), a foliar treatment with esfenvalerate, and an untreated check. Treatments were arranged in a randomized complete block with 4 replications. Each treated plot was four rows wide by 12 m long. Counts were made of the number of adults and larvae per 5 plants on one of the center two rows within each plot beginning at the two-leaf stage (V2) and continued at weekly intervals until mid-July. Foliar treatments were applied on 30 June.

Defoliation from adult and larval feeding was estimated in late July. Yield was based on seed weight per head. The experiment was repeated in 1998 at two locations in eastern North Dakota. Chemicals and rates tested included the following: seed treatment with imidacloprid (8, 16, 32 fl.oz/cwt), foliar applications of both esfenvalerate and lambda-cyhalothrin, and an untreated check. Foliar treatments were applied 1 July. Defoliation was estimated after feeding had ceased and heads were harvested to determine seed weight.

Natural enemies. In 1995, 6 species of native sunflowers at 15 locations in North Dakota and 5 species of *Helianthus* at 25 locations in both North Dakota and Minnesota were sampled for beetle larvae. The larvae were returned to the laboratory and dissected to determine the parasitoid species and rates of parasitism. Five commercial fields in southeastern North Dakota were sampled in both 1997 and 1998 to determine the distribution of sunflower beetle larval parasitism in the field at four different distances from the field margin (edge, 20m, 50m, 100m). Larvae were collected (50 per sampling location) at each distance from the field margin on four sides of the field and dissected to calculate the percentage parasitism. A number of different insects known to be predators were collected in sunflower fields in 1998 and placed in containers in the laboratory to determine whether they would feed on sunflower beetle eggs or larvae.

Planting date. Trials were conducted at four locations in North Dakota in 1998 and 1999. Plots were seeded at three dates, mid-May, late May, and early June. Because of wet field conditions during both growing seasons, planting dates had to be adjusted for each location in order to be separated by 7-12 days. The planting dates for the two years of the study were as follows: 15-27 May, 26 May-8 June, and 7-16 June. All plots (12 rows by 6 m) were seeded using a randomized block design with four replicates. During the study, adults and larvae were counted on 5 plants at 5 random locations at weekly intervals beginning in mid-June (about the time the latest planting was at the VE [seedling emergence] stage) until feeding was finished. In late July approximately 50 mature larvae were collected from each plot at all locations and dissected to determine the percentage containing the internal sunflower beetle larval parasitoid, *Myiopharus macellus* (Rheinhard). Percent defoliation was calculated by averaging the defoliation on the upper half of about 5 sunflower plants at 5 random locations within each plot. Ten heads were harvested from each plot to determine the seed weight.

Results and Discussion

Egg production and longevity. Based on the two year study, sunflower beetle females produced an average of 646 eggs over a period of 53 days with a mean of 12 eggs laid per day. Total egg production by females ranged from about 200 to almost 2000 eggs. A study of populations of the sunflower beetle from the southern Great Plains, conducted by Rogers (1977), reported a longer oviposition period (75 days), a similar daily egg production (15 eggs per day), and a somewhat higher total egg production (1027 eggs). Males lived longer than females surviving an average of 76 days and females 63 days. Longevity for males and females in Rogers' (1977) laboratory studies was 93 and 91 days, respectively. A mean of 74% of the eggs deposited by the females were fertile and hatched in the laboratory, which was similar to Rogers' (1977) findings of 71% survival. In the field we have found that egg survival is somewhat lower, due to either environmental conditions or lack of males for mating.

Overwintering biology. No overwintering beetles were recovered in any of the soil samples from the field margin collected in May 1996, but adults were in 73% of the soil samples from within the field. Adults that were recovered were collected at both the 0-5 cm and 5-10 cm soil depth, with the majority in the layer closer to the soil surface. Results were similar in the soil samples collected in the fall. No adults were present in any of the soil from the field margin, but were in soil samples from within the field. In the fall collections, adults were only recovered in soil at the 5-10 cm depth, with none at the 0-5 or 10-15 cm depth. Since sunflower beetle adults were collected closer to the surface in the spring samples, it is possible that they overwinter at 5-10 cm below the surface and move up in the soil in the spring prior to emergence. Findings from May 1997 were similar to the investigations on overwintering sites from 1996. Overwintering sunflower beetle adults were more abundant within the field than at the margin and the majority were located in the upper 5 cm of the soil surface. Results strongly indicate that the adults do not move away from the field to overwinter.

Cultivation. A total of 78 sunflower beetle adults emerged and were recovered from the cages placed over the fall-tilled, spring-tilled, and untilled portions of the previous year's sunflower field. There was no significant difference in the mean number of adults emerging from the cages among the three treatments. Although neither fall nor spring tillage reduced adult sunflower beetle survival compared with survival of beetles in untilled soil, there was a difference in the pattern of emergence. Emergence of beetles into cages over tilled soil was more prolonged than from untilled soil. Emergence from all treatments began on 19 May. The highest numbers of beetles emerging into the cages occurred during the first week of June. By then, emergence from the untilled soil had been completed. Emergence from fall-tilled soil ended 23 June, but emergence from spring-tilled soil was not completed until mid-July.

Adult emergence in 1997 began 24 May and ended by 13 July with the highest levels emerging from the soil the first week of June. The period of emergence was shortest in the fall cultivated plots with all adults leaving the soil by 22 June. The adults from the other two treatments (untilled and spring-tilled) completed emergence by mid-July. There was no significant difference in number of beetles emerging from any of the three treatments. Results from the two-year study showed that disturbing the adults by cultivating the field either in the fall or spring did not reduce adult emergence from the soil in the spring and summer. Although studies with another sunflower pest, the red sunflower seed weevil, *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae) revealed that tillage could be used as a control practice to reduce adult emergence (Gednalske and Walgenbach 1984), neither fall nor spring cultivation in these studies reduced survival of overwintering sunflower beetle adults.

Seed treatment. Data from 1997 showed little impact of seed treatments on the numbers of adults in the plots, with all three levels of imidacloprid having higher numbers of adults than the check. Esfenvalerate treated plots had adult numbers similar to the controls and after treatment adults were no longer detected in those plots. Esfenvalerate also was effective in controlling larvae of the sunflower beetle with no larvae present for up to 17 days after treatment. There was some evidence of control of larval numbers with imidacloprid, especially at the highest rate tested (32oz/cwt). Sunflower beetle larval populations were lower in the imidacloprid (32oz/cwt) treated plots throughout the season. The other two imidacloprid treatments (16 & 8oz/cwt) showed some response and plots had lower levels of larvae than the check on 10 July when larvae were at their highest levels of the season. A comparison of the defoliation of the sunflower leaves by adults and larvae also revealed evidence of lower damage in both the plots treated with esfenvalerate and imidacloprid at the highest rate. However, differences were minimal among the treatments and populations were not at economically damaging levels in any of the plots. There was no significant difference in yield among any of the treatments. This was probably because defoliation was only minor among all treatments in the study.

In 1998, the data showed little impact of the seed treatments on the number of adults in the plots at both sites, with all three levels of imidacloprid having higher numbers of adults than the check when populations were on the increase and at their highest levels. Foliar application of insecticides (both esfenvalerate & lambda-cyhalothrin) seemed to have little impact on adult densities since populations were decreasing when the sprays were applied and numbers in all plots after treatment were similar to the control plots. But, esfenvalerate and lambda-cyhalothrin applications were very effective in controlling beetle larvae since they were all but eliminated from the plots after treatment. There appeared to be little evidence of control of the larvae with any of the rates of imidacloprid tested. A comparison of the defoliation of the sunflower leaves by adults and larvae revealed that the foliar insecticides (esfenvalerate and lambda-cyhalothrin) were effective in reducing feeding damage. However, neither of the three rates of imidacloprid effectively reduced defoliation at either location compared with the control. Seed yield did not show any impact from the control of the sunflower beetles. The results were somewhat different than those from 1997 when there was an indication of response of beetles to the imidacloprid treatments. Preliminary results from a study conducted in 1999 with two different chemicals used as seed treatments also showed no reduction in adult or larval densities or defoliation compared with foliar treatment with esfenvalerate.

Natural enemies. Sunflower beetle larvae were recovered from 5 of 6 native sunflower species sampled in 1995 and 1996 in North Dakota and Minnesota. These included *Helianthus annuus*, *H. tuberosus*, *H. nuttallii*, *H. petiolaris*, and H. *maximiliani*. None were collected on *H. pauciflorus*. Parasitoids were present in larvae from the different species and were all the fly parasitoid, *Myiopharus macellus*. Parasitism was as high as 72% in larvae recovered from some species of *Helianthus*. Because beetle numbers were low at some locations, it is evident that this parasitoid is very efficient in searching for beetle larvae at different population densities.

The dissections of the larvae from the different fields in 1997 revealed no difference in rates of larval parasitism by *M. macellus* among any of the 4 locations (edge to 60 m) sampled in 5 commercial sunflower fields. In 1998, results were similar although a slightly higher rate of parasitism was noted at sites 20 m in the field compared to other locations. Results indicated that the adult parasitoid is capable of effectively searching throughout the field. The overall parasitization rates among the field sampled were very low in 1997 (4 to 7% of larvae attacked) compared with 1998 (7 to 15%). These rates were quite different than those reported earlier by Charlet (1992) which had been over 50% in some years. The reasons for the lower parasitism could not be accounted for by insecticidal treatment because many of the fields sampled during the two years had not been sprayed during the season.

There are a number of different insect predators recovered from sunflower fields that were shown in the laboratory to feed on the different life stages of the sunflower beetle. These included the lady beetles *Hippodamia tredecimpunctata tibialis* (Say), and *H. convergens* Guerin-Meneville, green lacewing, *Chrysoperla carnea* Stephens, the spined soldier bug, *Podius maculiventris* (Say), the stink bugs, *Perillus bioculatus* (Fabricius) and *P. circumcinctus* (Stal), the carabid beetle, *Lebia atriventris* Say.

Planting date Among the four locations studied in 1998, peak adult density occurred in mid-June in most sites, but was shifted to the end of June or early July in 1999. In 1998 the greatest larval populations occurred between early to mid-July, but in 1999, they were more variable with the greatest density occurring from late-June to late-July. In both 1998 and 1999, among all locations, the data showed that the latest planting date had the least number of both adults and larvae. The combined data for all four locations in 1998 and 1999 also showed that defoliation was significantly different among all dates with the least damage at the third planting date. Seed yield comparisons in 1998 from the different planting dates, although not as consistent as the defoliation data, did show that at most locations seed weights were less at the first planting date compared to the third planting date. However, in 1999 the data was less consistent with two of the four locations having no difference in yield among dates. The lack of response in yield to the defoliation shown in 1999 was probably because of the lower densities of the sunflower beetles and consequently the differences were due to factors other than feeding. Combining the data for all locations in 1998 showed that parasitism of beetle larvae by *M. macellus* was the same among the dates. Data from 1999 showed that overall parasitism was greater than the previous year at most locations and that parasitism was not different among dates at two locations. The combined data for all sites showed that there was slightly less parasitism at the first date, but no difference between the second and third dates. The results of this investigation showed the potential of planting date as an effective nonchemical management strategy to reduce numbers of sunflower beetle adults and larvae and the resulting defoliation. Delayed planting also prevented yield reduction caused by the leaf destruction of the sunflower beetle. In addition, this IPM tactic is compatible with biological control, another IPM strategy, since delaying the planting date did not reduce the effectiveness of the parasitic fly that attacks the sunflower beetle larvae. Planting date has also been shown to be a successful cultural control tactic with other sunflower insect pests including the red sunflower seed weevil (Oseto et al. 1987), the sunflower stem weevil (Oseto et al. 1982), and the banded sunflower moth (Oseto et al. 1989).

Conclusions

These studies add to our understanding of the biology of the sunflower beetle, its behavior and overwintering habits. Chemical control was shown to be effective when used as a foliar treatment against the beetle, but not when incorporated onto the seed. Although the cultural control tactic of cultivation did not appear to be effective in reducing populations of the beetle, delayed planting was revealed to be very successful as a management tool. Natural enemies are significant mortality factors in the population dynamics of this sunflower pest and should be conserved when possible. The long-term goal for the control of the sunflower beetle should be the use of IPM strategies combined with monitoring of fields for pest densities. While effective, the chemical control of the sunflower beetle should remain as a last resort, utilized only when the economic threshold has been reached.

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